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CONTENTS

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NATIONAL SETTLEMENT SYSTEMS IN COMPARATIVE STUDIES 1976–1984

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Before discussing in detail the present state of art in the field of research on national settlement systems, it seems proper to review shortly the situation in 1976 i.e. when the International Geographical Union established the Commission on National Settlement Systems during the General Assembly at the 23rd International Geographical Congress in Moscow.

Two factors contributed to the formation of the Commission and to the shaping of its research programme: an evident need for studies of settlement on the national scale as a constantly changing complex of interdependent units and apparent advantages of the application of the systemic concept and approach in such studies. However, even a superficial analysis indicated how difficult its actual application will be because of the rather loose ways in which the concept has been understood and used.

As a result, it was decided to apply the systemic concept only in a general, consciously vague way, without making any greather effort towards its closer definition. This position, obviously disputable, was the starting point for the formulation of the so-called 'Guide-lines' for individual reports on national settlement systems, prepared and approved during the First General Meeting of the Commission in Bochum, FRG (January 1977). In particular, the national settlement systems were assumed to represent the systems formed by a number of settlement units linked together by some significant interactions. This assumption implies that the definition of a specific national settlement system involves in each case "the identification of component settlement units, of their mutual interactions (i.e. of the functional structure of such a system) and of the relation of the whole system to its environment (including linkages with other systems)". At the same time the concept of settlement subsystems (as elements in the structure of national settlement systems) was introduced and the character of possible changes of the system in space and in time indicated.

According to the guide-lines in the national reports, which were meant to serve as a basis for the comparative studies, all attention was to be paid firstly to the presentation of the historical development of the given country's national settlement system, secondly to the present structure of such a system, thirdly to the role of urban agglomerations in the system, and finally to the foreseeable and proposed changes in the system.

In 1979 the 22 national reports were received and circulated during the Third General Meeting in Szymbark, Poland. In 1980, i.e. for the Fourth General

Meeting in Sapporo and Sendai, Japan, 5 additional reports and in 1982, i.e. for the Sixth General Meeting in Toronto, Canada, 5 more were submitted. Altogether the Commission possesses now 33 reports covering the national settlement systems of Australia, Austria, Belgium, Brasil, Canada, Czechoslovakia, Denmark, England and Wales, the Federal Republic of Germany, Finland, France, the German Democratic Republic, India, Ireland, Italy, Japan, Yugoslavia, the Netherlands, Poland, Portugal, the Republic of South Africa, Spain, Sweden, Tanzania, Thailand, Tunisia, the Union of Soviet Socialist Republics (as well as more detailed studies of the Russian and Transcaucasian republics), the United States of America, Venezuela and Zambia. The shortened version of 22 reports has been published in a book form in 1984 by the Oxford University Press.

As usual in case of international comparative studies these reports are very diverse in size, amount of information contained and analytical value. They reflect partly the state of geography and geographical knowledge in and of the given country. In addition, it should be stressed here that all the reports were to be prepared by the geographers from and for their native countries; this rule was essential and obligatory for research organized within the framework of the International Geographical Union. But the rather vague definitions included in the guide-lines on the national settlement system were certainly also responsible for various approaches characterizing these reports. However, this was intentional. Let us repeat: lacking a consistent theory of settlement systems, acceptable by consensus for at least a large majority, if not for all, it was necessary to proceed by analysing individual settlement systems. It was assumed that when the time for generalization and for synthetic studies is reached then this approach may be replaced by topical studies and an effort toward more integrated theories. Already twice the lists of problems for a second generation of reports were drawn and various geographers were invited to prepare them in the span of one or two years. A number of such reports was written but some quite important ones are still missing. To write a report on one's own country is comparatively easy, however, it is much more difficult to write on specific problems across the frontiers and for wider areas, specially when, generally speaking, these problems were not enumerated in the guide-lines. As a result, the papers prepared in this second stage are sketchy and the progress achieved is rather patchy. Nevertheless, significant results were obtained and the present paper is an effort to specify the achievements and bring them into focus. In doing this we shall follow — more or less — the main divisions as stated in the original guide-lines for the national reports.

I.

Although a full and detailed presentation of the emergence and transformation of national settlement systems has to wait for the implementation of extensive historical research — still to be undertaken and involving the participation of professional historians — a general outline of such a development in the past seems to be comparatively clear.

The history of national settlement systems is obviously connected with the birth of the nations themselves, specially when they have emerged as identifiable societies and later in the form of national states. The relation between 'nations' and 'states' is, in case of settlement systems, of extreme importance because of the decisive impact of the state policies and activities on the formation of any settlement system but in particular on the national scale. This is well demonstrated in the development of the national settlement systems in the post-colonial countries which have recently gained independence.

The structure and patterns of any national settlement systems are highly dependent on the settlement systems that preceded their emergence whether regional, local or supranational in scale. There are also cases, though rare, where practically no earlier settlement systems have existed.

Studies of national systems as formed historically were undertaken within the Commission in the following three provisionally defined groups: first, of the countries where present systems result from preceding evolutionary development, usually by integration of earlier regional systems; second, of the countries which – having gained independence – formed their systems out of the former colonial systems; and third, of the countries where the national systems were developed largely on virgin lands or sparsely populated areas.

In the first group, E. Dalmasso, in a paper read at the Lund Meeting in 1981, identified two characteristic roads of passage to a national settlement system from preceding regional ones, which may be defined as based on, or opposing the former systems. When the national system was a result of fusion of the preceding regional ones its structure and pattern were balanced on the whole and at least partly polycentric and decentralized, in some cases the structure of such a system, as of the state itself, was federal. On the other hand, when the national system was forcefully imposed, with partial destruction of former regional settlement systems, it became highly centralized with very distinct dominance of the capital city.

In the second group, F. L. Chaves presented a monographic study of Venezuela leading to a generalized description of national settlement systems in Latin America. The historical emergence and consequent transformation of national settlement systems are more complex there than in other formerly colonial countries, since they obtained their independence already in the first half of the 19th century, i.e. from one to one and half hundred years earlier than Asian and African colonial countries. The case of the United States, which won their independence even earlier, is different, as the major part of the national settlement system was developed there later, on sparsely populated and virgin lands. The complexity in the development of national settlement systems in Latin America is moreover connected with the imposition of another system of mainly extractive industries and settlements created and serving the foreign banks and at present international corporations – on the national settlement systems of central places, which had been typical for agricultural countries. In this way two systems coexist there: former colonial (imperial) ones transformed into the national and neo-colonial, economic ones. There are also vast wirgin lands where the settlement is being developed now by the initiative of national governments.

In the countries – Asian and African – which have obtained independence in the 20th century, the patterns are evidently different. There the old tribal or feudal settlement systems were at first partly transformed by the colonial rulers organizing conquered territories for commercial and later industrial exploitation and at present both systems are being integrated into national systems.

The colonial patterns, whether older or new, are characterized by the dominating role played first by the entrance (and exit) ports – connecting links with the settlement system of the imperial-colonial country, and later by the network of centers established in the interior for the administration of the conquered territory.

The new national settlement systems, as they are developing now, are characterized either by the dominance of the main urban center, the capital (the case of countries comparatively sparsely populated with an extensive, still at least partly tribal economy) or a more balanced structure where the new capital city is accompanied by other developed urban centers – former national and regional capitals, sometimes industrial cities (the case of densely populated countries with an intensive, still partly feudal, economy).

The third group was described for the Commission by J. Simmons who presented a generalized study based on the experience in development and transformation of the national settlement system of Canada. There the development took place along the communication lines with regional centers – capitals emerging at significant break-in-transportation points (seaports, crossing of large rivers and similar) or in the newly established trading, mining and administrative centers. The vast territories of these countries usually involve the federal structure (four levels in the central-place pattern of main urban centers) of the settlement system.

II.

A rough classification of national settlement systems was proposed as early as 1976 by K. Dziewoński and M. Jerczyński in their paper presented at the Moscow Congress; the authors subdivided them into three main groups: of developed countries – states with capitalist economies; of developing ones with mixed economies; and of socialist ones. Each group was further subdivided on the basis of intensity in land utilization and development as well as of density of population, i.e. countries with or without larger and significant reserves of virgin or at least sparsely populated lands. A further extension of such divisions by introducing the characteristics of high and low concentration in the urban networks has lately been proposed. On such basis a grouping of all the systems into twelve classes is possible but in fact there may be some empty classes.

However, to understand the structure of actual settlement, in particular of urban systems, indeed to work out a fully fledged theory of such systems, some grouping of settlement units is needed.

Two ways of approach have emerged. One is based on the assumption that there are nests of systems (subsystems) deriving from spatial interactions between individual settlement units. Evidently, certain hierarchical structures do develop then and the concept of the national settlement system itself implies that such systems exist. Generally speaking, in studies and discussions such systems have been identified at local, regional, national and supranational (whether federal or international) levels. They may be called 'territorial systems'. Another approach is along functional lines. F. Grimm systematized them in a number of studies and reports developing such an approach by identifying and defining the following three systems: of productive forces serving economic goals, of social needs (consumption and service activities) and for the implementation of social goals, finally of population structures, patterns and movements, on which an administrative organization and structures are imposed. They may be called 'functional systems'.

Each type of settlement systems, identified by either of those two approaches, is characterized by distinct spatial patterns.

The final system and distribution of settlements in a country is a result of the superimposition or the fusion of at least several such subsystems and their patterns. In fact, it becomes even more complex because in the historical processes of development the patterns also change with socio-economic formations and there is an additional phenomenon of an hiatus between population distributions and material forms of settlement due to differentiated adjustments to changes taking place in time. However, usually one of such systems (subsystems) in the historical processes of fusion becomes dominant at least regionally and then it may be used as the determining element in the over-all classifications of settlement systems. Such a classification could be presented in the form of a graph with three axes – of time, of territorial, and of functional systems.

Nevertheless, as already stated for the formulation of a fully developed classification, further historical studies are needed, which would identify the specific patterns and systems characteristic simultaneously for the given period and the given region of the world.

However, as it was already stated, the modern times are characterized by the strong integration at the national level of functional settlement systems with the state (i.e. national or federal) territorial, hierarchical settlement systems, as well as in the developing countries by the coexistence of the emerging national systems with the post-colonial supranational economic ones. Some significant supranational linkages of national settlement systems in the remaining countries are connected with such economic organizations as the European Common Market and the Council for Mutual Economic Aid, or with flows of migrant foreign workers.

III.

In addition, some interesting partial studies were carried out or undertaken in research initiated by the IGU Commission on National Settlement Systems. Some pertinent work pursued outside the activities of the Commission is cited here too.

One of the first themes to be tackled was the relations – interactions between settlement networks and territorial divisions of a country for administrative purposes (Cori 1980, Rysavy 1980). Obviously they are parts of distinct and separate systems but at the same time they are, and they have to be, closely correlated one way or another. Studies undertaken have led to a conclusion, which perhaps was to be expected, that there exist continuous efforts in both systems to adjust one system to changes taking place in the other. This usually leads to the enlargement of the areas within the administrative boundaries of cities, or to the creation of new forms of territorial administration, which happens in cases of large urban agglomerations. Still, the relation between local agricultural and rural systems of settlement and basic administrative units (communes as they are named in most countries) is not satisfactorily explored, although there is a general though unjustified tendency to identify such administrative units with basic rural settlement units. In most cases – probably in the majority of countries – the center of a commune can be identified as a settlement with low, perhaps even the lowest order of central places, of central functions.

Another subject widely discussed during the Szymbark Meeting (1979) and in Lund (1981) on the basis of studies presented by D. Bartels, is one of settlements functioning as a system of labour markets. Theoretically this subject may be considered as part of a wider research into the settlement as a productive system and a network of productive centers but in some aspects manpower is only an element in processes of production, and in others settlements there are the places where people find employment not only in production but also in services of all kinds. Settlements are, first of all, the clearing points for the provision of employment. Traditionally, it has been assumed so far that the phenomenon of settlement is identified by the concentration of dwellings. This assumption was implicit even in the theory of the urban economic base. The approach which states that the formative factor for the existence and growth of a settlement (in fact a town or a city) is found in possibilities and opportunities of employment, opens some interesting perspectives for the interpretation of known phenomena and new directions in the research. It should be stressed that the term 'labour market' is used here in a very wide sense, since it means only "a place where man works or may find work" without any reference to any organization –

any exchange within which problems of supply and demand of labour are being resolved.

The studies on the national urban system of Canada, presented at the Toronto Meeting of the Commission (1982), were partly connected with such research. All of them not only extend in depth the actual knowledge of structures existing within an urban system but also observe changes taking place within such structures. This effort to analyse processes along with the structures seems to be very characteristic of the latest studies and research.

A large part of these reports is concerned with the hierarchical networks and patterns of central places. This seems natural, as on the one hand, the central place theory is the most developed and the best known theory in modern geography of settlement and on the other – some excellent monographs have already been published, dealing with central places in Canada and some of its regions; they were prepared in the University of Toronto, where the meeting took place. The new element and approach was the concentration on changes and their causes. One approach, used in the report of R. E. Preston, consists in the search on stability and change in the ranking of central places; another of L. H. Russwurm and Ch. R. Bryant in the analysis of population growth, size and density of regional cities.

A quite different point of departure is contained in the study presented by J. Mercer on value differences and differentiation as conceived by people in advanced capitalist societies and their meaning for the structure of the urban systems in Canada and the USA. The unexpected novelty lies here in the demonstration of the impact made on settlement system by differences in social ideals and values as found in two neighbouring large states and communities with totally open frontiers and a strong, at least partially mutual interdependence.

Some studies on the impact of government policies (and expenditures) on settlement systems are being already pursued and discussed but this topic is still to be tackled on a much wider comparative basis. In particular, the problem of the postulated, future structure of national settlement system, defined as a specific aim of society and of the government and involving transformation of the present-day system, is of great interest to the Commission. A study of so identified problem demands not only a good knowledge and understanding of the existing system, its origin, background, structure and self-induced emerging changes but also their critical appreciation. Such an approach cannot leave the ideological aspects and socio-economic formations aside, within which both natural and planned changes are taking or are to take place. This may be the point at which the geography as a science would enter the predictive phase in its development and then the results of geographical research would become of greater practical importance for the national communities than they are at present.

Another problem, so far only raised in discussions, which in future should play a major role in the study of national settlement systems, is the supranational, i.e. spatially exogenous, factors involved in changes of such systems. Several typical phenomena of this kind have been identified in the work of the Commission. They are: the integration of individual national settlement systems under the impact of international economic bodies, such as the European Common Market, or the Council for Mutual Economic Aid; the consequences for the settlement systems of the existence of large supranational industrial and commercial corporations, forming international linkages between the largest cities with a partial subordination of settlement (mainly urban) systems in the developing countries; finally the changes in national settlement systems due to the movements of foreign labour forces.

These topics were discussed at the Seventh General Meeting of the IGU Commission, which has taken place in Leipzig in 1983.

IV.

Let us now turn to the problems of large urban agglomerations, their role in the national settlement systems and their internal structures. Half-way between this last topic and the formerly discussed one of the national settlement systems as wholes is the problem of actual changes taking place in urban agglomerations and the future role and importance of main urban centers. This problem was widely explored and discussed in the Commission, mainly in terms of population movements and flows – migrations. The studies of these topics are numerous and already so far advanced in regard to the concepts, methods of research and presentation, monographic and comparative research that the formulation of a well developed theory is possible, integrating together various partial approaches and achievements. Since the subject is very wide and giving here its proper exposition would throw the whole report out of all rational proportions – the discussion is limited to a very short, rather arbitrary, resume.

There is already a large amount of information and knowledge about the historical transformation of population numbers and structures as well as about its impact on migrations and settlement, in particular on processes of urbanization, allowing for the general interpretation of phenomena and the formulation of a theory dealing with successive interactions between population movements and settlement systems. This is additionally strengthened by the existence of mathematical models both operative (such as Rogers-Willekens model) and general (Alonso model). The first one makes possible the short-time projections and by application of the multistate statistical approach offers the large possibilities for further development in forecasting and simulation of future changes. The second one, by its impressive generality, makes it possible to integrate seemingly contradictory phenomena in a comprehensive and unified overview.

V.

At the same time, the number of detailed, partial studies of the problem within individual countries gives us already a good understanding of social and economic mechanisms connected with migrations and changes in settlement systems. The same material contains also valuable information and sources for the discussion on internal structures and their transformation in larger cities and urban agglomerations. Changes are both centripetal and functional. Two well-known patterns prevail in succession: either the core of the city is surrounded by residential districts, becoming poorer and poorer from the center to the outskirts, with squatter areas at the peripheries, or this order is reversed – immigrants, the poorest people, arrive and settle in the formerly better but now deteriorated old districts in the center whereas the well-to-do, the rich, move to new, modern houses in the suburbs and peripheries, or in search of a better environment even outside the urban agglomeration. The second pattern is characteristic of the developed capitalist countries, while the first of the developing countries of the Third World. In some countries, with so-called welfare economies (e.g. the Netherlands, Scandinavian countries, Canada) a mixture of these two patterns emerges, without any greater and sharp spatial division into the very poor and very rich districts. Finally, similar complex pattern with atomized, internal differentiation seems to crystalize in the socialist states which – generally speaking – are still in the earlier stages of economic growth, half-way between the developed and developing countries.

Both during the Lund and Toronto Meetings of the Commission, O. Warneryd presented an interesting overview, based on the Swedish experience of dialectic changes taking place in the housing locations and development as well as their dependence on and implications from the energy consumption both for heating purposes, as well as other household activities and in transport (mass and individual one).

However, the study of internal urban structures finds its place only in its general aspects within the reference terms of the Commission. The interest paid to the internal structure of large cities and urban agglomerations is, among others, the consequence of their scale – at present of supralocal, usually even regional scale. For this reason such structures form and explain at least part of regional settlement systems. In fact such systems in modern times are identical with the settlement systems of city-regions (whether mono- or polycentric).

When we return to the national scale, a question arises whether the regional systems integrate together into the national ones – this would represent the hierarchical pattern of central places – or the national system is somehow added to, or superimposed on the regional ones. The answer has to be historical – differing from one country to another. But for this question, another one may be substituted: is there a system of main urban centers implanted in and forming a distinct part of the national one? Some unfinished research, carried out in Poland, indicates that such system does exist there but is not yet strongly developed. Therefore, for other countries this additional question may be formulated as follows: (1) is there a significant system of main urban centers? (2) what is its structure? (3) is it stronger than the regional settlement systems? In other words, are the relations between the largest cities and urban agglomerations more important than their ties with regional hinterland? and are the functions of the capital city decentralized between other urban centers? The answers will define the character of national settlement systems and therefore can be used in comparative studies for the identification and characterization of national settlement systems. However, it should be remembered that such a procedure does not include the assumption that the classification defines one type of the national systems as better or more developed and advanced than the others. From that point of view the differences are purely formal, although in a historical study the national systems formed in specific social and economic formations may turn out to be closer to one type or to another. For instance, in the first socialist states with their characteristic primacy ot the communist parties and strongly centralized economies, the dominance of the main urban center or centers over the regional systems is evident, but in later phases with increased decentralization it may be significantly weakened.

The purpose of all these reflections and remarks is to demonstrate the present achievements in comparative studies although they are far from being completed or even well advanced. By bringing together the varying phenomena, interactions, patterns, their changes and transformations in individual countries they allow us a wider and bolder generalizations, construction of more comprehensive interpretations and theories. They make it also possible to understand better the problems facing geographers from different coutries. Finally, working and discussing in a group creates the friendships.

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A MULTI-FACETAL CONCEPT OF URBAN HIERARCHY: WITH SPECIAL REFERENCE TO THE POLISH URBAN SYSTEM

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INTRODUCTION

Investigations of hierarchies in settlement systems are widely recognized as a basic topic of urban geography. It has been the case since the central place theory, as provided by Christaller (1933), was commonly accepted in urban geography. The common acceptance of the theory involved, however, a tendency to view urban hierarchy in strict Christallerian terms. Yet, the notion of hierarchy is far from being unequivocal. Although in individual definitions of hierarchy, it is the ranking which is most strongly stressed (Hornby et al. 1972, Kopaliński 1975. Skorupka et al. 1968), it is also structural formalism of the system concerned which is connoted. It stems from the origin of the term which in its original Greek meaning denoted a *sacred order*.

The notion of hierarchy can be relatively unequivocal merely when defined within a theory, either explicitly formulated or being developed. In the literature of human geography and other socio-spatial sciences, several theories can be found as referred to hierarchy, although it is the central place theory which gained a most extensive acceptance in this respect. What is, however, argued here is that the individual theories concerning hierarchy did contribute to the common practice of investigations of urban hierarchy. A necessity is therefore felt to expand the tight Christallerian framework by an attempt to outline a new theoretical framework.

The theory being developed is based on dialectic as a more general explanatory framework. When concerning urban hierarchy, it is dynamism and holism that can be found as being two most important features of dialectical explanation. As seen from this perspective, urban hierarchy must be considered within a specified settlement system which is a necessary condition for the hierarchy to exist. The settlement system is on an incessant move, i.e. it permanently changes. Interrelations of the elements of the system are based on functions performed by the individual elements, the latter are therefore functionally interrelated. The interrelationships comprise both central-place and specialized urban functions. And it is on the relation between the two that any analysis of interrelations between hierarchical and non-hierarchical links must be based. In the central place theory, in which only central-place functions were considered, it was assumed that the analysed system is strictly hierarchically ordered, i.e. that it is only unequivocal hierarchical links by which elements of the system are interrelated (Christaller 1933). In more recent approaches, hierarchical links were considered as referred to central-place functions, and non-hierarchical to specialized functions, yet a strong tendency existed to identify non-hierarchical links with horizontal links (Wärneryd 1968, Pred 1973). A tendency also existed to understand functional links in terms of specialized links only (Jerczyński 1977). Even, however, if functional links were originally related to specialized functions, it was indicated that hierarchical relations develop within specialized functions when the settlement system develops (Zagożdżon 1978). Links within central-place functions would be therefore hierarchical whereas within specialized functions they would be either hierarchical or non-hierarchical. The latter can be either horizontal (i.e. between elements of the same rank) or skewed (i.e. between elements of different ranks from different subsystems).

Both central-place and specialized functions fall in the exogeneous functions category, as opposite to endogeneous (the terms being equivalent to the non-basic/basic functions opposition in the Anglo-Saxon urban economic base literature). Maik (1976), however, indicates that the division into endo- and exogeneous functions is relative as it applies to the spatial scale of the analysis involved. This therefore involves an analogous relativism when applied to the relation of central-place and specialized functions; a specialized regional function on the national scale can be found a central-place function in the intra-regional analysis, and vice versa. Highest rank functions are, for example, those of the central-place hierarchy, yet simultaneously they are specialized functions since they can be rather exceptionally found among urban centres, i.e. they are not typical for the whole body of urban system. The relativism concerning central-place versus specialized functions involves an analogous relativism concerning hierarchical versus non-hierarchical links. The latter relations is therefore quantitative rather than qualitative which is to say that relationships within settlement systems can be said to be more or less hierarchical.

As it was already argued, analysis of urban hierarchy can embrace many detailed questions. Nine such questions were identified herein to be discussed. It must be stressed that hardly any of the questions has not been either discussed in the literature, applied in analyses or at least suggested, although not necessarily merely within a central place theory context. What seems original in this paper, is an explicit identification of all the questions and discussing them within a common conceptual framework.

RANKING OF CENTRES

As it was already pointed to when discussing definition of hierarchy, it is ranking which is a most strongly emphasized detailed question of urban hierarchy. In the central place theory, the question of hierarchical ranks of centres is put as one of their centrality since only central-place functions are considered. The hierarchical ranks of centres, i.e. their centralities, are measured by the number of functions performed or number of (tertiary) enterprises located in the centres (Christaller 1933, Smailes 1944, Marshall 1971). Yet, problems of urban hierarchy cannot be limited to central-place functions, for specialized functions, say industrial, can also have their hierarchies (Zagożdżon 1978). More generally therefore, the ranking of centres analysed is based on their size as understood in terms of an empirical variable which can be recognized indicative for the problem under investigation. It is the rank-size analysis that gives information about the hierarchical rank distribution within the urban system (Robson 1973). Rank distributions are, however, more or less continuous while it is discrete divisions that are expected when analysing ranks in urban systems. The expected divisions can be obtained by cluster analysis.

The way of ranking which was discussed above is based on what Maik (1977) called the scalar criterion, and what could be also referred to as the non-spatial criterion or one which is exogeneous to the analysed pattern of interrelationships.

As an alternative, what Maik (1977) called the vectoral criterion can be used, which is based on the spatial pattern of the interrelationships; this could be also referred to as an endogenous criterion to the pattern. This criterion, as used by Nystuen and Dacey (1968), can be, however, recognized as derivative, for what it implies is an assumption that larger centres possess more expanded networks of interrelationships. A third way of ranking, intermediate to the two alternatives, is one based on differences between the number of functions performed by individual centres with the differences analysed in terms of flows between the centres (Maik 1977).

SPATIAL PATTERN OF HIERARCHICAL SUBORDINATIONS

Together with ranking of centres, the spatial pattern of hierarchical links is the most basic and most often analysed detailed question of urban hierarchy. Unlike ranking, however, it is an explicitly spatial question. In the central place theory, it is assumed that a centre of a certain rank is subordinated to a spatially nearest centre of any higher rank. This is to say that probability of hierarchical links between analysed centres is a negative function of distance between them. It is therefore in the central place theory itself that possibility is recognized of not fully developed hierarchical structures. It was implied by Christaller who assumed that a centre of any hierarchical level is simultaneously one of all lower levels.

The assumption that hierarchical structure of a settlement system is based on distance decay function is, however, involved by analysing central-place functions alone, specialized functions not being considered. In the case of the latter, the costs of transport constitute a smaller part of general costs that in case of central-place functions. Hence, spatial patterns of specialized functions do not fit the Chistallerian pattern. In case of real life urban systems, which comprise both central-place and specialized functions, the Christallerian pattern is a theoretical one from which the actual pattern deviates (Dacey 1966).

UNEQUIVOCALITY OF SUBORDINATIONS OR HIERARCHICAL DOMINANCE

Referring to classical hierarchical systems, and indirectly to the origin of the term *hierarchy*, it was assumed in Christaller's central place theory that hierarchical subordinations are full or unequivocal, i.e. that a subordinated centre is entirely dominated by the supremate centre. This is to say that, as far as higher order functions are concerned, a centre of a given rank *B* is entirely served by a higher rank centre *G*, which results from the rule of distance decay function. Such a deterministic pattern could be, however, accepted merely as far as central-place functions were analysed and, additionally, if a decisive role of transportation costs were recognized that increase proportionally to distance, as well as the consumer's limited sovereignity accepted when applied to free choice of the service centre. The latest does, in fact, occur in real life systems as far as territorially fixed functions are concerned.

In the central place theory, any physical differentiation of the analysed system is neglected, including transportation accessibility; as a result, the settlement network is assumed to be isotropic. Yet in real life settlement systems physical differentiations do exist, which involve irregularity of the settlement networks and differential accessibility. Beside central-place functions, specialized functions are performed by centres. This makes the settlement systems to possess structures which can be considered in probabilistic rather than deterministic terms. Umlands of centres of a given rank should be therefore analysed in terms of fuzzy sets. Therefore, a given centre can be subordinated to more than one centre of higher rank (Kariel and Welling 1977). Empirically, this can be put as a question of how much the relationships of the given centre are dispersed. Classically, however, hierarchical subordinations have been analysed as related to one centre only, i.e. that which most strongly dominates over the given centre; a question therefore arises of how important the subordination is for the analysed centre. Empirically, the question can be put in terms of the degree of closure of the interaction with the given supremate centre as related to the total interactions of the analysed centre. In other words, this is a question of the degree of hierarchical dominance of the supremate centre.

HIERARCHICAL AND NON-HIERARCHICAI LINKS

As it was already argued, the relation between hierarchical and non-hierarchical links is quantitative rather than qualitative. Since relationships within settlement systems can be more or less hierarchical, a question of hierarchicality arises, i.e. one of how much hierarchical/non-hierarchical the given relationship is. It was indicated elsewhere (Rykiel 1980) that degree of hierarchicality of interrelationships between a pair of centres can be understood in terms of effectiveness of the flows between them, i.e. the net to gross flow rate. A considerable positive effectiveness does not indicate, however, directly the supremate centre, for the latter can dominate over the subordinate centre with regard to either drainage or alimentation (of capital, goods, labour, information, etc.). A low effectiveness of flows indicates, however, that non-hierarchical links are analysed. Yet, a quantitative difference between hierarchical and non-hierarchical links implies that even in case of non-hierarchical links the supremate and subordinate centres can be identified, even though subordination is very weak. It is necessary to stress, however, that a weak subordination need not imply the weak relationship.

It should be also emphasized that no correlation is necessary between the degree of hierarchical dominance (i.e. unequivocality of interrelationships) and that of hierarchicality of interrelationships. Two hypothetical towns can be taken as an example: a large regional centre and a satellite town. The former closes most of the relations of the latter within the settlement system, but not vice versa, for the former possesses relations which are dispersed among other satellite towns and regional centres. The regional centre can be therefore said to dominate strongly over the satellite town as far as analysed relationships are concerned. It may turn out, however, that the relationships are non-hierarchical, for the flows in both directions are relatively balanced. Analogically, another hypothetical example can be provided such that a weak dominance is accompanied by strong hierarchicality. This is to say that interrelationships of the considered pair of towns although weak (of little probability) are hierarchical, i.e. if they occur at all, they are mainly one way directed.

IDENTIFICATION OF THE ELEMENT OF THE SYSTEM

Identification of the basic unit of analysis, i.e. the element of the system analysed, is fundamental for any analysis of urban hierarchy. Generally, two approaches to the question can be identified, viz. formal and functional. According to the former, formal units, as based on political and/or statistical criteria, are identified as elements of the urban system under investigation. This approach as pragmatic (as it is referred to the pattern of aggregation of statistical data) is frequently used in analyses of large-scale urban systems. Beside its pragmatism, this approach possesses a strong theoretical support in the concept of hierarchy itself which, originally, implies a strong formalism of the system under investigation.

The other approach, i.e. functional, is even more strongly supported by theory. The concept of system, which hierarchy cannot be abstracted from, implies functionalism as a rule which any system cannot be abstracted from, either. The intrinsic functional elements of the system are not necessarily identical to the formal elements. However, identification of functional elements of the system is a complex problem of its own which is rarely tackled with in analyses of urban hierarchies unless in detailed analyses of micro-scale settlement systems.

DELIMITATION OF THE UMLAND

The question of delimitation of umlands of central places is one which originates from Christaller's central place theory. The question was extensively analysed on the empirical ground (Chilczuk 1963, Werwicki 1965, Jakubowicz 1971), yet it can be easily proved that it is in fact a problem of regionalization, which as such possesses an extensive literature of its own; it is no reason therefore to discuss it here in any depth. What should be pointed to here is that the question of delimitation of the umland exists if and only if analysis of the spatial pattern of hierarchical subordinations is unexhaustive, i.e. if it does not go down beneath centres of a certain hierarchical level which is not basic. Else, i.e. in case of exhaustive analysis which does go down until centres of the basic level, the question of delimitation of the umland does not exist. Rather, it is a question of classification of basic centres that then is relevant.

DISCORDANCE OF SUBORDINATION PATTERNS ON INDIVIDUAL HIERARCHICAL LEVELS

It is to the question of exhaustive versus unexhaustive analysis of hierarchy, as discussed above, that the problem of discordance of subordination patterns on individual hierarchical levels can be referred to. Generally, according to the central place theory, centres on any hierarchical level are subordinated to a spatially nearest higher rank centre. On the other hand, multi-level hierarchies are characteristic of settlement systems which are, however, identified according to their very formal structural features. Lowest order centres are interrelated by a common dendrit to a highest order centre not because of any interactions between them but merely because there exists a chain of pairs of centres between them which are mutually hierarchically subordinated. In this case, the nearest neighbour rule is followed only by centres of the neighbouring levels of the hierarchy. In case of centres of the levels which are not neighbouring, the formal hierarchical pattern does not follow the rule, which produces discordance of subordination patterns on individual hierarchical levels. For exemple, it may happen for a basic centre A which is subordinated to a subregional centre B that the nearest regional centre is not C which B is subordinated to but another regional centre C'. The basic centre A, together with the area which belongs to it, is therefore the area of discordance of subordination patterns between the subregional centre B and regional centre C.

THE KIND OF RELATIONSHIPS ANALYSED

The fact that problems of urban hierarchy were most extensively discussed within the central place theory is responsible for a tendency to consider urban hierarchy merely in terms of the theory. Yet, the holistic approach which was referred to in Introduction makes it possible to expand this point of view considerably. There is no reason to recognize central-place functions as the only ones which contribute to urban hierarchy. Intrinsic general urban hierarchy is a highly complex totality which is composed of a great although finite number of particular hierarchies: economic and social, central-place and specialized, individual and common, perceptual and behavioural, objective and subjective, and so forth. Each of the particular hierarchies provides results which are more or less different from each other, yet each of them contributes to the recognition of the general urban hierarchy. To analyse any single particular hierarchy is equally good as any other and, on the other hand, equally insufficient as any other as the only source of information about the general urban hierarchy. The only way to approach the knowledge of the latter is to make investigations of relatively many particular hierarchies.

GENERALITY OF RESULTS

Since any system, including settlement systems, is on the permanent move or being permanently changed, any static illustration of the system must be unique, i.e. untypical. Yet, hardly any method has been worked out in socio-spatial sciences which would deal with changes through time rather than with a spectrum of illustrations of individual points in time. When analysing urban hierarchy, it is relationships involved by central-place functions that are more stable in time while relationships involved by specialized functions are more likely to change in time. Analyses of flows which are based on single points in time are therefore likely to comprise more elements that may be judged 'random' or untypical, i.e. which are related to the specialized functions. Analyses based on multi-annual averages provide results which are more smoothed and in this way the elements of the system which are related to the central-place functions are emphasized.

EMPIRICAL ANALYSIS

The empirical analysis which was carried out concerned Polish urban hierarchy as based on migration. The 1974 data on inter-urban migration were taken as well as 814 towns according to their 1975 boundaries and urban status. Gross migration totals for individual towns were taken as a basis of their ranking. According to earlier investigations (Rykiel and Żurkowa 1981), it was assumed that 6 hierarchical levels could be identified in the Polish urban system. Rank-size analysis of gross migration totals for individual towns indicated (Fig. 1) that the defined ranks were highly correlated with those of urban size. One 1st order or metropolitan centre was identified, 9 supra-regional or 2nd order centres, 39 regional or 3rd order centres, 129 subregional or 4th order centres, 410 supra-local or 5th order centres, and 226 local or 6th order centres.

The spatial pattern of hierarchical subordinations was identified according to one (viz. the strongest) relationship of each town. Yet, the pattern based on largest outflow is different than that which on largest inflow; besides, both provide information about the mechanism of migration (Rykiel and Żurkowa 1981). On the contrary, the pattern based on largest gross migration, which was chosen for this analysis, is still different, yet it seemed to be most appropriate for analysis of the urban system. It was assumed therefore that a given town was hierarchically subordinated to the town to which it was most strongly related by gross migration flow, regardless of their sizes. If loops of pairs of elements were found in the graph, it was the subordination of larger to smaller town (in terms of gross migration totals) which was omitted, and the opposite subordination remained; the larger town was then recognized as a supremate centre. If a town was equally strongly subordinated to two or three centres, the largest of them was chosen (in terms of gross migration totals); alternatively, the spatially nearest centre might have been chosen. In many cases the hierarchical subordinations were identified between centres of the same rank, which would imply that they are non-hierarchical links or that the intrinsic ranks of the centres are somewhat different than those identified in the analysis. The latest is even more evident in the case when a higher rank centre is subordinated to a lower rank centre.

36 supremate centres were identified, which according to they Nystuen and Dacey (1968) method would be recognized as the 1st order centres. As it can be seen in Fig. 1, the towns, although supremate to hierarchical urban systems, are of different ranks: 1 centre of 1st order, 4 of 2nd order, 12 of 3rd order, 8 of 4th order, and 11 of 5th order. Supra-regional, regional and local hierarchical urban systems can be therefore identified in Poland.

It would be justifiable, however, to put a question of to what extent such a considerable number of supremate centres results from the analysis which has been based on formal rather than functional urban units. Undoubtedly, the identification of many smaller hierarchical systems results from the fact that the loops of the strongest relationships are to be found within functional complexes (e.g. Jelenia Góra, Dzierżoniów, Kędzierzyn, Kraśnik). If the functional complexes were taken as elements of the analysed system, the internal flows would be omitted and, for instance, Jelenia Góra and Dzierżoniów would be subordinated to Wroclaw, and Kraśnik to Lublin. Yet, majority of regional hierarchical systems would remain. Szczecin, for example, as a formal unit is the most strongly related to Police but as a functional unit, i.e. after aggregation with Police, it would be still most strongly related within the region (to Świnoujście and Stargard Szczeciński) rather than with any supra-regional centre.

Although supra-regional, regional and local hierarchical urban systems can be found in Fig. 1, a dominant number of them fall in the regional systems category of differential sizes. In regions of high communication accessibility to the regional centres (Warsaw, Białystok, Cracow) or of considerable human mobility (Wroclaw) only two levels of hierarchical subordinations can be found, regardless of the number of hierarchical ranks of centres. This is to say that no multi-level pattern of Christallerian type can be found in the regions; rather, individual towns, regardless of their ranks, are directly related to the regional centres. As it was indicated elsewhere (Rykiel and Żurkowa, 1981), such a pattern of interrelationships is characteristic of urban regions. At the other end of the spectrum, regions with dense urban network can be found with Christallerian type pattern still prevalent which, however, does not exceed three levels (Greater Poland). A majority of regional systems takes intermediate position in the spectrum; beside two-level patterns, three- and four-level patterns can be found within the regions.

Strict hierarchical subordinations can be referred to when a supremate centre unequivocally dominates over the subordinate centre. Yet, in real life settlement systems a degree of dominance of supremate centres, or unequivocality of subordination of subordinate centres, is different. An analysis of the Polish urban system indicated (Fig. 1) a lack of dominance in interrelationships of supra-regional, regional, and more distant subregional centres. Majority of intra-regional relationships can be classified as of weak or at the most moderate hierarchical dominance. Strong dominance can be found among local relationships, including those between large and middle-sized towns with their satellites. Overwhelming dominance can be exceptionally found; of 4 relationships in Poland, 3 apply to the Białystok region; the city of Białystok itself is the most strongly dominant regional centre in Poland.

In further analysis it was assumed that centres being not hierarchically dominated (i.e. those of which the supremate centre accounts for less than 10 per cent of their gross migration) should be rather recognized as dominant centres themselves. The 98 towns should be therefore included to this category (Fig. 2).

When analysing the degree of hierarchicality of interrelationships, effectiveness of migration, i.e. the net to gross migration rate, was used. In most cases the subordinate centre depends on the supremate centre by being drained by, in some, however, e.g. the one of Zgorzelec → Bełchatów, by being alimented by. Analysis of effectiveness of flows itself cannot therefore be used for identification of supremate centres. The analysis indicates, however, regional differentiation of the degree of hierarchicality of interrelationships (Fig. 2). The highest degree of hierarchicality can be found in regions with official restrictions on migration to the regional centres; they comprise strong hierarchical links in the Warsaw region, and explicit hierarchical links in the Poznań, Cracow and Łódź regions. An apparent paradox is that it is the regional centres which indicate a strong positive effectiveness, i.e. the cities in which in-migration is officially limited. In fact, however, the difficulties to get to the cities make potential out-migrants unlikely to move while by producing myths they stimulate additional in-migration which, although restricted, turns out not to be unsuccessful.

In regions where there are no restrictions on migration, a whole spectrum of relationships can be found of differential degree of hierarchicality (e.g. the Szczecin, Wrocław, Białystok and Lublin regions). A causal explanation of degree of hierarchicality of interrelationships between individual pairs of towns would require analysis of their economic base. Interestingly, non-hierarchical or even explicit non-hierarchical links interrelate the supra-regional centres with resorts in their respective regions (e.g. Cracow with Krynica, and Wrocław with Karpacz, Kudowa Zdrój and Polanica Zdrój). Weak hierarchical links are in many instances (e.g. in the Opole, Lublin, Kielce and Wroclaw regions) resultants of hierarchical links involved by central-place functions and non-hierarchical involved by urban specialized functions.

A comparison of Figures 1 and 2 allows to find differences between unequivocality and hierarchicality of relationships. Some small towns in the Białystok region, being strongly or even decidedly dominated by the city, are non-hierarchically interrelated to the city. Towns in the Warsaw region, on the contrary, are weakly dominated by the city, being, however, strongly hierarchically related to it. As a matter of fact, however, a conceptually based hesitation is felt to recognize the strict hierarchical patterns under weak dominance, for it is to say that relationships of the town within the urban system are dispersed, hence relationships to the regional centre are relatively weak. On the other hand, the relationships are highly effective, i.e. mainly one-way directed. The structure of the Polish urban system, as reflected by migration, should be therefore recognized as quasi-hierarchical. What is characteristic of the structure is flows up the urban hierarchy which are both highly effective and considerably dispersed, which results from a relatively high density of the urban network. A basic disaggregation of the national urban system is regional disaggregation.

CONCLUSIONS

The main scope of the paper was of a conceptual nature. It is, however, empirical investigations that can and should verify even most refined theoretical concepts. Not all of the nine detailed questions of urban hierarchy, as identified in the paper, were empirically analysed herein, even though most of them were.

Empirically, the most important question the present paper has dealt with is that concerning the structure of the national settlement system. The present analysis is one of the few approaches to the pattern of hierarchical subordinations on the national scale, after those by Rykiel and Zurkowa (1981), Rykiel (1984), and Korcelli et al. (1981), the latest dealing, however, with 351 rather than 814 urban units. The analysis provided herein was based on migration which, as it was argued, is as good and as insufficient as any single kind of relationships. Analyses of different kinds of relationships would therefore be welcome.

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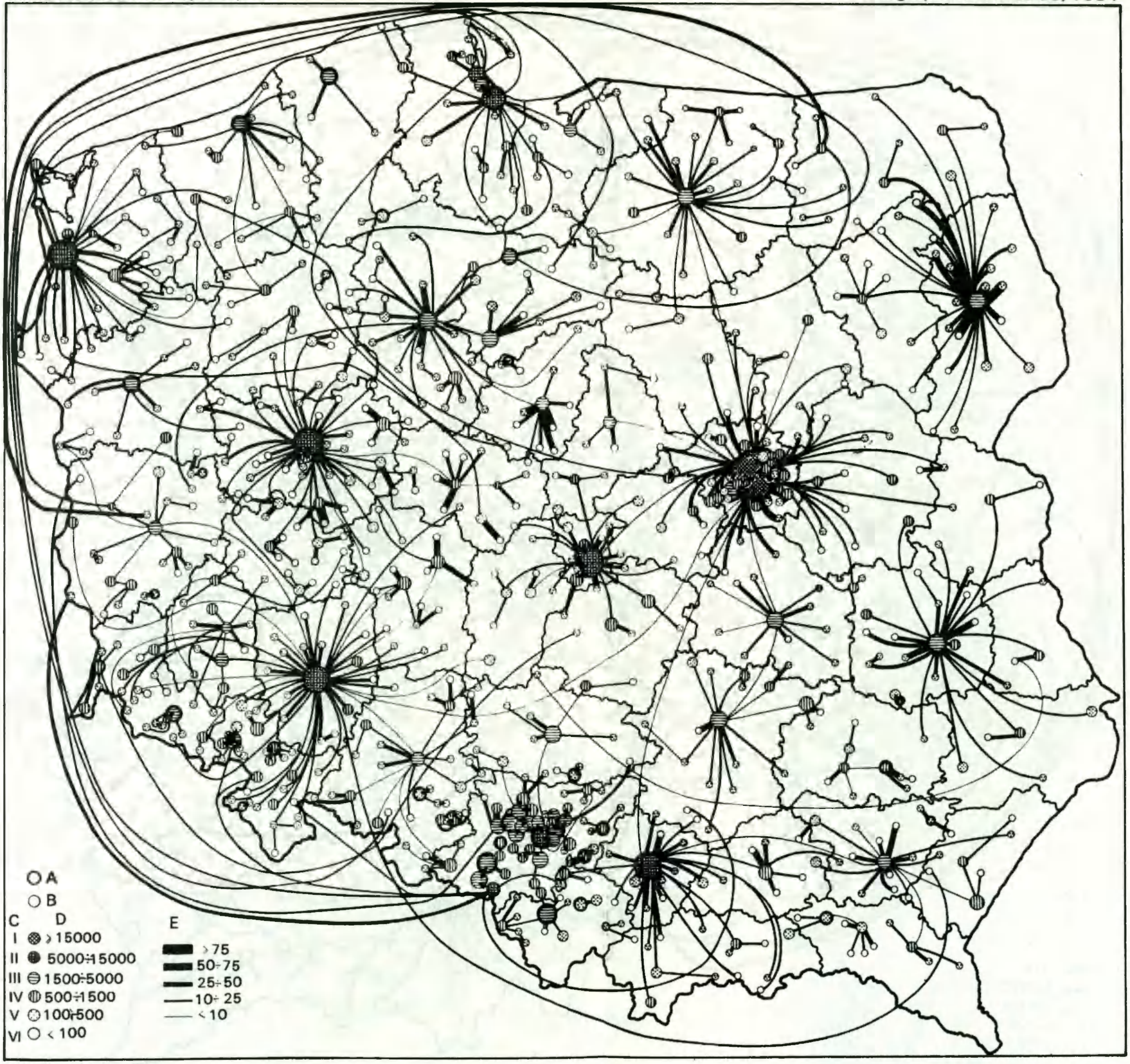

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Fig. 1. Hierarchical dominance in the Polish urban system as reflected by migration, 1974

A – dominant towns, B – dominated towns, C – hierarchical rank, D – gross migration totals, E – strongest relationships of a dominated town as related to its turnover in the system (%); arrow indicates subordination of town when opposite to the ranking indicated. Dominance: 1 – overwhelming, 2 – strong, 3 – moderate, 4 – weak, 5 – no

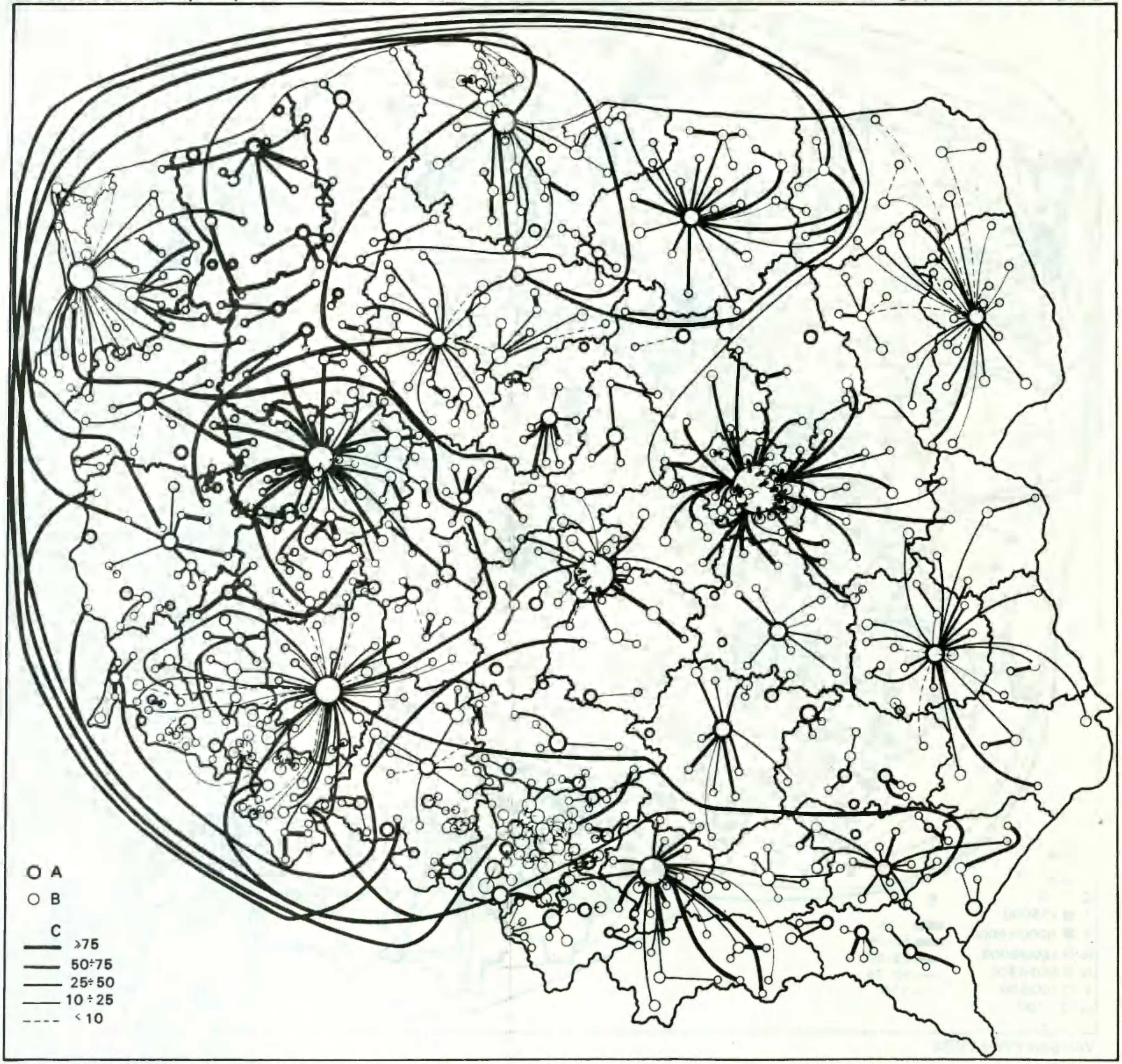

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Fig. 2. Hierarchical subordinations in the Polish urban system as reflected by migration. 1974

A – supremate town. B – subordinate town. C – effectiveness of migration (‰). Relationships: 1 – strong hierarchical. 2 – explicit hierarchical. 3 – weak hierarchical. 4 – non-hierarchical. 5 – explicit non-hierarchical

THE WARSAW URBAN REGION: INTERDEPENDENCES BETWEEN PLACES OF WORK AND PLACES OF RESIDENCE

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BASIC ASSUMPTIONS AND HYPOTHESES

The authors of geographic studies dealing with the development of agglomerations in Poland have paid little attention to the assessment of the internal patterns and differentiation of agglomerations, that is, to spatial, demographic or social structures. Research interest has tended to focus primarily on the definition and explanation of the essence and general conditions determining the development of agglomerations and on delimiting their boundaries. As regards the delimitation of agglomeration bundaries, recent years have witnessed a departure from composite criteria and structural features in favour of link measures. Accordingly, the boundaries of an agglomeration are viewed to be identical with the extent of an area that displays a high degree of closure of the zones of daily contacts between the inhabitants of the agglomeration, in particular the zones of daily commuting from places of residence to places of work and back. This line of definition was, among others, followed by Berry (1966, 1968, 1973) and Hall (1973), and by Korcelli (1982) in Poland, who connected these definitions with the concepts of the functional urban region or the daily urban system.

The concept of the functional urban region refers to zones of direct contacts between inhabitants and to the spatial relations between the patterns of residences, workplaces, schools, service centres, sites of social contact and recreation areas. The present study is mainly intended to examine the concept of the functional urban region. In accordance with this concept, the boundaries of the outer zone of the Warsaw agglomeration are regarded as identical with the extent of the area displaying spatial links with its inner zone, following from the distribution of places of residence and work. Practically, it has been assumed that the daily extent of the investigated area is determined by commuting to work in Warsaw from suburban areas as in 1973, while the percentage relation of people commuting to work in Warsaw to the number of people employed in the nonagricultural sectors in the given administrative unit (community or town) is taken as the basic measure of link intensity. The marginal value of the indicator of links has been taken to be 0.01, less than the analogous marginal values used in the literature up to now (Fig. 1, see also Potrykowska 1983).

The study of the spatial structure of functional urban regions has its theoretical foundation in the theory of social interaction in space. A spatial structure is composed of a set of several spatial networks or patterns (including patterns of workplaces, residential units, of shopping, recreation, social contacts and others) superimposed one on another and corresponding to the fundamental domains

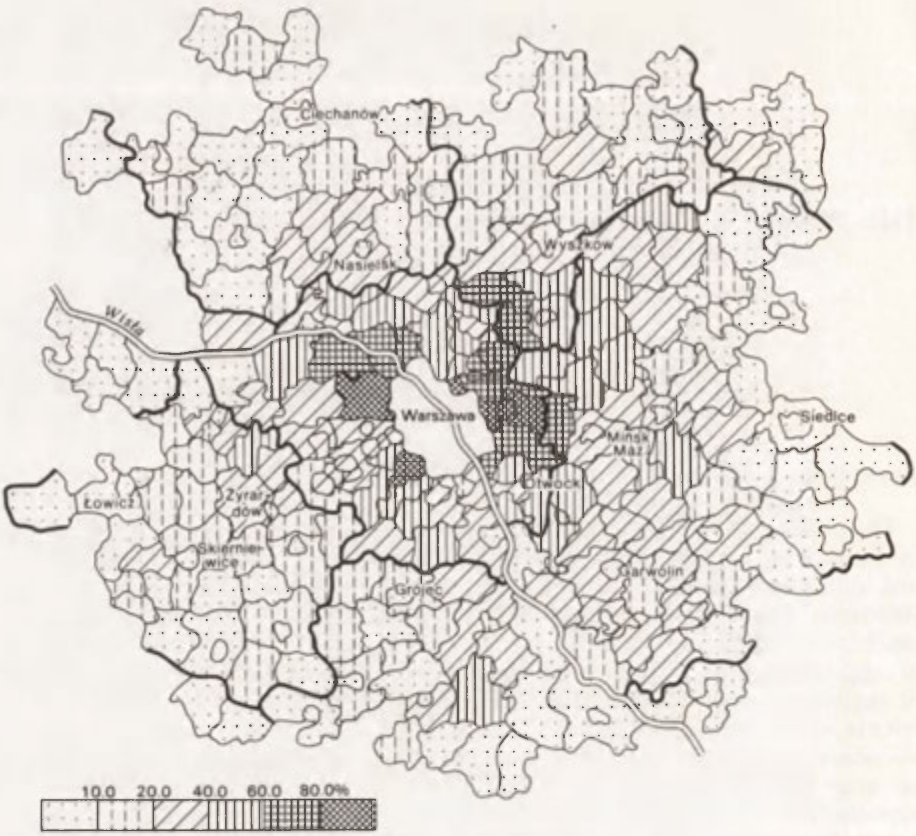

Fig. 1. Percentage of commuters to work in Warsaw in relation to economically active population, 1973

of human life and activity. The interaction of these patterns, especially those of workplaces and of residence units, is assumed to determine the spatial structure of the agglomeration. The intensity of interaction rises with the spatial accessibility of the elements of those networks.

It is indispensable to determine the spatial relations between the patterns of workplaces and of residential units in the Warsaw functional region delimited on the basis of a link indicator. In accordance with this assumption, attention must be focused on flows of people within the region, in particular on the connection between those flows and the socio-occupational spatial structure; the latter can, for the sake of simplicity, be preliminarily reduced to a pattern of concentric zones additionally disaggregated into sectors (Table 1).

Trips from zone to zone or from sector to sector are conditioned by their mutual relations as regards the distribution of population, woıkplaces, and housing resources. A sectoral differentiation in the volume and intensity of trips manifests itself also when the region is divided into parts west and east of the Vistula. The prevalence of commuting from the east-bank part of the region (58.7% of all commuters in 1973) is mainly connected with excess of labour reserves in that industrially less developed area. The distribution of commuter trips in the west-bank part, which is industrially more advanced, is of course different (currently 41.3% commuters come from that area).

TABLE 1. Structure of commuting to work in Warsaw in 1973, by distance zones and sectors, according to directions of trips, in %

Zones		Sectors																	
		Płock		Łowicz		Skierniewice		Radom		Otwock		Siedlce		Wołomin		Nasielsk		Total	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
up to 20 km	t	–	–	0.26	0.27	4.67	4.56	1.27	1.06	1.16	1.04	1.87	1.63	6.12	5.78	1.59	1.28	16.94	15.61
	c	2.24	1.69	0.34	0.28	0.55	0.48	2.86	2.39	–	–	0.55	0.38	0.72	0.59	1.47	1.04	8.74	6.86
20–40 km	t	–	–	0.52	0.43	1.44	1.24	0.68	0.58	3.30	2.32	1.06	0.90	0.63	0.46	0.80	0.44	8.44	6.37
	c	1.32	0.69	0.31	0.20	0.48	0.35	1.46	0.90	1.34	0.77	1.59	1.26	2.51	1.52	0.45	0.25	9.47	5.94
40–50 km	t	–	–	–	–	0.73	0.40	0.15	0.06	–	–	–	–	0.20	0.11	0.14	0.05	1.21	0.62
	c	0.06	0.03	0.19	0.09	0.43	0.27	0.20	0.07	0.96	0.48	0.46	0.26	1.53	0.76	0.58	0.10	4.42	2.06
50–60 km	t	–	–	0.47	0.25	–	–	0.09	0.06	0.12	0.03	0.04	0.02	0.07	0.05	0.10	0.02	0.84	0.43
	c	0.15	0.02	0.21	0.05	0.11	0.02	0.22	0.08	0.60	0.20	0.55	0.23	0.83	0.26	0.29	0.07	2.98	0.93
60–80 km	t	–	–	0.14	0.02	0.38	0.11	0.06	0.01	0.04	0.01	0.02	–	0.17	0.05	0.30	0.04	1.08	0.25
	c	0.02	0.01	0.41	0.06	0.69	0.09	0.46	0.05	1.00	0.02	0.63	0.03	0.74	0.18	0.10	0.02	4.04	0.63
80–100 km	t	0.08	0.01	–	–	–	–	0.04	0.01	0.02	0.01	0.11	0.01	–	0.01	0.01	–	0.26	0.05
	c	0.02	0.00	0.10	0.01	0.09	–	0.13	–	0.05	–	0.11	0.01	0.70	0.11	0.13	–	1.33	0.11
More than 100 km	t	0.02	0.00	0.04	0.01	0.01	0.00	–	–	–	–	–	–	0.04	0.01	0.04	0.01	0.14	0.03
	c	0.02	0.00	–	–	–	–	–	–	–	–	0.02	–	0.03	0.01	0.01	0.00	0.10	0.01
Directions, total		6.4		4.7		17.1		12.9		13.6		11.8		24.2		9.3		100.0	

M – males, F – females, t – towns, c – communities
Source: Author's own calculations on the basis of *Spis kadrowy* (Labour-force census) 1973 (1975).

Still, commuting to work within the region involves more complex and varied movements. In the suburban zone, trips to work in Warsaw dominate, accounting for three-fourths of commuting beyond the given residence unit. Apart from Warsaw, the structure of commuting to work in the region is dominated by the industrial towns in the vicinity of Warsaw in the direction of Skierniewice (Ursus, an independent town till 1978; Pruszków, Grodzisk Mazowiecki, Piastów and Milanówek) as well as the towns Wołomin and Otwock in the east-bank part of the region. Every fifth person leaving his or her residence unit commutes to workplaces in the suburban zone. Commuting from the suburban zone outside to the region is insignificant. Remarkably enough, the number of commuters to Warsaw exceeds that of excessive labour reserves in the source areas; this means that the large number of people commuting to work in Warsaw generates labour deficits in those areas, which in turn are offset by commuters arriving there from still more distant areas. Another characteristic feature is that the west-bank part records a clearly higher surplus of commuters over excessive labour reserves than the east-bank part of the region.

Studies of the socio-economic changes called forth by industrialization and urbanization in the Warsaw urban region have shown that the pattern of commuting described here is marked by a specific socio-economic set of features (cf. *Kompleksowe badanie ruchu*, 1969, Pióro 1977, Ginsbert and Ziółkowski 1978). Most commuters (67.1%) found jobs in three sectors of the city's economy: industry (36.6%), construction (16,7%), as well as transport and communication (13.8%). But these three sectors comprised jointly only 52.5% of total employment in Warsaw. This indicates the dependence of the capital-city on the influx of labour to its basic economic sectors from outside its boundaries. The people who commute from towns and communities situated closer to the region's centre, generally hold higher qualifications (better education) and are looking for easier jobs, while less-qualified people, willing to take harder jobs, generally commute from distant villages. Moreover, the spatial distribution of commuting to Warsaw also displays certain definite demographic features among the commuters (cf. Lijewski 1967, Pióro 1977, Potrykowska 1980). Males account for 60% of all commuters. The difference between male and female commuters is lowest in the central zone: it amounts to 1.3% for commuters from towns and to 1.7% for commuters from communities. With distance from the region's centre, the difference between male and female commuters rises regularly (to be 8-fold in the outer zone); with a rising proportion of males and, in terms of residence units, of commuters from villages (Table 1).

This pattern of daily intensive trips (contacts) reflects a further kind of links, in particular an advanced functional specialization and the concomitant exchange of goods and information. In accordance with the definition of the functional urban region given at the outset of this study, the pattern of daily commuting to work is conditioned by the mutual relations between the distributions of workplaces and residential units, respectively. Those relations are indicative of an interdependence of the two networks, especially of the interdependence between the volume and structure of commuting to work in Warsaw on the one hand, and the demographic and socio-occupational structure of the population of the Warsaw urban region on the other. The literature of the subject in such cases mentions two kinds of relations. The first implies that with the expansion and consolidation of the fields of commuting to a big city, the structure of the areas constituting the fields gradually transforms. The transformation concerns the socio-occupational structure in the first phase, the structure of education and of basic investment and consumption models in the next phase, and the features of the demographic structure in the third phase. Such changes, which essentially consist in the assimilation of these structures to those predominant in the big city itself, have been closely analysed and discussed in studies of what are called industrializing areas (Dobrowolska 1976). The other of the two relations implies that the directions of expansion of the fields of commuting are determined by the features characterizing the areas surrounding the centre of commuting, such as the agrarian structure, population density, the level of qualifications and cultural features of the population as well as the structure of the transport network in the region (Pióro 1977).

In keeping with these two relations, I have adopted the following hypotheses:

(A) The volume and spatial distribution of commuting to work is conditioned by the socio-economic and demographic structure of the population.

(B) Daily commuting to work generates changes in the population's socio-demographic structure.

(C) The sectoral spatial distribution of commuting to work corresponds to the differentiation of the population's socio-economic features.

(D) The concentric spatial distribution of commuting to work corresponds to the differentiation of the population's demographic features.

Hypotheses C and D fall within the ecological concept in geographic studies of the urban spatial structure which implies that the spatial differentiation of an urban community is composed of sectoral and concentric elements, specifically that

– the differentiation of socio-economic features takes a sectoral form, while
– the differentiation of demographic features takes a concentric form.

THE INTERDEPENDENCES BETWEEN THE SOCIO-ECONOMIC LINKS AND STRUCTURES OF WORKPLACES AND PLACES OF RESIDENCE A CANONICAL ANALYSIS

Canonical analysis is a convenient research tool in determining the mutual links (interaction) between different patterns of variables (Clark 1975, Cooley and Lohnes 1971). As a generalized form of multiple regression, it consists in searching for relations between two sets of variables – the dependence between a set of q explained variables and a set of p explanatory variables. In the present study, canonical analysis was applied to consider the interdependences between the patterns of workplaces and of residence units in the functional urban region of Warsaw, by towns and communities as in 1973.

The canonical analysis was carried out using the sets of initial dependent and independent variables described below. The dependent variables characterizing the pattern of workplaces constituted vector y, whereas vector x was composed of the independent variables concerning the demographic-social and occupational structures of the population resident in the studied region.

(a) The set of independent (explanatory) variables:

x_1 – distance in km
x_2 – population density per km^2
x_3 – % of males
x_4 – natural increase per 1000 persons
x_5 – net migration per 1000 persons
x_6 – percentage relation of workplaces and residential units of employees (indicator of relative independence of the studied unit as regards the number of jobs available)
x_7 – industrial employment per 1000 persons
x_8 – % of people employed in agriculture
x_9 – % of people with higher education employed in the socialized sector

x_{10} – % of people with elementary education employed in the socialized sector
x_{11} – dwellings completed in 1973 per 1000 new marriages
x_{12} – rooms completed in 1973 per 1000 persons
x_{13} – number of dwellings per 1000 persons

(b) The set of dependent (explained) variables:

y_1 – % of commuters to work in Warsaw in the nonagricultural employment in the socialized sector
y_2 – % of commuters to work in Warsaw in total population
y_3 – % of commuters to work in Warsaw in total number of people leaving their residential units
y_4 – % of commuters to work in Warsaw's industrial plants in total number of commuters
y_5 – % of commuters to work in Warsaw's construction sector in total number of commuters
y_6 – % of males in total number of commuters to Warsaw
y_7 – % of persons aged under 29 in total number of commuters to Warsaw
y_8 – % of persons with higher education in total number of commuters to Warsaw
y_9 – % of persons with elementary education in total number of commuters to Warsaw

The canonical analysis started with a compilation of a 250×22 matrix of observations which contained the numerical values of sets (a) and (b). The analysis used nonstandardized variables. Since the set of dependent variables y consisted of nine variables, nine pairs of canonical variates were obtained, as min $(p, q) = 9$.

The coefficients of canonical correlation between the particular pairs of canonical variates are presented in Table 2; it is seen that not all coefficients differ significantly from zero at 0.05. To test the significance of those coefficients, Roy's maximum root was employed (cf. Krzyśko and Ratajczak 1978). The canonical correlation coefficients are significant only for the pairs u_1v_1, u_2v_2, u_3v_3, u_4v_4, u_5v_5, u_6v_6.

Using the formula

$$R^2_{y \cdot x} = \sum_{i=1}^{q} \frac{\sum_{k=1}^{q} r_i^2 \operatorname{Var} y_k \operatorname{Cor}^2(y_k, v_i)}{\sum_{k=1}^{q} \operatorname{Var} y_k}$$

we can obtain the coefficients of multiple correlation in the sense of multiple regression which show the percentage of variance of dependent variables that is explained by the set of the original independent variables. Table 3 indicates what part of the variance of the dependent variables $(y_1, y_2, \ldots, y_9)$ can be accounted for as a result of the application of canonical analysis. Information as to the degree to which all canonical variates of the space of the independent variables jointly explain the total variance of all dependent variables can be gained from the composite determination coefficient $R^2_{y \cdot x}$. In our analysis this is coefficient amounts to 0.4893. This implies that the total variance of dependent variables y explained by the particular canonical variate u determined from the vector x amounts to 48 93%. The interpretation of the canonical variates was made using the determination coefficients, in order to establish the variation of the original features (cf. Krzyśko and Ratajczak 1978). The coefficients of determination between all original variables characterizing the trips and the features of the source

1) $u_1 = -0.015892x_1 + 0.0005453x_2 - 0.0841190x_3 - 0.0037165x_4 + 0.0009557x_5 - 0.0045441x_6 + 0.0027901x_7 + 0.0008548x_8 + 0.0730210x_9 +$
$+ 0.0049306x_{10} - 0.0003412x_{11} + 0.0132461x_{12} + 0.0039446x_{13}$
$v_1 = -0.0278028y_1 + 0.0757134y_2 + 0.0189703y_3 + 0.0005653y_4 + 0.0035969y_5 - 0.0123546y_6 - 0.0124080y_7 + 0.0487952y_8 + 0.0014248y_9$

2) $u_2 = 0.0096725x_1 + 0.002341x_2 - 0.0004277x_3 + 0.0416665x_4 + 0.0052307x_5 - 0.0207726x_6 - 0.0009921x_7 - 0.0101451x_8 + 0.0388909x_9 +$
$- 0.0026182x_{10} - 0.0001564x_{11} + 0.0134892x_{12} + 0.0001750x_{13}$
$v_2 = 0.0923310y_1 - 0.0015847y_2 - 0.0492442y_3 - 0.013675y_4 + 0.0018335y_5 - 0.0064264y_6 - 0.0076526y_7 - 0.0364604y_8 - 0.0043170y_9$

3) $u_3 = + 0.0337339x_1 + 0.0005349x_2 - 0.1266055x_3 - 0.0775697x_4 + 0.0107357x_5 - 0.0426498x_6 + 0.0118346x_7 + 0.0089040x_8 +$
$+ 0.0863634x_9 + 0.0132663x_{10} - 0.0002187x_{11} + 0.0198060x_{12} + 0.0048957x_{13}$
$v_3 = 0.0363042y_1 + 0.0489937y_2 + 0.0525700y_3 - 0.0299314y_4 - 0.0118127y_5 + 0.0149881y_6 - 0.0233594y_7 + 0.052608y_8 - 0.0027203y_9$

4) $u_4 = + 0.186423x_1 + 0.0001306x_2 + 0.0346003x_3 + 0.1910007x_4 + 0.0232351x_5 - 0.0007927x_6 - 0.0010573x_7 - 0.0514867x_8 +$
$+ 0.2193759x_9 + 0.0123996x_{10} - 0.0011472x_{11} + 0.0406765x_{12} + 0.0017971x_{13}$
$v_4 = 0.1016507y_1 + 0.3134801y_2 + 0.0273565y_3 + 0.0086018y_4 - 0.0171482y_5 + 0.0564704y_6 + 0.0078778y_7 - 0.0396288y_8 + 0.0095051y_9$

5) $u_5 = - 0.0054462x_1 + 0.0001696x_2 + 0.1425867x_3 + 0.0358611x_4 + 0.0263386x_5 + 0.0082497x_6 + 0.0069306x_7 - 0.0137579x_8 +$
$+ 0.0148204x_9 - 0.0228450x_{10} + 0.0027289x_{11} - 0.1034434x_{12} - 0.021785x_{13}$
$v_5 = + 0.0084538y_1 - 0.1510230y_2 + 0.0460119y_3 - 0.0202140y_4 - 0.0105092y_5 + 0.0014358y_6 - 0.0011484y_7 + 0.0808613y_8 + 0.0791804y_9$

6) $u_6 = - 0.0006023x_1 + 0.0019527x_2 + 0.1263151x_3 + 0.0455639x_4 - 0.0615829x_5 + 0.0077011x_6 - 0.0073603x_7 + 0.0059797x_8 +$
$- 0.0427873x_9 - 0.0169499x_{10} + 0.0039648x_{11} - 0.1070538x_{12} + 0.0064346x_{13}$
$v_6 = - 0.0017647y_1 + 0.0864300y_2 + 0.0014320y_3 - 0.0024999y_4 + 0.0413887y_5 + 0.0433248y_6 - 0.0053660y_7 + 0.0091326x_8 -$
$+ 0.1235040y_9 + 0.0121365y_{10}$

7) $u_7 = + 0.0015265x_1 - 0.0011179x_2 - 0.2808070x_3 + 0.0835875x_4 - 0.0339711x_5 - 0.0068592x_6 + 0.0105816x_7 + 0.0091326x_8 +$
$+ 0.1235040x_9 + 0.0121365x_{10} + 0.0027119x_{11} - 0.1071317x_{12} + 0.0023378x_{13}$
$v_7 = - 0.0197064y_1 + 0.0921165y_2 + 0.0092691y_3 - 0.0886076y_4 - 0.0203027y_5 - 0.0358628y_6 + 0.0847853y_7 + 0.0100388y_8 + 0.0147679y_9$

8) $u_8 = + 0.0027399x_1 + 0.00060004x_2 + 0.1175615x_3 + 0.1147883x_4 + 0.0226284x_5 - 0.0184162x_6 + 0.0020095x_7 + 0.0542661x_8 - 0.0267419x_9 +$
$+ 0.0918386x_{10} + 0.0010166x_{11} - 0.0231236x_{12} - 0.0015507x_{13}$
$v_8 = - 0.0342845y_1 + 0.1484335y_2 - 0.0371208y_3 + 0.0336397y_4 + 0.0172210y_5 - 0.0621096y_6 - 0.0147797y_7 + 0.0604627y_8 + 0.01025516y_9$

9) $u_9 = + 0.0017263x_1 - 0.0005667x_2 + 0.1376242x_3 + 0.0142885x_4 + 0.0620385x_5 - 0.0020229x_6 - 0.0060561x_7 + 0.0114519x_8 +$
$+ 0.0736753x_9 - 0.0018716x_{10} + 0.0019966x_{11} - 0.0936675x_{12} + 0.0155720x_{13}$
$v_9 = + 0.0366517y_1 - 0.090304y_2 - 0.0148079y_3 + 0.0426331y_4 - 0.0288129y_5 - 0.0900898y_6 - 0.0753673y_7 + 0.1572932y_8 + 0.0859677y_9$

TABLE 2. Canonical correlation coefficients

No.	Pair of variates	Coefficient of canonical correlation
1.	u_1 v_1	0.904285
2.	u_2 v_2	0.821835
3.	u_3 v_3	0.580988
4.	u_4 v_4	0.410745
5.	u_5 v_5	0.316213
6.	u_6 v_6	0.268680
7.	u_7 v_7	0.168386
8.	u_8 v_8	0.085449
9.	u_9 v_9	0.0533162

Level of significance: $\theta_{0.05}(9,1,5,113) = 0.194$
$\theta_{0.01}(9,1,5,113) = 0.216$

area on the one hand and all canonical variates on the other, are presented in Tables 4 and 5.

Table 4 presents all determination coefficients between all variables of the vector y and all canonical variates, the total sum of all coefficients in a row being equal to 1 (100%).

TABLE 3. Multiple determination coefficients. Percentage of variance of successive dependent variables y explained by all original variables of vector x

Dependent variables	R^2
Y_1	67.8
Y_2	71.6
Y_3	61.7
Y_4	33.6
Y_5	22.6
Y_6	58.1
Y_7	17.4
Y_8	67.8
Y_9	48.3

TABLE 4. Correlation squares matrix. Determination coefficients between variables y and canonical variates v

Number of variables	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9
y_1	.35689	.53973	.05668	.00106	.02117	.00001	.00018	.02131	.00296
y_2	.59105	.31887	.01850	.06159	.00127	.00062	.00644	.00018	.00059
y_3	.52994	.17344	.16973	.01376	.07016	.00007	.00000	.04261	.00029
y_4	.23428	.02757	.29397	.00360	.15890	.10083	.10182	.00299	.07605
y_5	.17805	.01071	.05597	.04076	.00051	.64780	.00440	.05078	.01102
y_6	.62846	.02837	.06581	.07047	.04246	.11969	.02038	.02017	.00418
y_7	.02605	.01951	.28448	.07488	.23589	.01159	.20414	.00042	.14303
y_8	.73364	.05890	.06012	.08414	.01898	.00030	.00006	.00256	.04130
y_9	.51552	.03180	.00228	.06235	.26999	.00949	.00001	.10424	.00433

On the basis of the values of R^2, from Table 4 one can find the dependent variables y that contribute most to the construction of the individual canonical variates v. Below are listed the individual canonical variates v that could be clearly distinguished, together with the original variables y that contribute decisively to the construction of those canonical variates:

v_1 – the canonical variate characterizing the level of qualifications and the sex structure of commuters

y_8 73.4 – commuters with higher education
y_6 62.8 – % of male commuters
y_2 59.2 – % of commuters in total population
y_3 53.0 – % of commuters to Warsaw
y_9 51.5 – commuters with elementary education

v_2 – the cononical variate characterizing commuting to work in relation to the economic structure of areas sending out the commuters

y_1 54.0 – % of commuters in relation to nonagricultural employment

v_3 – the canonical variate characterizing young Warsaw workers commuting to work in industrial plants

y_4 29.4 – commuters to industrial plants in Warsaw
y_7 28.5 – commuters aged under 29

v_6 – the canonical variate characterizing commuters to construction establishments in Warsaw

y_5 64.8 – commuters to building establishments

Analogously, on the basis of the highest values of R^2, from Table 5 one can find the independent variables x that contribute most decisively to the construction of the individual canonical variates u. Below are presented the individual canonical variates u that could be clearly distinguished, together with the original

TABLE 5. Correlation squares matrix. Determination coefficients between variables x and canonical variates u

Number of variables	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9
x_1	.70629	.12759	.11439	.02726	.00836	.00696	.00051	.00182	.00008
x_2	.51215	.16741	.05468	.01631	.02730	.11342	.05999	.00441	.00746
x_3	.16354	.10414	.07648	.00001	.03113	.04291	.08661	.05045	.00017
x_4	.06687	.09564	.09603	.36879	.00000	.03037	.07506	.11029	.01373
x_5	.18544	.27053	.00370	.04361	.05695	.08993	.09365	.00381	.15865
x_6	.04710	.84607	.06482	.02020	.00202	.00150	.00094	.00124	.00344
x_7	.31208	.43145	.00119	.01061	.03535	.00830	.02932	.00465	.04263
x_8	.07578	.00122	.00102	.22288	.04751	.01008	.01663	.12046	.01127
x_9	.32191	.05018	.00094	.06156	.00016	.00245	.02769	.04062	.02384
x_{10}	.04413	.14383	.00827	.00099	.03966	.07846	.00376	.36937	.02423
x_{11}	.03090	.11111	.00609	.05165	.00118	.00143	.07580	.00023	.00296
x_{12}	.04733	.04343	.00636	.06495	.04073	.00914	.17107	.00025	.05681
x_{13}	.32039	.07341	.01121	.00000	.25969	.01904	.00224	.01202	.17144

variables x that contribute most decisively to the construction of those canonical variates:

u_1 – the canonical variate characterizing the big-city character of the urban structure

x_1 70.6 – distance in km from the centre of Warsaw
x_2 51.2 – population density
x_9 32.1 – employees with higher education
x_{13} 32.0 – number of dwellings
x_3 16.3 – % of males

u_2 – the canonical variate characterizing industrial specialization in the given unit

x_6 84.6 – indicator of relative independence of the units as regards workplaces (percentage relation of workplaces to residence units of employees)
x_7 43.1 – indicator of industrial employment
x_5 27.0 – net migration
x_{11} 11.1 – increment of housing resources

u_4 – the canonical variate characterizing natural increase

x_4 36.9 – natural increase

u_7 – the canonical variate characterizing housing conditions

x_{12} 17.1 – rooms completed in 1973 per 1000 persons

u_8 – the canonical variate characterizing the agricultural population

x_{10} 36.9 – % of employees with elementary education in the socialized sector
x_8 12.0 – % of agricultural employment

These findings and the canonical correlation coefficients suggest that the interpretation should be confined to the first two pairs of canonical variates that could be clearly distinguished in the sets of variables (u_1, v_1) and (u_2, v_2). The canonical correlation coefficient for the pair $u_1 v_1$ is 0.904, while that for the pair $u_2 v_2$ equals 0.8218, both being high values.

It is to be pointed out that the first pair (u_1, v_1) of highly correlating canonical variates determined on the vectors of original variables is indicative of close interdependences in the region between its population's high mobility as expressed in the proportion and features of commuters to Warsaw and the variate characterizing urbanization processes which reflects the big-city character of the structure.

The construction of the variable v_1 is affected by: the indicator of demographic character (% of male commuters to work in Warsaw) and of social character (% of commuters with high and elementary education), the variables that indicate direct links with Warsaw (% of commuters to work in Warsaw in relation to total population), and the percentage of commuters to Warsaw in the total number of persons commuting to work outside their residence unit. This can be termed an interaction variable. So can the variable u_1, whose construction is decisively determined by distance as well as the demographic features of the region's population (population density per km^2 and % of males), or the variables characterizing the population's social structure such as the percentage of people with higher education or the number of dwellings. The spatial distribution of the first pair of canonical variates is shown in Fig. 2.

From what has been said, it follows that the first pair of canonical variates composed of two separate sets of variables contains similar elements of the population's demographic and social structure and that the strength of interdependence between variables gives evidence of the character and intensity of the processes taking place in the region, that is, the general urbanization processes whose occurrence is implied in the guiding hypothesis of this study, that the constituent elements of that structure affect the pattern of links in the region.

One of the preliminary hypotheses, namely that implying that the elements of the demographic and social structure of the population affect the pattern of links between the networks of workplaces and residential units in the form of intensive commuting to Warsaw, can thus be recognized as confirmed by the results of our canonical analysis.

The second pair of canonical variates (u_2, v_2), which also correlate strongly $(R_{xy} - 0.8218)$, presents a less involved structure that can be unequivocally determined. Namely, in the structure of the second of the canonical variate, v_2, there is but a single original variable – y_1, which characterizes the percentage of commuters to Warsaw in relation to nonagricultural employment. The canonical variate u_2, though, which has been termed industrial specialization in the given unit, is composed of the indicator of relative independence of the unit x_6 (Dziewoński and Jerczyński 1977) and the indicator of industrial employment as well as the concomitant demographic variables (net migration) and the increment in housing resources. The character and structure of these variables are the evidence of processes of functional specialization under way that affect the intensity of intraregional links against the background of general urbanization processes. What is especially noteworthy is the fact of a strong connection between the proportion of people commuting to work in industrial plants and the rate of housing development in the source area.

This contention can be supported by the conclusion that emerges from the interpretation of two further canonical variates determined on the vector of dependent variables y and of three other variates determined on the vector of

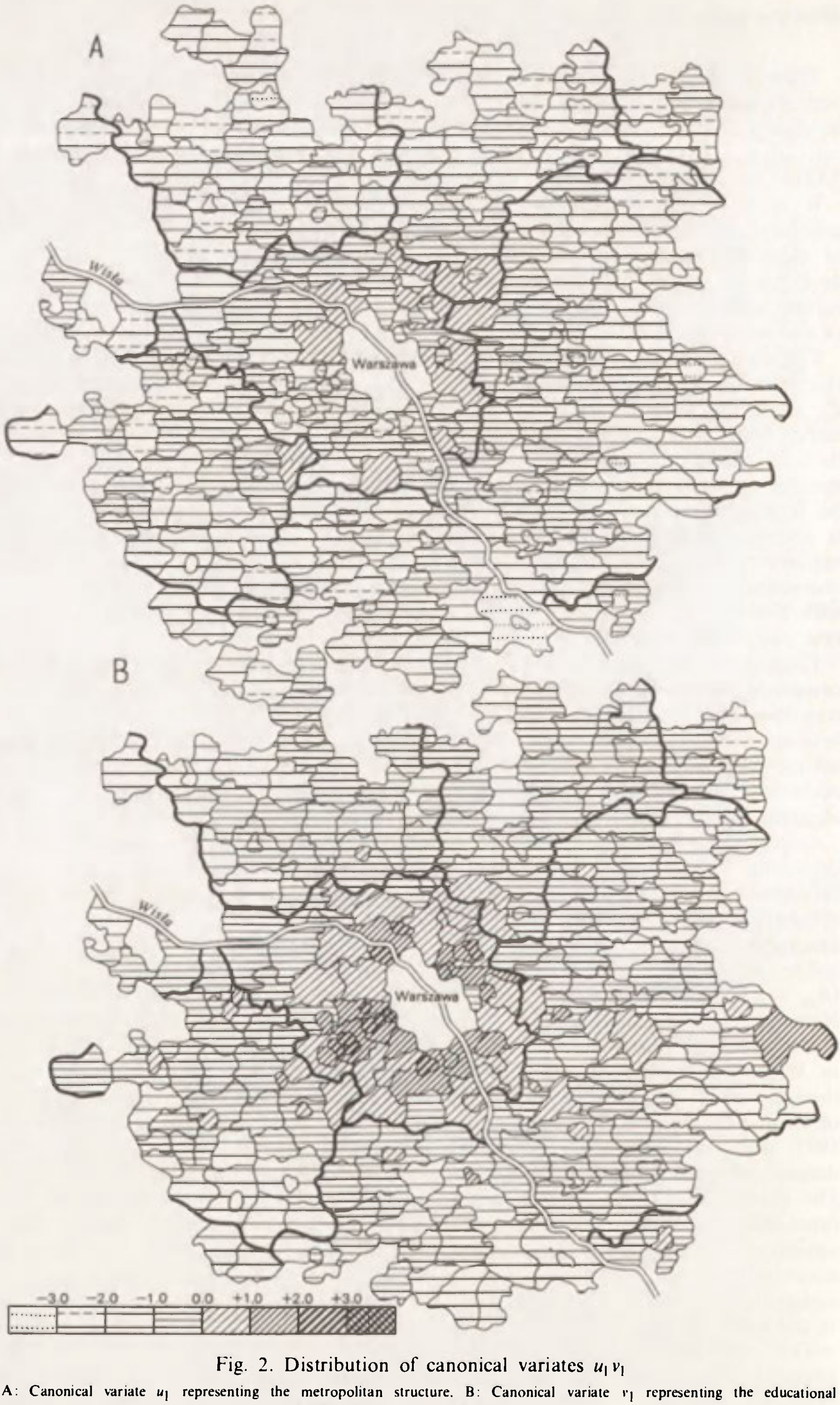

Fig. 2. Distribution of canonical variates $u_1 v_1$

A: Canonical variate u_1 representing the metropolitan structure. B: Canonical variate v_1 representing the educational level and sex structure of commuters

Fig. 3. Distribution of canonical variates $u_2 v_2$

A: Canonical variate u_2 representing the industrial specialization in given unit, B: Canonical variate v_2 representing commuting to work in relation to the economic structure of areas sending out the commuters independent variables x. Namely, the variates v_3 and v_6 are clearly related to the percentage of commuters to work to Warsaw in industry and construction, the two most important sectors of the region's economy. The former of these two variates in its composition is extended by the contribution of the demographic variable characterizing the percentage of persons aged under 29 commuting to work in Warsaw (v_3 – the canonical variate characterizing young Warsaw workers). In the variate u_4, one demographic variable has been distinguished – that characterizing natural increase, while the variates u_7 and u_8 are dominated by the features of the social and occupational structure. The hypothesis is thus confirmed that in the Warsaw functional region the features of the socio-demographic structure correlate strongly with workplace-residence type links (see Fig. 3).

The results of our canonical analysis vindicate the contention that the features of commuters and those of the source areas in the Warsaw functional region are strongly interdependent. They furnish a further confirmation of the hypothesis presented at the outset and point to the two-way nature of that dependence.

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THE DEMOGRAPHIC DEVELOPMENT OF POLAND'S AGGLOMERATIONS OVER THE PAST 100 YEARS[1]

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Studies of urban agglomerations in Poland have so far furnished little on the understanding their formation or their population developments. Research interest has tended to focus on their delimitation, the definition of their demographic-economic potential and on concepts of their further demographic growth. This particular research bias can be explained by the necessity to concentrate on problems of the country's space-economic development. In that situation, what tended to dominate were immediate planning exigencies, which made retrospective studies impossible. A further reason for the scanty research results in this respect is the considerable deficiency of available statistics. Taken together, these factors do account for the relatively insignificant scientific presentation in Polish economic-geographic literature of the issue in question.

This study is to present the dynamics of urban agglomerations from 1868/1871 to the latest data for 1975, or exactly for the past 105 years. Population size will be given for the agglomerations in eleven historical cross-sections: 1868/1871, 1897/1900, 1910/1913, 1921/1925, 1931/1933, 1939, 1946, 1950, 1960, 1970, 1975. Over the last century, what is now Poland's national territory had belonged to different state organisms; hence, the differing statistics and the different census years. Censuses had been carried out in different years both in each of the three partitioning powers before the First World War and on the territories belonging to the German state between 1918 and 1945, which accounts for the double data given for some of the above time cross-sections. Data for 1939 and 1975 rely on estimates rather than on census statistics. All that accounts for the high differentiation of the statistics now available.

In an earlier paper I have presented the development of Polish agglomerations between 1950 and 1970[2]. Two decades are a relatively short interval to say anything definitive about the historical development of settlement patterns. This study covers a whole century, one which abounded in historical events. It was during that period that the settlement system of modern Poland was growing up from the original network of small towns. It comprises the years of the first industrial revolution and the emergence of major urban groupings, the years of the First World War, the inter-war interval, the destructive consequences of the

[1] This article is an abridged version of the article published in Polish in *Przegląd Geograficzny*, 50, 1978, 2, pp. 235–254.

[2] P. Eberhardt, Przemiany systemu osadniczego Polski w okresie 1950–1970 (Changes in Poland's settlement system in 1950–1970), *Miasto* 4, 1975, pp. 2–9.

Second World War and the thirty years of socialist Poland. Over that time Polish territories had been delimited anew, had seen war cataclysms and experienced vehement urbanization developments. To this, one must add the total substitution of population on one-third of the national territory following the Second World War.

In analysing the population development of the agglomerations we shall not scrutinize the genesis of the historical events that found their reflection in the studied processes or in urbanization changes. We give a statistical presentation. The possible causes for such rather than other demographic magnitudes will not be explored. In the form adopted here, this study is to serve as a preliminary informative presentation. It is a hard task to secure an interpretation of the statistical data furnished here or to detect any definite regularities. Developmental trends change too. It is only on grounds of abundant historical, political and economic documentation that one can venture a full explanation of the presented statistics.

Recent years have brought several tentative delimitations of the agglomerations. Just as in the analysis of the dynamics of the twenty-year interval between 1950–1970, we shall again rely here on the delimitation suggested by S. Leszczycki, P. Eberhardt and S. Herman[3]. No other delimitation has so far been used for retrospective analyses. When using this delimitation we can carry out certain comparative studies. The three authors delimited 16 agglomerations which in their entirety claimed nearly 40% of Poland's total population in 1970, or 13.2 million people. From the administrative point of view, those agglomerations were composed not only of cities but also of rural units. The 17.6% of the total population of the agglomerations in 1970, or 2.3 million people, was rural.

Retrospective demographic studies for entire agglomerations constitute a hard task. The reason for this is the volatility of Poland's administrative division. To furnish an accurate picture of the development of rural population within the territories of agglomerations we would have to rely on census areas which would involve complex and time-consuming statistical calculations. On the other hand, it is relatively easy to determine the urban population developments in agglomeration territories. It is this type of statistical analysis that we are going to apply in the present study. The populations of each of the 16 urban agglomerations within their territories have simply to be added up, each for eleven moments in the full time series. The statistical data have been borrowed mainly from A. Jelonek.[4]

Additional sources of information were found in the Central Statistical Office's statistical yearbooks and census publications. The urban population of the agglomerations has been determined from the population statistics for towns and urban-type settlements situated in the present-day territories of the respective spatial units between 1868/1871 and 1975.

The rural population in the territory of the expanding urban center has been entirely disregarded. Administrative changes are known to lead to the incorporation of predominantly rural areas into the town's own territory. Therefore, with the historical cross-sections receding more and more into the past, the considered urban units will comprise smaller and smaller territories of the agglomerations concerned. This is a straightforward consequence of the persistent tendency of

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[3] S. Leszczycki, P. Eberhardt, S. Herman, Aglomeracje miejsko-przemyslowe w Polsce 1966–2000 (Urban-industrial agglomerations in Poland, 1966–2000), *Biuletyn KPZK PAN*, 67, 1971.

[4] A. Jelonek, Ludność miast i osiedli typu miejskiego na ziemiach polskich od 1810 do 1960 roku (The population of towns and urban-type settlements on Polish territories, 1810–1960), *Dokumentacja Geograficzna*, 3/4, 1967.

towns to expand. Considering the low stability of administrative divisions in the case of Poland, we shall soon find the spatial expansion of towns to be reflected in alterations of administrative boundaries. Hence, when cast into the present administrative boundaries, the population data given here for the more remote historical cross-sections are somewhat lowered.

Subsequent studies in demographic development should take account of the total – both urban and rural – population living over the entire territory of the agglomeration.

A comparison of the research results of these two types of studies would provide very useful materials for studies in the formation and evolution of the structures of Poland's urban agglomerations.

In this approach, the agglomerations will be composed of smaller settlement units without spatial continuity but displaying a steady tendency to expand territorially. From the statistical point of view, the information provided may raise certain technical reservations. Yet, it must be borne in mind that we take thereby account of the actual structural changes as reflected in the continuing process of urbanization and in the rising proportion of fully urbanized zones within the territories of the urban agglomerations.

The towns analysed within the individual agglomerations constitute now the continuous integrated systems of strong functional-spatial links. Understandably enough, the more remote the time cross-section the more do they remind one of merely statistical compilations of geographically close towns with a few mutual functional links. The many limitations notwithstanding, though, the information in the presentations provided may serve as the starting-point for studies on the emergence of modern patterns as represented by urban agglomerations in Poland.

In keeping with our methodological assumptions, Table 1 presents the absolute figures of agglomeration populations over the past century. The territory now occupied by all the agglomerations was in 1868/1871 inhabited by 1.5 million people only, that is, half the population now living in the Katowice agglomeration alone. The Warsaw agglomeration was the only one with a population exceeding a quarter of a million, and besides only four claimed populations above the 100 000 limit. Most of the agglomerations had small demographic potentials. Remarkably, as many as seven of them had failed by then to reach the 50 000 population limit.

The last three decades of the 19th century were a period of strong urbanization processes. The population of the agglomerations rose then by more than 2 million people, having exceeded the 50 000 population limit, while the four biggest ones (Warsaw, Katowice, Wrocław, Łódź) became by the end of that period relatively large urban concentrations on European scale and two others (the Sudetes and the Szczecin agglomerations) exceeded the 200 000 population limit.

The first decade of the 20th century was also a period of strong demographic growth of the agglomerations. The urban population concentrating in them rose to nearly five million. By the time of the outbreak of the First World War, the Katowice and the Warsaw agglomerations had reached the 1-million population limit while two others (Łódź and Wrocław) had exceeded the 0.5 million limit. These four together concentrated 3 million people, or 40% of total urban population and 60% of the population living in the agglomerations.

The differences between the 1910/1913 and the 1921/1925 time cross-sections are relatively small, which indicates that the period of the First World War inhibited the demographic development of the urban agglomerations. Their population increased during that interval by a mere 350 000. The agglomerations of Bielsko-Biała and Białystok recorded even the small population declines.

As compared to the decades before the First World War, urbanization processes during the years between the two world wars slowed down a little. The agglomerations

TABLE 1. Urban population of the agglomerations, 1868/1871–1975 (thousands)[a]

No.	Urban agglomerations	1868–1971	1897–1900	1910–1913	1921–1925	1931–1933	1939	1946	1950	1960	1970	1975
1.	Katowice	196.2	617.8	981.4	1 033.0	1 291.1	1 378.8	1 135.7	1 566.7	2 298.0	2 616.0	2 992.7
2.	Warsaw	264.1	709.6	969.0	1 014.3	1 292.3	1 463.0	608.9	958.1	1 502.0	1 730.2	1 894.3
3.	Łódź	67.8	381.7	526.3	535.9	726.9	813.0	581.6	736.7	858.1	926.7	969.3
4.	Cracow	117.7	193.3	258.0	273.5	334.4	391.3	390.3	445.7	644.6	782.6	914.5
5.	Gdańsk	95.2	149.4	197.6	235.8	303.2	420.8	242.9	359.4	537.3	686.5	789.8
6.	Sudetes	151.6	229.4	257.6	293.6	321.3	360.5	359.8	347.0	548.5	611.1	635.7
7.	Wroclaw	216.7	433.7	523.3	571.4	637.5	651.4	180.2	316.8	442.1	541.5	600.6
8.	Poznań	60.8	121.8	162.1	174.8	253.8	283.9	279.0	333.6	445.5	514.2	565.0
9.	Old Polish	40.4	91.6	128.2	156.8	211.3	244.1	186.9	217.3	362.9	458.1	515.9
10.	Bydgoszcz-Toruń	46.8	88.5	111.3	132.4	185.7	232.6	210.0	252.0	350.7	429.8	483.8
11.	Szczecin	91.1	228.5	255.3	276.4	296.1	414.8	75.6	183.7	283.5	357.3	398.1
12.	Opole	47.9	82.1	100.2	115.6	138.1	152.1	79.9	108.6	199.5	261.6	309.1
13.	Lublin	22.7	53.5	68.8	64.4	112.5	122.0	99.4	116.6	194.0	258.4	298.7
14.	Bielsko-Biała	40.7	64.4	77.1	65.0	90.7	113.5	87.0	132.1	211.6	253,7	288.8
15.	Częstochowa	25.3	67.2	106.7	106.9	152.2	176.6	130.2	154.9	228.5	265.2	285.4
16.	Białystok	22.6	74.6	90.7	87.8	105.4	122.2	67.5	80.5	137.7	187.9	218.7
Urban population of agglomerations		1 507.6	3 587.1	4 813.6	5 167.6	6 452.5	7 341.1	4 714.9	6 306.7	9 244.2	10 880.8	12 160.4
Urban population of Poland[b]		4 100.0	6 209.7	8 093.9	8 596.3	10 656.7	11 480.0	7 424.6	9 604.6	14 112.3	17 030.8	19 030.5
Poland's population[b]		17 000.0	23 417.0	28 630.0	26 688.0	29 931.0	32 955.0	23 930.0	25 008.0	29 776.0	32 642.0	34.186.0

[a] Polish territories within present boundaries

[b] Data from: K. Dziewoński, L. Kosiński, *Rozwój i rozmieszczenie ludności Polski w XX wieku* (Poland's population in the 20th century: development and distribution), Warszawa 1967.

were growing at a lower rate. Significantly enough, the first decade of that inter-war period saw a higher rate of demographic development of the agglomerations than the latter one. Presumably that was partly due to the great crisis as well as to the declining natural increase in Polish towns towards the end of the 1930s.

The Second World War brought about considerable changes in the country's settlement pattern. Population losses, the destruction of many urban centres and the new layout of state boundaries, all affected the population size of the entire country, of the agglomerations and of Polish towns in general. The population of the agglomerations decreased by more than 2.6 million. The Warsaw agglomeration in particular suffered a huge drop in population, and so did some of those in the Regained Territories: the loss of the Warsaw agglomeration amounted to 850 000 people, that of Wroclaw to 470 000, that of Szczecin to 340 000. How great were those losses in fact, can be seen from the fact that the population sizes for 1946 in the Wroclaw and Szczecin agglomerations were lower than the corresponding figures for 1868/1871, a step back by nearly 100 years. The Sudetes, Cracow and Poznań agglomerations were the only ones which have not recorded population losses.

The period of reconstruction (1946–1950) was the one of rapid compensation for war-time losses. The agglomeration population grew then by more than 2.1 million, with the demographic growth rates highest in the agglomerations destroyed during the war. Five of them considerably exceeded their pre-war size limits, above all the Katowice agglomeration which by 1950 had 200 000 inhabitants more than in 1939. Nevertheless, several agglomerations had still failed to reach their 1939 levels by then. The Wroclaw and Szczecin agglomerations were then only approaching half their respective population sizes of the 1930s.

Of the entire period under study here, it was during the 1950–1960 decade that the highest rate of urbanization was recorded. The total urban population of Poland rose then by more than 4.5 million people, with the corresponding proportion in total population having risen from 39.0 to 48.4%. The population of the agglomerations increased during that decade by nearly 3.0 million. The Katowice agglomeration had already more than 2.2 million people in 1960, while the Warsaw agglomeration had reached 1.5 million. That of Białystok, the smallest of all, went much above 100 000 population limit. Only two agglomerations failed to attain their pre-war levels.

The next decade (1960–1970) displayed slower urbanization processes. There were several reasons for that. One important factor was the significant decline in the natural-increase coefficient in the urbanized areas then. The declining rate of industrialization decreased also migration from rural areas to urban centers. During that decade urban population rose by 2.9 million people, that of the agglomerations by more than 1.6 million. In absolute figures, the biggest population increases were recorded in the Katowice and the Warsaw agglomerations, while in percentual terms-in the agglomerations situated in eastern Poland (the Białystok and Lublin agglomerations). The Łódź and the Sudetes agglomerations, on the other hand, displayed relatively low population growth rates.

As compared to the preceding decade, the last five years (1970–1975) saw quite a considerable acceleration of the country's urbanization rate. That found its expression above all in the higher population dynamics of the agglomerations. The total agglomeration population grew by nearly 1.3 million to exceed the 12-million level. By now the agglomerations network displays a high demographic potential already and its role in the country's space-economic structure is very significant. As many as nine agglomerations have become urban concentrations with populations of more than 0.5 million people; the Katowice agglomeration has come close to 3 million people, that of Warsaw has been approaching the

2-million limit, whereas those of Łódź and Cracow will soon hit the 1-million limit. The country's smallest agglomeration, that of Białystok, has exceeded 200 000. But two have still failed to attain their pre-war sizes (those of Wrocław and Szczecin). To judge by the rate of development, the Szczecin agglomeration should reach that level by 1978, while that of Wrocław not before about 1980.

Over the past century, population of Poland in its present boundaries doubled, urban population nearly quintupled, while the population of the agglomerations has by now become eight times the original figure. Urbanization processes are the most significant feature of modern civilization. The differences between data for 1868/1871 and 1975 give evidence of the huge structural changes that have taken place. Small towns have emancipated into settlement groupings with high population and economic potentials. That process was taking place in two clearly distinctive phases, the first from 1868/1871 to 1910/1913, the other from 1946 to 1975. Those have been shown to have been intrinsically heterogeneous periods. Nevertheless, both signified the revolutionary urbanization changes that totally altered Poland's spatial structure.

Processes of spatial concentration in Polish settlements basically never came to a halt, though their rate differed throughout the period under study. This is

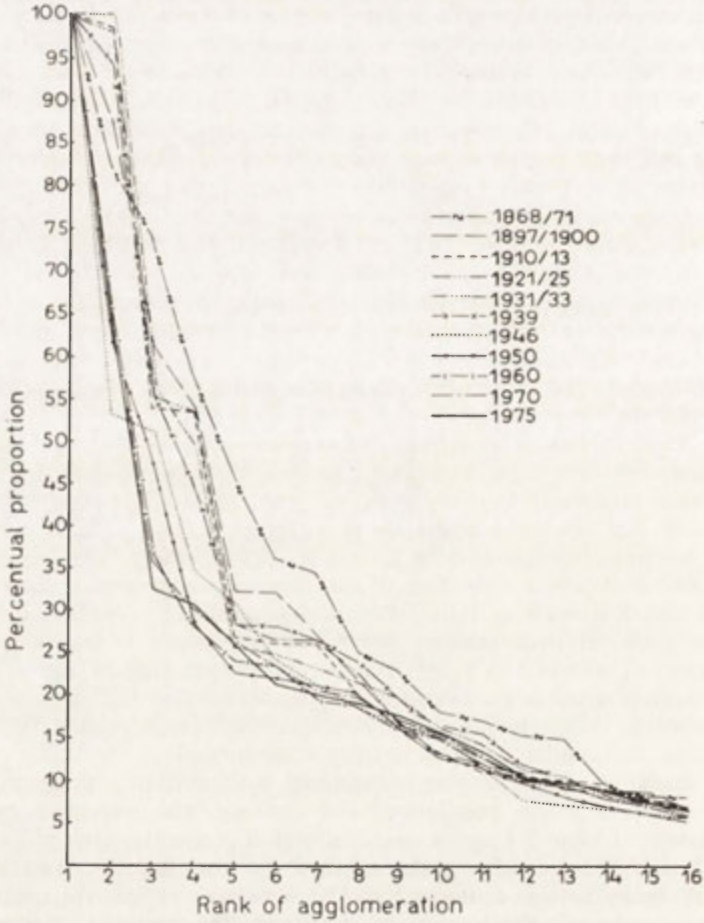

Fig. 1.

clearly seen when one analyses the proportion of the agglomeration population in Poland's total population figures (Fig. 1).

In 1868/1871, a mere 8.8% of the population concentrated in the urban centers that were situated in the present-day agglomeration areas. During the ensuing 40 years that proportion doubled to reach 16.8% by 1910/1913 already. After the First World War it was as much as 19.3%. That proportion was rising slower during the inter-war period, which was indicative of a certain decline in the intensity of spatial concentration of the nation-wide settlement process. The war-time destruction brought about an insignificant decrease of the proportion in question. Right after the war, in 1946, it was nearly that of the early 1920s. Since then the proportion has been rising strongly. By 1950, the agglomeration population accounted for more than 25% of the country's total population, by 1960 for 31.0%, by 1970 for 33.3% and by 1975 for 35.5% already. A rise from 8.8% up to 35.5% over one century gives strong evidence of the rising proportion of agglomerations in the country's total population and of strong processes of population concentration in the biggest urban groupings.

It is interesting to study that proportion for each individual agglomeration. A rise in certain percentual indices is a characteristic feature here. The proportion of the Katowice agglomeration in the country's total population rose over the study period from 1.1% to 8.7%, that of Warsaw from 1.5 to 5.5%, that of Łódź from 0.4 to 2.8%, and so on. If we consider the first and the last of the cross-sections only the course of the phenomenon seems to be fairly regular and easy to interpret. The picture is more complex when we submit it to a more detailed analysis. The behaviour of the indices even vindicates the contention that each of the agglomerations was going through a very specific development indeed. By way of example, let us point out here that the Wrocław agglomeration recorded the highest value of that proportion in 1933 while that of Szczecin in 1939. Still, the fact that the scale of population concentration processes was increasing in all agglomerations is undisputable.

The processes of spatial concentration unfold to a certain extent differently if we consider them in the scale of urban settlement alone (see Fig. 2). The last three decades of the 19th century were marked by very strong concentration processes. The indicator of the proportion of urban population of the agglomerations in the nation-wide total of urban population grew within those 30 years from 36.7 to 57.7%, that is, by 21 percentage points. By contrast, within the next 75 years that indicator rose from 57.7 to 63.9% or 6.2 percentage points only. Thus, it can be tentatively said that, in the scale of urban settlement, strong concentration processes came to the end at the turn of the 19th and 20th centuries. The proportion discussed here reached its maximum in 1959, when 65.6% of the urban population concentrated in the areas of 16 urban agglomerations. Over the next twenty-year period it declined by 1.8 percentage points. This implies that by 1950 the trend was reversed and deconcentration processes began to prevail.

That proportion increased in all agglomerations between 1868/1871 and 1897/1900, which shows that urban population was growing quicker in the 16 agglomerations than nation-wide. In the next interval the situation became extremely diversified and hard to interpret. Beside of agglomerations concentrating an increasing proportion of urban population, there are agglomerations with declining proportion in the nation-wide total of urban population. For instance, the respective proportions of the Katowice, Cracow, Gdańsk and Old-Polish agglomerations increased over the past 75 years considerably, whereas those of the Warsaw, Łódź, Wrocław and Szczecin agglomerations distinctly fell. The Wroclaw and Szczecin agglomerations attained their maxima at the turn of the 19th and 20th centuries, that of Warsaw in 1939, those of Łódź or Bydgoszcz-Toruń in 1946 etc. This points to the irregular

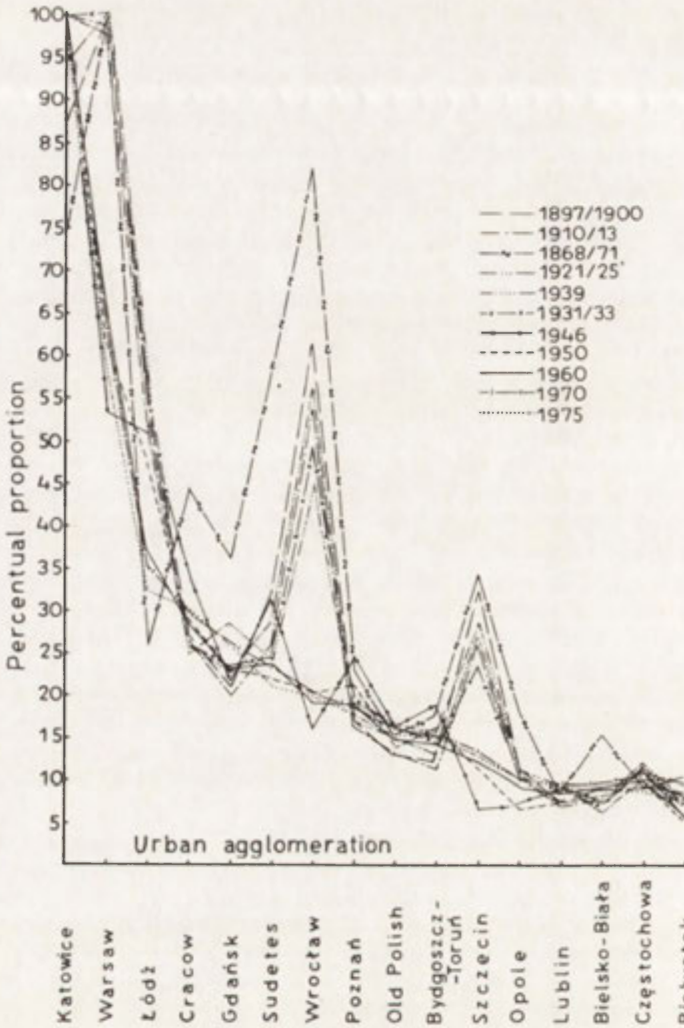

Fig. 2.

development of the individual settlement groupings and to great alterations within the network of agglomerations. A more profound explanation of the differences indicated here must be preceded by more datailed case studies.

In what follows we shall use what is called the rank-size rule. The size distribution patterns of towns by virtue of that rule has been fairly often studied in geographic literature. In Poland, K. Dziewoński was the first to employ it in 1962.[5] Up to now, though, it has not been used for the study of the

[5] K. Dziewoński, Procesy urbanizacyjne we współczesnej Polsce (Urbanization processes in modern Poland), *Przegląd Geograficzny*, 34, 1962, 3, pp. 459–506. I have employed that method to estimate the size distribution of Poland's biggest cities in my study on "Big cities as concentration foci of economic and social activity in Poland" (Wielkie miasta jako ośrodki koncentracji działalności gospodarczej i społecznej w Polsce), *Biuletyn KPZK PAN*, 47, 1968.

TABLE 2. Distribution of agglomerations by the rank-and-size rule, 1868/1871–1975

No.	Urban agglomerations	1868–1871	1897–1900	1910–1913	1921–1925	1931–1933	1939	1946	1950	1960	1970	1975
1.	Katowice	74.3	87.0	100.0	100.0	99.9	94.2	100.0	100.0	100.0	100.0	100.0
2.	Warsaw	100.0	100.0	98.7	98.1	100.0	100.0	53.6	61.1	65.3	66.1	63.3
3.	Łódź	25.6	53.8	53.6	51.8	56.2	55.5	51.2	47.0	37.3	35.4	32.3
4.	Cracow	44.5	27.2	26.8	26.4	25.8	26.7	34.3	28.4	28.0	29.9	30.5
5.	Gdańsk	36.0	21.0	20.1	22.8	23.4	28.7	21.3	22.9	23.3	26.2	26.4
6.	Sudetes	57.4	32.3	26.2	28.4	24.8	24.6	31.6	22.1	23.8	23.3	21.2
7.	Wroclaw	82.0	61.1	53.3	55.3	49.3	44.5	15.8	20.2	19.2	20.7	20.0
8.	Poznań	23.0	17.1	16.5	16.9	19.6	19.4	24.5	21.3	19.3	19.6	18.8
9.	Old Polish	15.3	12.9	13.0	15.1	16.3	16.6	16.4	13.8	15.7	17.5	17.2
10.	Bydgoszcz-Toruń	17.7	12.4	11.3	12.8	14.3	15.9	18.5	16.0	15.2	16.4	16.1
11.	Szczecin	34.5	32.2	26.0	26.7	22.9	28.3	6.6	11.7	12.3	13.6	13.3
12.	Opole	18.1	11.5	10.2	11.2	10.6	10.4	7.0	6.9	8.6	10.0	10.3
13.	Lublin	8.5	7.5	7.0	9.1	8.7	8.3	8.7	7.4	8.4	9.8	10.0
14.	Bielsko-Biała	15.4	9.0	7.8	6.2	7.0	7.7	7.6	8.4	9.2	9.7	9.6
15.	Częstochowa	9.5	9.4	10.8	10.3	11.7	12.0	11.4	9.8	9.9	10.1	9.5
16.	Białystok	8.5	10.5	9.2	8.5	8.1	8.3	5.9	5.1	6.0	7.1	7.3

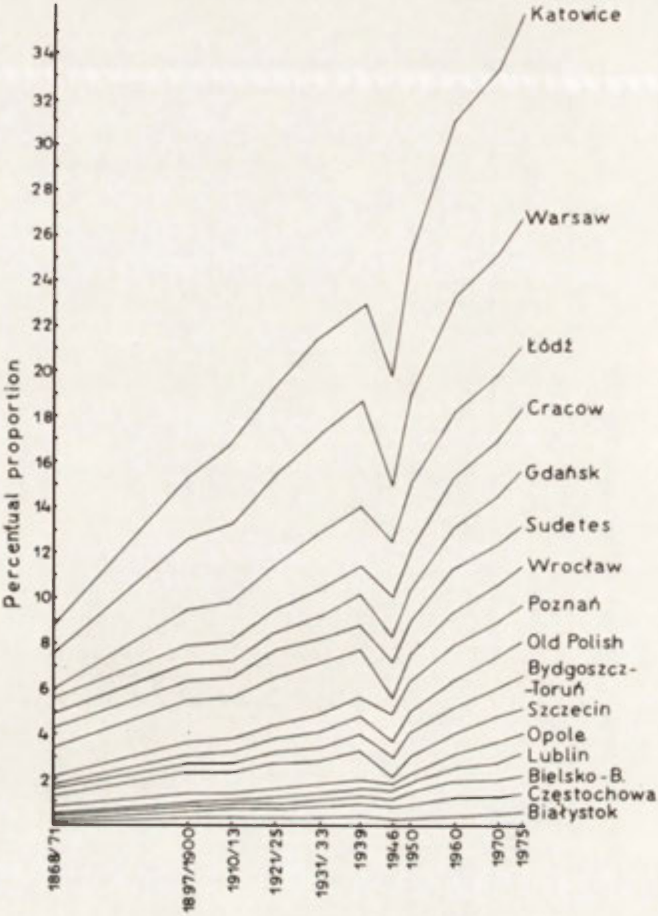

Fig. 3.

emergence and transformation of the network of urban agglomerations in Poland.[6]

The patterns of Poland's agglomerations by the rank-size rule is presented in Table 2 and the accompanying Figs. 3 and 4. These differ from each other considerably. Figure 3 has been plotted in keeping with the classical pattern of G. K. Zipf[7], in which the elements of the studied set are arranged in the decreasing order of their size. The curves on such a diagram that reflect the size distribution of the urban agglomerations go asymptotically close to the abscissa x.

Figure 4 is a modification of Zipf's pattern. The agglomerations are ranked on the abscissa in their decreasing order as in 1975. In view of the fact that over

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[6] A comparative analysis of the size distribution of Poland's agglomerations with regard to those of other countries is given in: P. Eberhardt, S. Herman, Koncentracja przestrzenna ludności w aglomeracjach miejskich w wybranych państwach świata (Spatial concentration of population in urban agglomerations in selected countries of the world), *Przegląd Geograficzny*, 47, 1975, 2, pp. 369–380.

[7] G. K. Zipf, *Human behaviour and the principle of least effort*, Cambridge, Addison-Wesley, 1949.

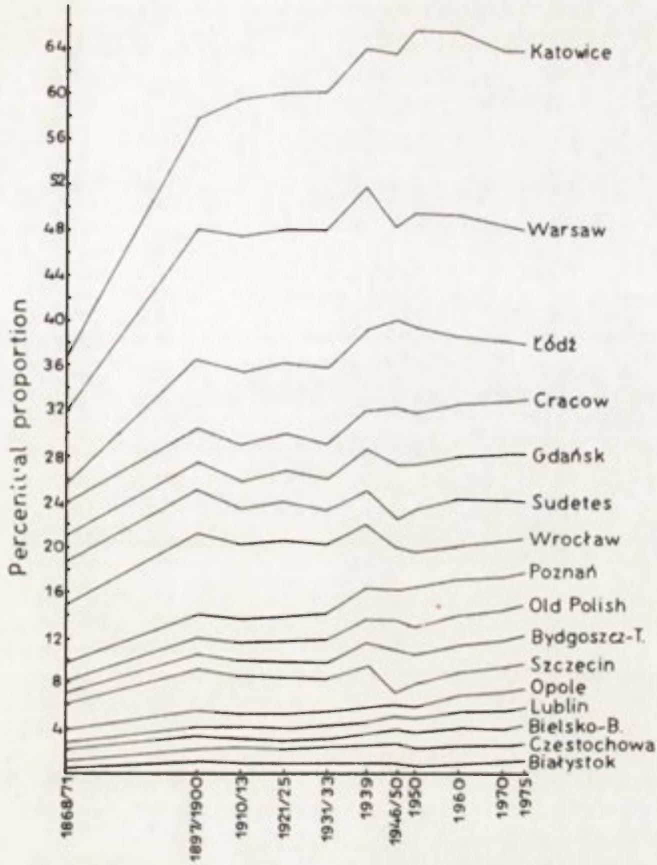

Fig. 4.

the studied century the order of the agglomerations was steadily changing, the curves on the diagram are not regular ones, fitting the theoretical Zipf distribution. The applied modification discloses in the graphical picture presented not only the size distribution but also changes in ranks of individual agglomerations between the different time cross-sections.

By the rank-and-size rule, the element of the studied set that has the highest value is given the rank 1 and, successively, the elements with decreasing values are then ranked in their size order. To facilitate interpretation, Table 3 gives the ranks the individual agglomerations take in the studied time cross-sections.

One characteristic feature of the sets of agglomerations compared is their high variation in time. The considerable reshuffle gives evidence of the low stability and the irregular population development of the urban agglomerations. Very strong changes took place especially between 1868/1871 and 1950. The mutual size relations between the agglomerations during the recent 25 years have been displaying a considerable stability.

Around 1910, the Katowice agglomeration overreached the Warsaw agglomeration to become the largest settlement grouping. The situation changed in the 1930s. The strong tendency to transform Warsaw from a provincial city of the former Russian empire into a great European metropoly dates back to those years.

TABLE 3. Rank of agglomerations by size, 1868/1871–1975

No.	Urban agglomerations	1868–1871	1897–1900	1910–1913	1921–1925	1931–1933	1939	1946	1950	1960	1970	1975
1.	Katowice	3	2	1	1	2	2	1	1	1	1	1
2.	Warsaw	1	1	2	2	1	1	2	2	2	2	2
3.	Łódź	8	4	3	4	3	3	3	3	3	3	3
4.	Cracow	5	7	5	7	5	7	4	4	4	4	4
5.	Gdańsk	6	8	8	8	7	5	7	5	6	5	5
6.	Sudetes	4	5	6	5	6	8	5	6	5	6	6
7.	Wrocław	2	3	4	3	4	4	10	8	8	7	7
8.	Poznań	9	9	9	9	9	9	6	7	7	8	8
9.	Old Polish	13	10	10	10	10	10	9	10	9	9	9
10.	Bydgoszcz/Toruń	11	11	11	11	11	11	8	9	10	10	10
11.	Szczecin	7	6	7	6	8	6	15	11	11	11	11
12.	Opole	10	12	13	12	13	13	14	15	14	13	12
13.	Lublin	15	16	16	14	14	15	12	14	15	14	13
14.	Bielsko-Biała	12	15	15	16	16	16	13	13	13	15	14
15.	Częstochowa	14	14	12	13	12	12	11	12	12	12	15
16.	Białystok	16	13	14	15	15	14	16	16	16	16	16

For a brief period, the Warsaw agglomeration became the country's largest settlement grouping. One factor which contributed to that was the boundary line having been drawn right across the centre of Upper Silesia. From 1946 onwards, the Katowice agglomeration has been reinforced its first rank by size among Poland's agglomerations.

The Łódź agglomeration ranks now third after the Katowice and the Warsaw agglomerations. A century ago it ranked eighth. Its vehement expansion came at the turn of the 19th and 20th centuries. After the Second World War, however, its proportion in the relative size distribution of the country's largest agglomerations has been steadily declining. It is likely to give soon a way to the dynamically expanding Cracow agglomeration as the third largest agglomeration of Poland. The shifts in rank of some agglomerations are interesting – Wroclaw (second to tenth), Szczecin (six to fifteenth), Cracow (fourth to seventh) etc. The analysis of shifts in rank in different time cross-sections may furnish valuable materials for the study of the role of individual urban agglomerations in the country's spatial structure.

The considerable individual shifts do not alter the specific character of the studied size distribution pattern. One permanent feature of the size distribution pattern of Poland's agglomerations is its polycentrism and the relatively insignificant differences between the agglomerations of the successive size ranks. This can be clearly read out from the scatter of indicators and relations to the largest agglomeration. A comparison to Zipf's regular pattern makes this conspicuous. In terms of Zipf's theoretical distribution, the percentual proportion of the successive cities with regard to the largest one was as follows: 50%, 33.3%, 25.0%, 16.6%, 14.3%, 12.6%, 11.1%, 10.0% etc.

The pattern of Polish agglomerations during the whole century took values higher than those given by Zipf. It follows that Poland's polycentric settlement system shaped in the latter half of the 19th century has survived up to now.

Over the studied period that polycentrism was undergoing only some modification. In 1868/1871 it displayed a slight dominance of the biggest sity and relatively high ranks of the next seven biggest agglomerations. Between 1900 and 1939 it took the shape of a biocentric system. The two biggest agglomerations were much the same size. The third and fourth, in turn, were about 50% of the biggest agglomeration. After the great changes brought about by the Second World War the system under study became more regular and fitted Zipf's theoretical pattern better.

New trends in development showed during the last 30 years. They consist above all in the attenuation of size disproportions. The smallest agglomerations display the highest growth rates and their proportion in comparison to the largest ones has been steadily rising. Settlement groupings ranking third to tenth display the lower homogeneity, and their developmental trends are more differentiated.

The present study furnishes a relatively abundant stock of facts concerning the population dynamics of the country's largest settlement groupings. It should add to our knowledge of urbanization process in Poland. Apart from their epistemological value, retrospective studies in the geography of settlements can also be used for planning purposes. The study of developmental trends is a significant component of any prognostic concept. The author's intention herewith is to provide a contribution to prognostic inquiry into the future development of urban agglomerations in Poland.

SPATIAL PATTERNS OF URBAN DEMOGRAPHIC STRUCTURES ON THE EXAMPLE OF SOUTH-POLISH TOWNS

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THE PROBLEM

The spatial structure of towns has long been a common topic of interest to researchers in different fields. The problem of urban spatial structure cropped up first in studies on the physiognomy of towns and, through deepened analyses of the historical development of towns, of their gradual accretion and diversification, they gradually comprised the functional differentiation of individual city quarters. Parallel with studies on the spatial structure of immovable facilities and on the functional differentiation of the urban territory, the demographic line of research in urban studies was developing too. Population size and population density were the demographic factors that most frequently appeared in those studies. Subsequent studies involved the age and sex structures of urban populations, their education and occupation structures (Bystroń 1915, Wąsowicz 1935, Jelonek 1968, Jelonek and Werwicki 1971). On the ground of socio-cultural premises, a broad research trend known as urban social ecology has developed too (Węclawowicz 1975, Zbieg 1978). An analysis and a comparison of studies in those various research directions vindicate the contention that morphological and demographic phenomena in urban space are interdependent.

The present study relies on the following theoretical postulates:

– As regards the total body of demographic relations, the contemporary socio-economic space can be assumed to display a spatial differentiation of population size, structure and dynamics. Hence it follows that within the boundaries of the individual town the demographic phenomena are also spatially differentiated.

– The causes of differentiation of the demographic structure within the boundaries of towns should be variable too, as should the processes of their development and the regularities of their distribution in urban space.

These postulates enable us to formulate research goals and tasks so as to obtain assessments of those problems not only theoretical but also useful for the practical tasks of demographic policy and of planning.

PURPOSE OF THE STUDY

The purpose of the study under the above assumptions was to:

– disclose the spatial differences of demographic structures of selected towns in Poland,

– identify the regularities in the distribution of the individual components of that structure, with special attention to the age and sex structures,

– determine the correlation between various components of the age and sex structures and migration movements.

Thus put, the research could only be carried out on the ground of National Census data for 1970. The other available sources made dynamic assessments imposible, whereas the units of spatial aggregation of data thus obtained could not be made comparable with those of other studies carried out previously for some towns.

Different criteria were applied in selecting the research objects. The most important of them were the following:

– A relatively high differentiation of towns by size. Ten towns were included in the list (thousand people): Cracow (611), Gliwice (172), Tarnów (86), Rzeszów (83), Dąbrowa Górnicza (62), Będzin (43), Nowy Sącz (41), Racibórz (40), Krosno (27), Wadowice (12).

– At similar population sizes, account was taken of the different ranks the towns were holding in the administrative hierarchy of the time, for instance the poviat town Tarnów and the voivodship capital Rzeszów.

– Functional differentiation was considered by studying predominantly industrial towns and towns with a predominance of administrative, service, educational-cultural and other functions.

– The studied towns are all situated in South Poland, which was conditioned by the necessity to collect statistical and cartographic data in the local statistical service centres. Not unimportant was also the author's own familiarity with those towns from his earlier studies or from his co-workers. This was of special significance in interpreting some odd-out phenomena.

– Care was taken to select towns situated in demographically different regions, which secured that a relatively representative set of Polish towns should be chosen.

SOURCE MATERIALS

These included the data of the National Census of 8 December, 1970, concerning sex and age structures (Table: "Permanent residents born 1970–1905 or earlier living in family, special-type and collective households"). Migration was studied by analysing data on people born elsewhere and population that had arrived to their present residences in 1961–1970. The statistical data were compiled for census districts within the administrative boundaries of towns. Population size in the districts was between several tens of thousand to two thousand. To avoid an accidental deformation of the picture of demographic structures, numerically small districts were joined together so as not to fall below 200 persons. As empirical investigations had shown, that size limit still allowed for a division of the community into three age groups. The joined districts had to be adjoining districts; moreover, only such districts that had similar types of housing developments were to be joined together because this was expected to favour the aggregation of population classes of similar demographic structures. The total number of people living in collective households (monasteries, homes for the aged, boarding-houses etc.) was stated for each census district. The detailed statistics enabled us to freely aggregate data into age groups.

THE STRUCTURE OF THE ANALYTICAL STUDIES

The main body of this contribution is composed of ten analytical studies for each of the towns involved according to one plan. Preliminary remarks on the situation, the history and the functions of the town are followed by the sex structure measured by the proportion of males in the total population of each census district. Age structure analysis for the same pattern of spatial units was carried out for three age-class groups: pre-productive 0–18, productive 19–59, and post-productive 60 and more years of age. The pattern of classes of percentual proportions was identical in all groups and comprised 6 classes. The classes equalled each other as regards the value of the proportions and they were constructed so that the average value for the whole town was lying on the boundary line between the third and fourth classes or close to it.

The picture of distribution of the percentual proportions of males and the three age classes was a conglomerate of spatial patterns specific for each town and hard to generalize. Tests have suggested a simple method for obtaining a more generalized picture. For this purpose, analyses were carried out and supplemented by a collection of maps showing the age and sex structures and the origin of the population as measured by the proportion of people born outside their present places of residence and by the proportion of arrivals to the present residence places between 1961 and 1970 in a pattern of concentric rings. The point of origin of the 500–meter rings was taken at the old-town market-places in historically developed towns, or else the old-town centre from which the town began to develop (e.g. Dąbrowa Górnicza). A statistical district was classed within a definite ring when it fell within that ring, wholly or partly. In this latter case, the location of housing developments rather than the whole area were ultimately decisive. The percental proportions of individual phenomena were most often divided into 6 classes equal by size of those proportions.

The analytical studies include also statistical tables of age and sex structures for the census districts and the 500-meter rings.

THE SPATIAL PATTERNS OF DEMOGRAPHIC STRUCTURES IN TOWNS

The studies of spatial patterns of age and sex structures carried out in ten representative towns of South Poland vindicate the statement that in individual towns the patterns of demographic structures are historically determined. There are numerous links with the successive phases of accretion of housing developments as well as with the town's morphology and with the functional differentiation of the town quarters. Particularly conspicuous are new town quarters developed either as new towns (Nowa Huta near Cracow or West Tarnów – the previous Mościce, Fig. 1) or large stretches of new housing blocks (Lipski estate at Dąbrowa Górnicza). Those quarters perturb the previous, often concentrically accruing housing estates creating the new nuclei of spatial patterns. They are populated within relatively short time intervals and therefore have at first populations whose demographic and social features differ from those of the remaining parts of the given town. This leads to the development of a separate pattern of demographic structures perturbing the stated concentric patterns of phenomena (Fig. 2).

Administrative incorporations of rural areas into urban territories do not bring about changes in demographic structures, of course. Rural areas do not differ from the remaining parts of towns as long as intensive housing developments do not grow up in them. But the reconstruction of the housing resources in the same habitats plus the very small number of new buildings started by people coming from outside the area, lead to a long-lasting entropy of demographic structures.

Studies carried out in towns of West Poland and in other areas that had experienced massive migration movements after the war vindicate the contention that there, too, demographic structures were spatially differentiated. The regularities

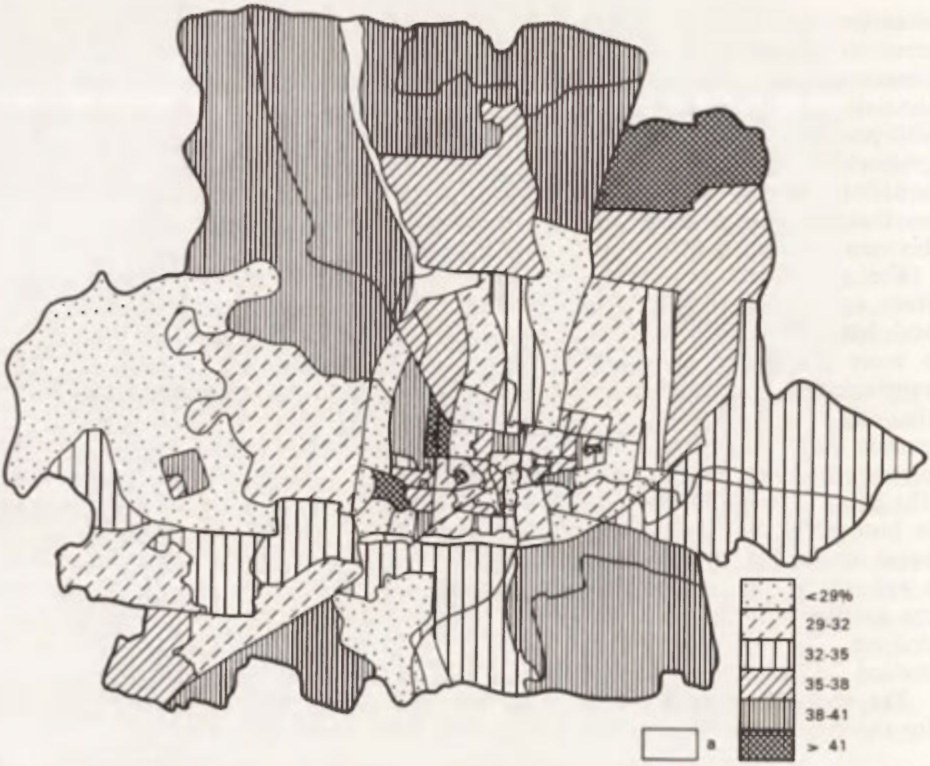

Fig. 1. The town of Tarnów. People aged 0–18 as per cent of total population in statistical regions

a – Non-inhabited regions

of distribution of the structures occurring there apply to the studied towns with very few exceptions only.

Studies have confirmed that the conditions of geographic environment, especially of relief, the network of surface waters, and the suitability of land plots for building purposes, all affect the spatial patterns of demographic structures. That is an indirect influence in the sense that it conditions the development of construction, its character and intensity; it undergoes changes with time. A similar influence is clearly attributable to the pattern of the transport network that determines the development of building. Roads tend to elongate building sites affording the amoeba-like appendices. Railway lines are often unsurmountable barriers to construction and thereby constitute the boundary strips in patterns of demographic structures.

The detailed analyses of the spatial distribution of proportions of population by sex and age as well as by the origin of the population as measured by place of birth and change of residence over the 1961–1970 decade vindicate the following regularites:

– The demographic structures of both large and small towns are spatially differentiated (Figs. 2 and 3).

– The regularities of spatial differentiation are the same, regardless of town size.

– Spatial patterns of demographic structures are modified, or display considerable perturbations, in the case of collective households (children's homes, homes for the aged,

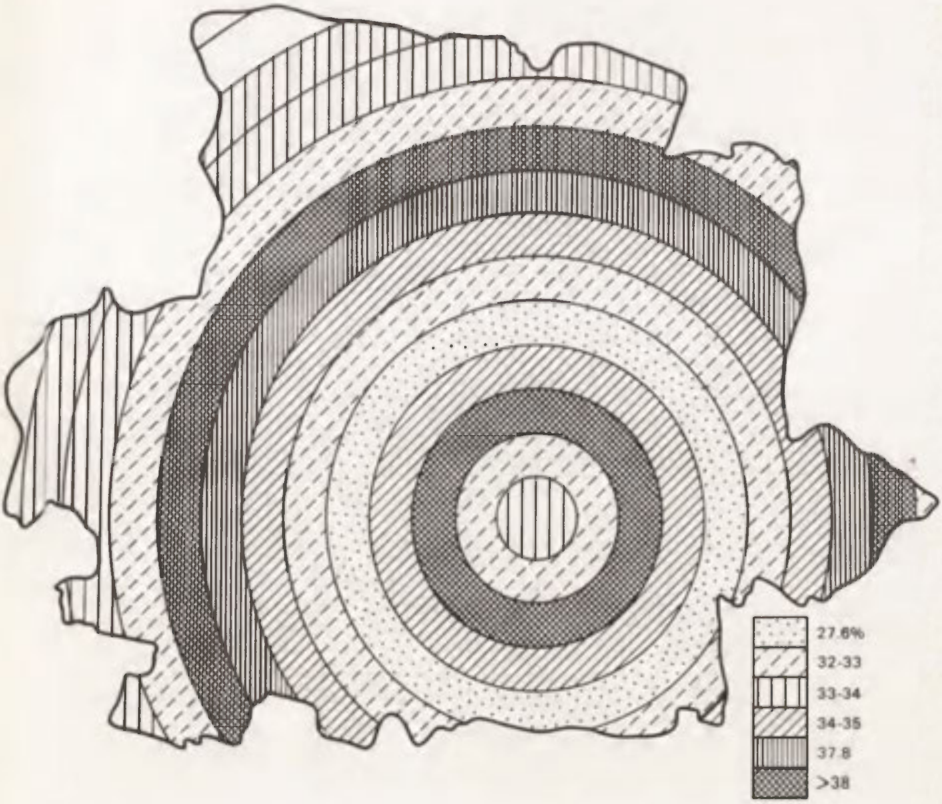

Fig. 2. The town of Tarnów. People aged 0–18 as per cent of total population in 500 meter rings

worker's hostels, monasteries) situated singly, but especially so when in groupings (student's hostel townlets, workers' hostels grouped together).

– Towns of compex morphological patterns also have a complex pattern of demographic structures. For the time being, the want of any comparable data for towns makes a definition of the duration of separate structures impossible. The case of the morphologically complex Cracow suggests that the persistence of those structures is limited in time and that, after a full integration of housing developments, demographic phenomena also become entropic.

– The distribution of the percental proportions of males displays a concentric pattern. The lowest proportions occur at the town centres and rise centrifugally. The values of male proportions were decreasing at some distance from the centre. In the peripheries of towns, lower with higher values may intertwine but they are always higher than in the town centre.

– The spatial distribution of proportions of the 0–18 age class also displays a concentric pattern. Low proportions of that group of population occur in the town centres to increase gradually up to a certain culmination after which they subside again. A renewed increase in values occurs in the peripheral areas, where we often observe the highest proportions of that age class. A slightly different pattern was found in Racibórz and Gliwice where minimal values were observed in areas around the town centres (Figs. 2 and 3).

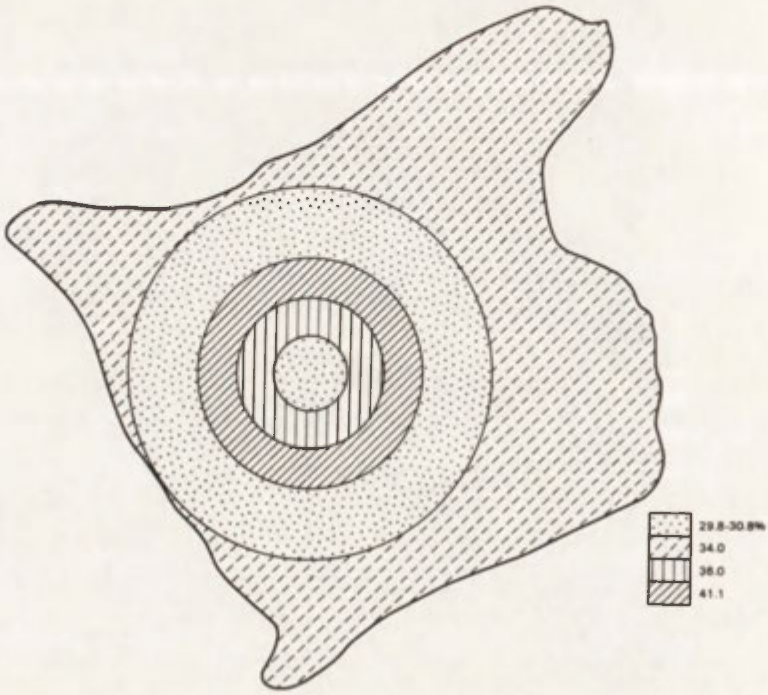

Fig. 3. The town of Wadowice. People aged 0–18 as per cent of total population in 250 meter rings

— The spatial distribution of the 19–59 age class groups reveals greater differences in individual towns. In most towns the town centre itself does not have the highest percental proportions, the areas surrounding the centre circularly have. High proportions of the productive age class occur in areas of continuous building. Those proportions decrease in the peripheries of towns. They may also be high or very high in areas of the new large groupings of housing estates. Yet, a longer time of observation is needed to say how persistent that phenomenon actually is.

— The spatial distribution of proportions of population aged 60 and more, displayed great regularities. The highest percental proportions of that population group were recorded in the town centre, then gradually declined to rise again in the peripheries. In Racibórz alone, the town centre displayed lower proportions of that population group than the averages for the whole town and they were rising toward the peripheries.

The difference in spatial distributions of the age classes of 0–18 and 60 and more, found in Racibórz (Fig. 4) and Gliwice suggest that in case of a mass-scale exchange of population in the Western and Northern Territories the structure patterns are somewhat different from those in other Polish towns.

— The distribution of people born elsewhere is characterized by that the generally high or highest proportions of that population group occur at the town centre and decrease centrifugally to reach the lowest values in the town peripheries. In towns with strong concentrations of housing construction very high proportions of people born elsewhere occur usually in the peripheries. Remarkably, the highest proportions of locally born population occur in areas recently incorporated into the towns (Fig. 5).

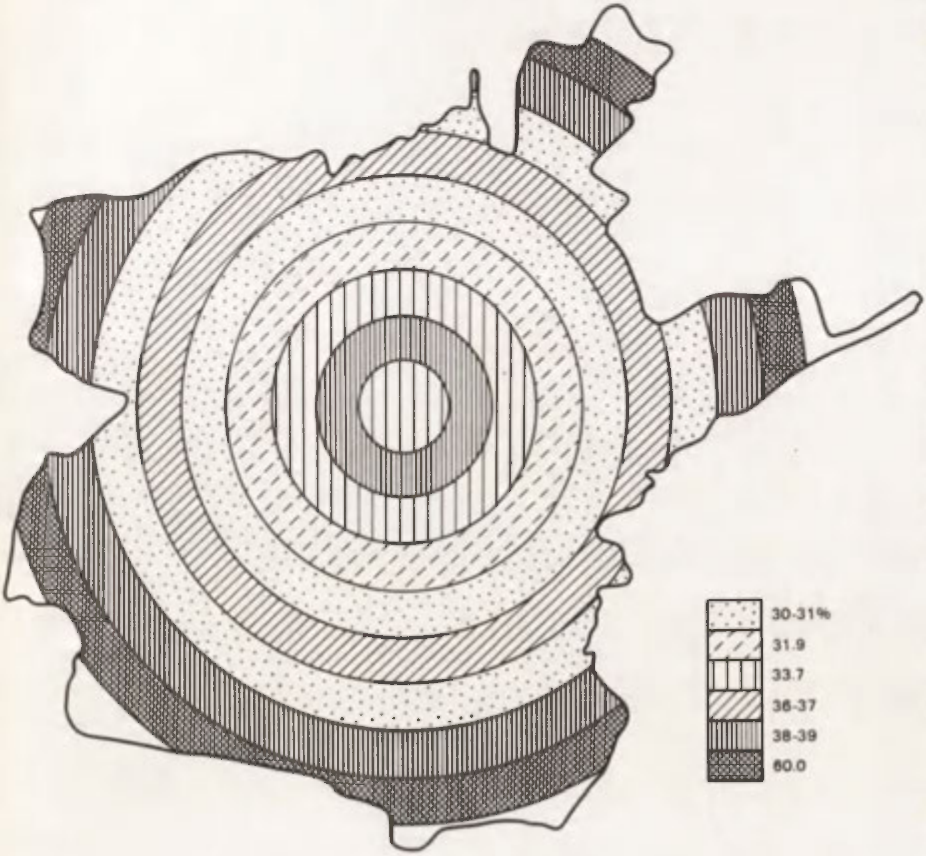

Fig. 4. The town of Racibórz. People aged 0–18 as per cent of total population in 500 meter rings

– In the spatial distribution of proportions of arrivals in 1961 to 1970 the following regularities can be observed: in the central parts of the town there are generally low proportions of arrivals. Very low proportions occur also at town boundaries in the incorporated villages. High proportions of arrivals of the past decade, since the inception of this study, are connected with the advancing emergence of new housing estates and localized in different parts of the town (Fig. 6).

To state correlation in spatial patterns between individual structures and migration movements the Spearman's rank correlation calculus was applied to the 500-meter rings which fairly well generalizes the spatial patterns of those structures. The following correlations were stated.

– The spatial pattern of the proportions of males was found to correlate weakly positively with that of the 0–18 age class.

– The spatial pattern of males was found to correlate weakly negatively with the productive age class (19–59). Towns with a domination of industries employing mostly males may be exceptions to this regularity.

– The spatial pattern of males strongly negatively correlates with that of the 60 and more years age class.

– The spatial pattern of males as a rule correlates weakly negatively with that

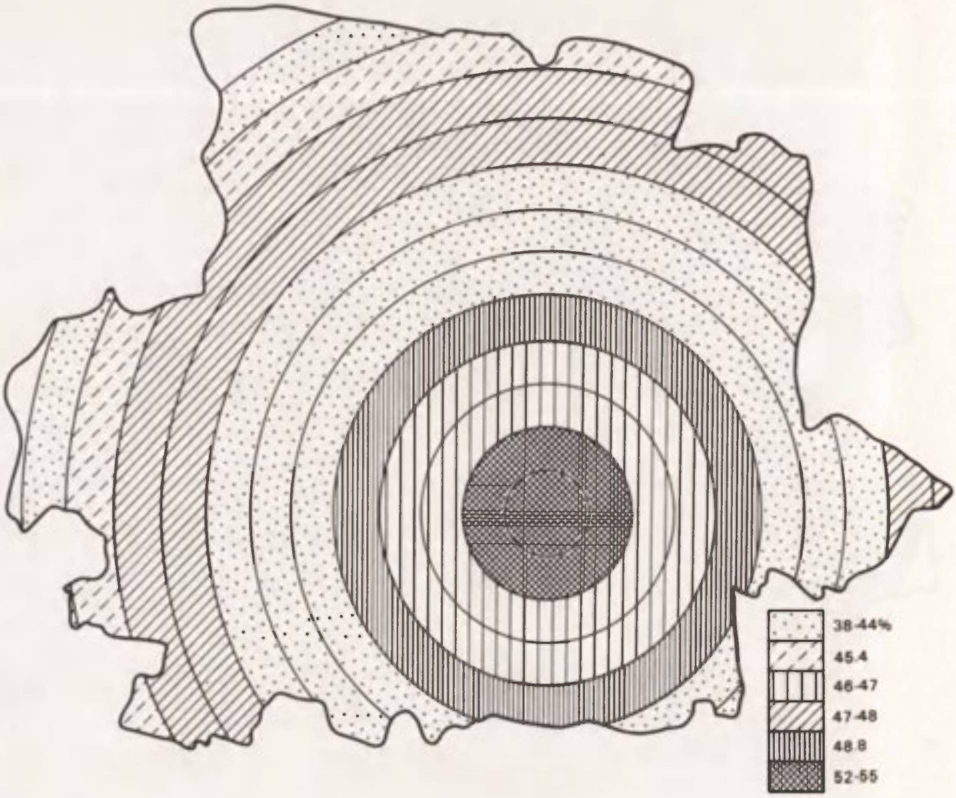

Fig. 5. The town of Tarnów. People born elsewhere as per cent of total population

of proportions of people born elsewhere and with that of arrivals of 1961–1970. In the case of arrivals, a strong positive correlation may occur in towns with functions preferring the males. On the other hand, in towns with a predominance or of female-employing service or industrial functions, a strong negative correlation may occur.

– No correlation was found between the spatial pattern of the 0–18 age class and that of people born elsewhere. But, on the whole, correlation between that population group and arrivals of 1961–1970 is positive.

– The spatial pattern of the 19–59 age class and that of people born elsewhere is strongly positive. Also positive but weak is the correlation between the population group discussed here and arrivals of 1961–1970. The correlation links of this latter population group depend significantly on the duration of stay – the longer it is the lower the numerical predominance of the 19–59 age class to the benefit of newborns and the increasing post-production population group.

– Correlation between the spatial patterns of people aged 60 and more and of people born elsewhere was weakly negative, while correlation of this latter group with arrivals to the present places of residence in 1961–1970 on the whole was strongly negative.

It must be added that the correlation links found for the spatial patterns of demographic structures and migration movements are a generalization of most

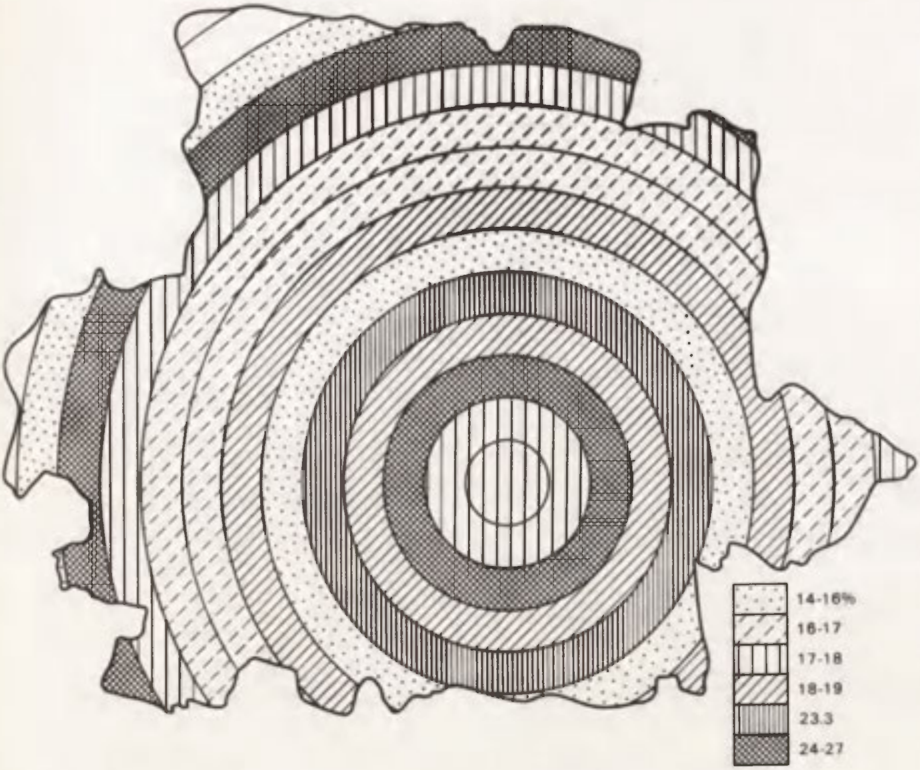

Fig. 6. The town of Tarnów. People arrived in 1961–1970 as per cent of total population

commonly occurring facts but do not preclude certain divergencies in individual towns. They often express the specific course of the given town's historical development or specific patterns of distribution of definite population groups.

CONCLUSIONS

Studies have confirmed the contention phrased at the outset that the patterns of demographic structures are differentiated within the boundaries of towns. If we assume that the studied group of towns was representative and if we take account of previous studies in this field, then we may safely say that such a differentiation exists in all towns of Poland.

There was also found the recurrence of definite regularities in the distribution of individual demographic structures and, on the ground of case studies in the above-mentioned and other towns, also of social structures. The present study is statical in character and does not vindicate any definitive conclusions regarding the persistence of the stated regularities in time or the possible trends of change in the stated spatial patterns of demographic structures.

As a result of studies the correlations between different components of the age and sex structures and migration movements were stated, which may be of great significance for the formulation of goals of demographic and socio-economic policy.

TABLE 1. Values of correlation coefficients

Towns	Males and 0–18 age class	Males and 19–59 age class	Males and 60 and more age class	Males and people born elsewhere	Males and arrivals of 1961–1970	0–18 age class and people born elsewhere	0–18 age class and arrivals of 1961–1970	19–59 age class and people born elsewhere	19–59 age class and arrivals of 1961–1970	60 and more age class and people born elsewhere	60 and more age class and arrivals of 1961–1970
Będzin	−0.37	−0.03	0.66	0.37	−0.03	0.43	0.66	−0.03	0.20	−0.26	−0.71
Dąbrowa Górnicza	0.66	−0.15	−0.58	−0.20	−0.18	0.05	0.31	0.71	0.16	−0.32	−0.30
Gliwice	−0.03	0.04	−0.13	−0.35	0.46	−0.35	−0.49	0.65	0.54	−0.15	−0.14
Cracow	0.44	−0.30	−0.36	−0.17	−0.03	−0.30	0.10	0.77	0.40	−0.20	−0.42
Krosno	0.74	−0.91	−0.50	−0.17	0.17	0.17	0.59	0.06	−0.41	−0.34	−0.72
Nowy Sącz	0.45	−0.45	0.07	−0.62	−0.10	−0.21	0.43	0.14	−0.02	−0.21	−0.62
Racibórz	0.19	0.26	−0.60	0.45	0.26	−0.17	0.14	0.45	0.26	−0.86	−0.86
Rzeszów	0.29	−0.11	−0.61	0.43	0.64	0.14	0.29	0.18	−0.04	−0.43	−0.50
Tarnów	0.37	0.01	−0.22	−0.55	−0.10	−0.24	−0.06	0.29	−0.13	−0.10	0.04
Wadowice	0.54	−0.89	−0.31	−0.89	−0.49	−0.49	0.37	0.83	0.37	0.37	−0.31

Apart from the natural demographic process, migration is one factor of particular significance in determining the population's age and sex structure. This is most clearly seen in the emergence of new large housing groupings. In the course of this process, demographic structures may undergo deformations. The large population living continuously in an area is undesirable for social and economic reasons. In definite age classes there is demand for certain services, their satisfaction requires institutional forms (nurseries, schools etc.). Those needs change with time, new wants appear, some facilities appear to be in excess while others are in deficit. This raises investment spending and subsequently leads to their incomplete or unsuitable usage. For social and demographic reasons, there should be prevented the emergence of too large groupings of collective households with deformed age and sex structures and of communities with evened out age classes. This requirement can be materialized both by way of definite planning procedures and by the home-granting policies.

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DIFFERENTIATION OF TRANSPORTATION INFRASTRUCTURE AS A CONSEQUENCE OF FORMER POLITICAL DIVISIONS

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Poland's present territory is an interesting example of a differentiation of the transportation infrastructure resulting from different history of its individual components. In some aspects, the consequences of the 19th c. political division remain visible till today. This is particularly true of the railway network, the bulk of which dates back to the times when Poland's territory was split in three parts by three partitioning powers.

The Polish state did not exist from 1795 till 1918, except for a short time during the Napoleonic Wars, when the Duchy of Warsaw played the part of a surrogate state. In the course of those 123 years, Europe had developed a modern transport network, which included railways, highways and inland canals. In the Polish territory this network was designed and constructed by alien states in consideration of their own interests and not the needs of Poland, which was not to regain independence till 1918.

Each of the three partitioning states was at a different stage of economic development and pursued a different transport policy, which resulted in a considerable differentiation of the transportation infrastructure in the area of Poland. The situation became particularly evident after 1918, when areas of extreme disparity as regards the density of the transport network fell within the borders of one country.

DEVELOPMENT OF THE TRANSPORT NETWORK IN PRUSSIA

From 1871 the core of the German Empire, Prussia was the first to expand its transport infrastructure. The country enjoyed the highest level of economic development and owing to the contributions collected after the victorious war against France, it could afford major investment ventures.

The density of highways in Prussia grew fast. They were constructed not only as links between the main towns and administrative centres, but also in agricultural areas to serve individual villages and farms. The roads stimulated the growth of agricultural production, as the surplus production of goods and economic plants was easily exported. The dense network of agricultural and food processing plants, most of which operate till the present day, dates back to those times.

As regards railway construction, Prussia was the leading country in Central Europe. Already around 1860 the major connections between the provinces and Berlin had been constructed. and by 1875 the whole network of major trunk lines. still the mainstay of the railway network in this part of Poland. had been established. In late 19th and early 20th centuries the railway network grew denser, as a great number of local and narrow-gauge lines were constructed, providing access by rail to nearly all small towns and major rural settlements. In the area adjoining the Russian border, the lines were built dead-ended, stopping short nearly on the borderline. As it was to turn out later, behind it there were military reasons.

Also in the field of waterways, Prussia's contribution was the biggest. The rivers Odra and Lower Vistula as well as the major tributaries of the Odra (the Warta, the Notec) were trained. In the Warmia and Mazurian Lake District regions the canal systems were constructed between major lakes, and lakes of the Ostróda-Ilawa region gained even connection with the sea.

DEVELOPMENT OF THE TRANSPORT NETWORK IN AUSTRIA

Within the boundaries of contemporary Poland, the former Austrian partition is the smallest part. As regards the level of economic development, Austria was half-way between Prussia and Russia. Besides, the economic situation varied greatly from one part of the huge monarchy of Austria-Hungary to another. In the Polish area, economic development was the most advanced in the western region of the Austrian partition, namely the Cieszyn Silesia and a part of the Upper Silesian Coal Basin. The density of the railway network constructed there, matched that of the area under Prussian rule. Also highways were extensively constructed, albeit their density was smaller than in the neighbouring German Silesia. What was missing was the stimulus of highly productive agriculture.

As one proceeded eastwards, the transportation infrastructure deteriorated despite of high population density. Some of the railway lines were constructed for strategic rather than economic reasons, therefore preference was given to connecting Galicia with the rest of the empire via the Carpathian Mountains, whereas the railways failed to fully satisfy the local transportation requirements. Local and narrow-gauge lines were next to non-existent, even though a mountainous area is predestined to the construction of such lines (as is evident in the selfsame Austria). The borderland with Russia suffered the total neglect; not a single line was built to cross the frontier except for the oldest Warsaw-Vienna line, which crossed the Austrian-Russian border close to the Prussian border.

The network of highways was similarly underdeveloped and their quality was below that of roads in other parts of Poland. In mountainous areas roads were frequently destroyed due to floods, heavy rain, and snowfalls and landslides.

DEVELOPMENT OF THE TRANSPORT NETWORK IN RUSSIA

The transport network was the least developed in the area of the Russian partition, which included the central part of the Polish territory (the Polish Kingdom founded in 1815 under Russian protectorate). The reason was a general economic backwardness of contemporary Russia, which made the Polish provinces stand out for their higher economic development, especially stronger industrialization.

The construction of railways progressed at the slowest pace there. Although the first line (Warsaw–Vienna) was constructed already in the years 1845–1848, a thirteen-year break in railway construction ensued. The lines built later or designed by the government were primarily aimed at connecting the territory with Central Russia and satisfying the strategic requirements of defence. Economic reasons and local needs were swept to the background. Therefore, railway lines were located in

Fig. 1. Development of standard- and broad-gauge railway network of Poland

1 — lines constructed before the First World War, 2 — lines constructed in the years 1914–1944, 3 — lines constructed in the years 1945–1980, 4 — lines closed, 5 — boundaries of partition sectors, 6 — inter-war state boundary, 7 — boundary of present-day Poland; A–D — regions

sparsely populated and industrially undeveloped regions of agricultural land and forests, whereas some industrial and administrative centres lacked railway connections. Two capitals of guberniyas (provinces) were not connected with the railway network until about 1900, and two others did not acquire any railway connection under the Russian rule (Fig. 1).

The manner of locating railway lines was symptomatic of the practice of overlooking local needs. Unlike in the German and the Austrian partitions, the lines did not pass through towns, but swept across the country without regard to the network of settlements. Thus, many traditionally established towns were skipped by the railways and consequently declined, whereas the location of railway stations and junctons boomed the development of new urban settlements, many of which grew to a considerable size and superseded the neglected old towns in their administrative and servicing functions.

Another factor detrimental to the quality of transport services was the location of railway stations. They were generally spaced every 15 to 30 km (in the German and Austrian partitions every 5 to 8 km), frequently far from the towns which they were to serve. Only in a few cities the railway stations were constructed in city centres.

The manner of construction of highways was somewhat similar. The highways built were by far fewer than in other countries of Central Europe. Priority was given to arterial roads, which connected main towns, frequently bypassing smaller towns on the way. Local roads leading to villages were next to nonexistent. To reach a village, one usually had to swerve from the main road and follow an unsurfaced one.

One characteristic feature of the transport policy of Tsarist Russia was a roadless zone along the borders, which was to protect the country against possible external aggression. There were nearly no railways in the zone, and the network of highways was sparse and usually not connected with highways of the neighbouring countries.

No efforts were made to improve the natural waterways and connect them by canals. The canals already constructed and those under construction suffered such neglect that they lost their transport significance or were simply never opened. This is to some extent understandable as the river mouth parts of the main rivers (the Vistula, the Warta, the Niemen) were German territory and Russia was not committed to developing navigation on those rivers and transit through foreign harbours.

INTEGRATION OF THE TRANSPORT NETWORK IN INDEPENDENT POLAND

Established anew in 1918, the Polish state faced a challenging task. It had to integrate the transport networks of the three partitioning powers and adapt them to its own needs. To make matters worse, the roadless zones along the borders of the Tsarist Russia eventually became the central part of the country and separated its other parts. Hence, the first transport undertakings after 1918 were railway lines which crossed the former borders between partitions (some of them were built already during the First World War by the struggling armies).

Afterwards, the disparities in the transport infrastructure of different parts of the country were gradually levelled. Most of the investment ventures were undertaken in the area of the former Russian partition, as the shortages were the most acutely felt there. New railway lines were constructed, the network of stations along the existing lines grew denser, junctions were expanded, and new stretches were added to the network of highways.

All in all, the area of the former Russian partition accounts for nearly a half of the length of new railway lines constructed from 1914 till 1944 in the present area of Poland (the partition covers 40% of Poland's present territory). In this area the density of the network of highways grew 2.8 times in the inter-war period, whereas in other parts of the country it increased less then twofold.

Poland's frontiers changed in 1945. Losing the least developed eastern territories, Poland gained the western and northern territories (up to then within the German borders), which were well equipped in the transport network. The integration process has been easier there, especially in the western area, where the territory on both sides of the inter-war border had similar transport facilities, mostly dating back to before 1918 (when the border was delineated).

Starker contrasts have remained along the inter-war northern frontier, where former East Prussia borders on the economically underdeveloped and sparsely populated strip of the former Russian borderland, whose old backwardness has not been fully overcome yet.

LEVELLING DISPARITIES IN THE TRANSPORTATION INFRASTRUCTURE OF CONTEMPORARY POLAND

Contemporary Poland may be divided into four regions, each with a different political past and in consequence a different standard of the transportation infrastructure. The regions are:

A. The western and northern territories, which belonged to Germany until 1945.

B. The territory of the former Prussian partition, which was returned to Poland after 1918.

C. The territory of the former Austrian partition, which has belonged to Poland since 1918.

D. The territory of the former Russian partition, including the so-called Polish Kingdom, which has constituted the central part of Poland since 1918.

Up till the First World War the level of development of the transportation infrastructure in regions A and B was the highest, in region C, average or under the average, whereas in region D, the lowest. In the inter-war period, the infrastructure was improved especially in region D, as most of the investment ventures were concentrated there. Progress in regions A and B was slower, as their saturation with the transport network had already matched that of the developed countries of Western Europe. In region C the fewer construction ventures were undertaken than one might infer from the proportion between its area and the area of the rest of Poland.

After the Second World War, progress in regions A and B has been considerably slower, reasons being the same as in the inter-war period. There has not been so much need to extend the transport network and the needs have not been so pressing as in other parts of the country. The only exception is the area of the Upper Silesian Industrial District, where the railway network has been greatly extended due to the huge increase in coal extraction. In region A the railway network has suffered a regression due to the war-time damage, post-war dismantling, and afterwards a planned closing down of the least profitable lines. The planned closing down of railway lines has also been taking place in region B, but so far it has been slower than the construction of new lines (the Upper Silesian Industrial District is situated in this region). In region C the railway network has been expanding slowly, mainly in the vicinity of Cracow. On the other hand, the road network has been there expanding at a much faster pace. The density of highways in the region has doubled after the war, with Cracow voivodship taking the lead in Poland as regards the density of those roads.

However, most of the new transport ventures have been undertaken in region D, whose share in those ventures has grown further in comparison with the inter-war period. The reasons are the standard of the transportation infrastructure in this region, still the lowest in Poland, its central location and the fact that it comprises Poland's two largest cities — Warsaw and Łódź. This region accounts for nearly 70% of the length of new railway lines constructed in Poland after the last war and some 60% of the length of highways constructed at that time. The density of highways in this region has increased the average of 2.4 times, and in the most deprived eastern part, it was more than trebled.

Table 1 shows data on the size of transport construction in the above regions as compared with the area and population share of those regions. The statistical

TABLE 1. Distribution of transport network increase by historical regions

Region	Per cent share		Per cent share of total increase					
	of area	of population[a]	in standard-gauge railway network			in road network[c]		
			till 1914[b]	1914–1944	1945–1980	till 1913	1914–1944	1945–1980
A	33	26	52	22	5	49	36	14
B	15	20	24	21	9	21	16	9
C	12	15	8	8	17	14	8	18
D	40	39	16	49	69	16	40	59
Total	100	100	100	100	100	100	100	100

[a] In 1980
[b] Till the outbreak of First World War
[c] Approximate data

data are approximate, as the present units of administrative division overlap with the former provinces and frequently one voivodship includes parts of two regions, and even all four in the Katowice voivodship.

THE EXISTING DIFFERENTIATION OF THE TRANSPORTATION INFRASTRUCTURE IN POLAND

Despite all the efforts, the area of Poland is still widely differentiated as regards the transportation infrastructure, due not to the level of economic advancement or population density, but different history. Table 2 presents the 1980 indices of the density of railway lines and highways (in relation to national averages) compared with indices of population density and the level of industrialization (the latter measured by the number of people employed in industry per 1000 inhabitants).

The level of the transportation infrastructure diverges from those economic indices, especially as regards the railway network, which is the most durable and unchanging component of the engineering infrastructure. There are major disparities as regards the density of servicing points (stations and stops, freight loading points), which indicates the varying character of railway lines. In regions A. B. C. railways are of greater service to local needs, stations and loading points are more densely spaced and situated closer to settlements.

In region D, one can observe the consequences of the old location of railways; although the greatest number of new railway stops have been established in this region in the inter- and post-war period, stations and stops are still fewer there than in other areas and frequently located in places inconvenient to the inhabitants. Within the reach of the commuter lines around Białystok, for instance, the number of passenger stops has increased nearly threefold since 1913, even though the railway network has not otherwise been extended. As regards the commuter railway services of Warsaw, the number of stops along standard-gauge railway lines has grown three times over that time, the network itself been slightly extended, among other things due to electrification. However, narrow-gauge railways where the stops were very densely spaced, have been closed down.

TABLE 2. Differentiation of the 1980 transportation infrastructure by historical regions (100 = national average)

Region	Population density	Level of industrialization[a]	Standard-gauge railways (density in area)			Highways (density in area)
			lines	passenger stops	freight loading points	
A	76	102	120	123	111	95
B	139	112	167	164	177	103
C	127	99	77	98	97	115
D	99	93	66	58	64	97
Total	100	100	100	100	100	100

[a] Measured by the number of people employed in industry per 1 000 inhabitants

The spread of the road network is much more uniform. The inter-war and especially the post-war investment ventures have greatly levelled the old disproportions. Some voivodships in regions C and D, in the past the most deprived, have advanced to the lead in the field of road density. However, the easternmost voivodships in region D are still lagging behind, just like after the First War, despite the significant progress achieved there. The huge disparity between those voivodships and the more advanced ones has not been overcome.

The different history of various parts of Poland may now be better traced through examining the character of the road network, including the details of road location. In regions A, B, and C, highways usually connect one settlement with another, pass through their centres, with an abundance of roadside buildings and bends. In region D, highways pass more independently of settlements, are usually straight lines and often bypass towns or villages at considerable distances. This is an advantage from the viewpoint of long-distance, fast motor traffic; those roads are safer, permit greater driving speed, are easier to widen or change into two-lane. Roads in regions A, B, and C, on the other hand, are of better use to local traffic and provide direct service to more settlements.

Naturally, there is great internal differentiation within each of the four regions. There are particularly stark contrasts between the areas of urban agglomerations and the sparsely populated areas with a predominance of agricultural land and forests. Generally speaking, the density of the transportation infrastructure diminishes in regions A, B, and D as one proceeds from the south to the north, together with population density and the degree of industrialization. In region C, which is situated along parallels of latitude, the density of the infrastructure decreases somewhat as one progresses to the south, and the mountains become higher, as well as when proceeding from the west to the east, which is historically explicable.

The disparity in the transportation infrastructure poses diverse problems in spatial planning in different parts of Poland. In regions A and B, for instance, some local railway lines remain to be closed down, and there is practically no need to extend the network any further. On the other hand, it would be desirable to increase the density of the railway network in regions C and D through ventures such as the construction of more trunk lines and some local lines. It is also necessary to establish more stations along some of the already existing lines, which would enhance their usefulness. As for the newest lines constructed exclusively for long-distance freight traffic, fast passenger trains should also be introduced and a number of new stations should be set up to serve the areas intersected by those lines.

As regards the road network in regions A, B, and C, it is more necessary to construct the long-distance dual highways and motorways, whereas more pressing task in region D is to increase the density of local roads, thus providing access to all the rural settlements by car. Considering the pace of investment processes in the field of the transportation infrastructure, one should not expect a levelling of the existing disproportions in Poland's tranportation infrastructure before the end of this century.

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THE DIFFUSION OF RAILWAY NETWORK IN POLAND AS A SPACE-TIME PROCESS

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The process of spatial diffusion, or spread, is tackled in the literature of the subject either descriptively or in model terms. These two approaches are also adopted in studies of transport (Taylor 1980). Most frequent are studies of the development of transport networks (e.g., Godlund 1952, Garrison and Marble 1965, Ray *et al.* 1974, Pawson 1977, Moyes 1978), sometimes in connection with economic growth (e.g., of the United Kingdom, see: Mitchell 1964) or with changing form of the space-economy (e.g., of England and Wales: Moyes 1978). Less frequent are studies of the diffusion of new kinds of links for the urban street networks (Burnett 1975), the modernization of road networks (MacKinnon 1974), the spread of billboards along highways radiating out of a city (Colenutt 1969), the development and forecasting of private cars (Bartosiewicz 1977), the spread, and later disappearance, of urban tramways (Jones 1978), etc.

The scope of this study[1] is determined by the availability and generality of relevant statistics. The data[2] comprise a full time series (for 1842–1977) of the lengths of the standard-gauge railway network throughout the Polish territory and in smaller spatial units corresponding to the present-day voivodships (regions). The voivodship seems to be the proper – in terms of size – spatial unit suitable for analysis and comparison. The results obtained may contribute to the furtherance of knowledge concerning the development of Poland's railway network.

The diffusion of innovation is a process whose course in time is well characterized by the saturation curves, and the logistic function (also called an S-shaped curve) being the most frequent of them:

$$P = \frac{U}{1 + e^{(a - bT)}}$$

where:

P – the dependent variable (in our case, the cumulative length of the rail network in time T),

U – the upper limit of phenomenon, sometimes referred to as the saturation level (in our case, the saturation level U denotes the maximum length of the railway network in a given spatial unit, either region, or country),

T – the time since the process of innovation diffusion started (independent variable),

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[1] The research forms part of a project MR.I.28.04.5

[2] I am grateful to Professor Teofil Lijewski for supplying those data and other information.

e – a constant, the base for natural logarithm,
a – a parameter, which determines the value of *P* when $T = O$,
b – a parameter: the rate at which *P* changes with time *T* (gradient).

This definition of the saturation level *U* has been adopted because the logistic function can be used to characterize the process in the case when the railway network considered displays a predominant upward trend, possible with an insignificant periodic stagnation or a slight drop in the course of the process (although not in its final phase). The value of *U* was a preliminary criterion for a division of the studied spatial units: the detailed analysis did not comprise the spatial units (present-day voivodships) in which the length of railway lines displayed a downward trend at the end of the studied time series (Fig. 2).

The logistic function applied in the study permits to: (1) present the process in a generalized form and thus enables us to compare the development of the network without considering its detailes, (2) compare the studied process in different spatial units which enables us to distinguish different types of regions (today's voivodships) according to various mean rate of railway network building growth.

TABLE 1. The characteristics of logistic functions

Voivodship (region)	Upper level of 'saturation'(*U*)	*a* value	*b* value
Biała Podlaska	154	.44	.05
Białystok	490	1.05	.04
Bielsko-Biała	399	2.47	.07
Bydgoszcz	1 177	3.26	.08
Częstochowa	558	2.65	.04
Kalisz	473	1.29	.05
Katowice	1 349	1.96	.04
Kielce	469	.29	.01
Konin	176	1.13	.02
Krosno	208	– 40	.05
Lublin	252	.46	.05
Łomża	179	1.06	.04
Łódź	151	2.26	.05
Nowy Sącz	307	.32	.05
Ostrołęka	282	1.81	.04
Piotrków	282	1.06	.02
Płock	227	2.53	.05
Poznań	870	2.69	.06
Przemyśl	188	.76	.04
Radom	263	.57	.02
Rzeszów	224	1.01	.03
Siedlce	460	.86	.03
Sieradz	233	.49	.04
Skierniewice	268	1.06	.02
Tarnobrzeg	328	.42	.01
Tarnów	206	1.12	.06
Warszawa	410	3.04	.05
Wrocław	·170	1.45	.05
Zamość	224	.82	.02
Poland, total	24 397	3.39	.07

Parameters *a* and *b* of logistic functions (Table 1) have been estimated by the least-squares method while the goodness of fit of the functions to the actual values have been checked by the *F* test (Table 2).[3]

The tentative hypotheses phrased in virtue of the existing views, concepts, and empirical observations can be presented as follows:

1. A spread rate of innovation (railway) in Poland depends above all on the previous incorporation of a given area into any of the three foreign states – Prussia, Austria, and/or Russia. This concerns also, though to a much lesser extent, Polish north-western territories that belonged to Germany in the inter-war period.

2. A strong propensity to faster extension of railways is noticed in the lead regions, and in those with greater dynamics of socio-economic development, especially of industrial output, and more urbanized.

3. The extension of the railway network took less time in areas where the new transport mean was adopted later.

Hypothesis 1 has been derived from the premise that the period of intensive expansion of rail transport coincides with the interval ending in 1918. That was a time when Poland was divided up and incorporated into the state territories of the three partitioning powers, each pursuing then different policies in this respect. In Hypothesis 2, the differing propensities to innovation follow from the various technological and economic possibilities in areas under review. The verification of both hypotheses have been carried out mainly on the basis of the spatial analysis of gradient values (*b*) distribution; these have then be used to identify four types of voivodships characterized by different mean rate of railway network building growth. The identification of such types (which are characterized in connection with the economic development of the regions) seems to be more meaningful than the comparison of the absolute lengths of the network or of its densities in given spatial units. The underlying assumption is that it is economically unsound, if not undesirable, for every regional network to be equally long, or equally dense. To verify Hypothesis 3, we study the dependence between the year of adoption and the time needed to achieve the saturation level in a region.

An upward trend has been found to have predominated in the nation-wide railway network and in the case of 29 voivodships.

Lijewski (1959, 1973) has discriminated the following periods in the historical development of Poland's railway network:

(1) the construction of the main links (1842 to about 1880),

(2) the construction of secondary and commuting lines (about 1880 to 1914),

(3) the construction of war-time strategic and operational lines (1914 to 1918),

(4) the interconnection of the networks of the former sectors of partitioned Poland (1919 to 1939),

(5) damages and devastation during the Second World War,

(6) the post-war reconstruction, extension and modernization (since 1945).

The above periods have left only slight marks on the actual values curve, where one can notice three indents signifying decreases in the overall length of the railway lines. The decreases were caused by (1) the damages suffered during the First World War and during the Polish-Soviet war of 1919–1920; (2) the destruction and dismantling of many lines (tracks) following the Second World War, and (3) the contraction of some loss-incurring lines in the mid-1960s, respectively.

The logistic curve describing the development of standard-gauge railway network

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3 The computations have been done on CDC 6000 and 7600 computers at the University of London Computer Centre. .

TABLE 2. Variance analysis

Voivodship (region)	Source of variation	Degrees of freedom	Sum of squares	Mean square	*F* value
	a	1	607.59	607.59	498.1223
Biała Podlaska	b	109	163.45	1.22	
	c	110	771.03		
	a	1	470.68	470.68	364.1480
Białystok	b	114	173.20	1.29	
	c	115	643.89		
	a	1	1049.69	1049.69	641.3659
Bielsko-Biała	b	121	219.31	1.64	
	c	122	1269.01		
	a	1	1417.73	1417.73	801.4539
Bydgoszcz	b	125	237.04	1.77	
	c	126	1654.77		
	a	1	308.74	308.74	471.6469
Częstochowa	b	130	87.72	.65	
	c	131	396.46		
	a	1	762.50	762.50	470.1579
Kalisz	b	105	217.32	1.62	
	c	106	979.83		
	a	1	421.96	421.96	868.5996
Katowice	b	131	65.10	.49	
	c	132	487.05		
	a	1	67.16	67.16	91.1630
Kielce	b	91	98.71	.74	
	c	92	165.87		
	a	1	122.35	122.35	28.5660
Konin	b	88	573.94	4.28	
	c	89	696.29		
	a	1	611.65	611.65	369.5016
Krosno	b	104	221.81	1.66	
	c	105	833.46		
	a	1	729.41	729.41	559.0876
Lublin	b	101	174.82	1.30	
	c	102	904.23		
	a	1	434.98	434.98	650.3406
Łomża	b	114	89.63	.67	
	c	115	524.60		
	a	1	607.12	607.12	205.3187
Łódź	b	110	396.23	2.96	
	c	111	1003.35		
	a	1	800.44	800.44	628.0626
Nowy Sącz	b	100	170.78	1.27	
	c	101	971.22		
	a	1	383.74	383.74	249.0352
Ostrołęka	b	114	206.48	1.54	
	c	115	590.21		

Voivodship (region)	Source of variation	Degrees of freedom	Sum of squares	Mean square	*F* value
	a	1	93.83	93.83	278.5322
Piotrków	b	130	45.14	.34	
	c	131	138.96		
	a	1	684.45	684.45	194.4816
Płock	b	115	471.60	3.52	
	c	116	1156.05		
	a	1	766.14	766.14	936.6668
Poznań	b	128	109.60	.82	
	c	129	875.75		
	a	1	370.13	370.13	630.3082
Przemyśl	b	117	79.96	.60	
	c	118	450.09		
	a	1	88.56	88.56	90.6202
Radom	b	91	130.96	.98	
	c	92	219.52		
	a	1	196.84	196.84	266.0210
Rzeszów	b	118	99.15	.74	
	c	119	296.00		
	a	1	184.46	184.46	166.2370
Siedlce	b	114	148.69	1.11	
	c	115	333.15		
	a	1	574.53	574.53	206.2997
Sieradz	b	75	373.18	2.78	
	c	76	974.71		
	a	1	117.89	117.89	429.8507
Skierniewice	b	131	36.75	.27	
	c	132	154.65		
	a	1	24.07	24.07	30.0907
Tarnobrzeg	b	89	107.21	.80	
	c	90	131.28		
	a	1	675.34	675.34	850.1705
Tarnów	b	120	106.44	.79	
	c	121	781.79		
	a	1	635.53	635.53	730.6731
Warsaw	b	131	116.55	.87	
	c	132	752.09		
	a	1	490.21	490.21	222.1125
Wrocław	b	114	295.74	2.21	
	c	115	785.95		
	a	1	92.05	92.05	37.0390
Zamość	b	89	333.03	2.49	
	c	90	425.08		
	a	1	918.26	918.26	1485.9941
Poland, total	b	134	82.80	.62	
	c	135	1001.06		

a – regression, b – residuals, c total

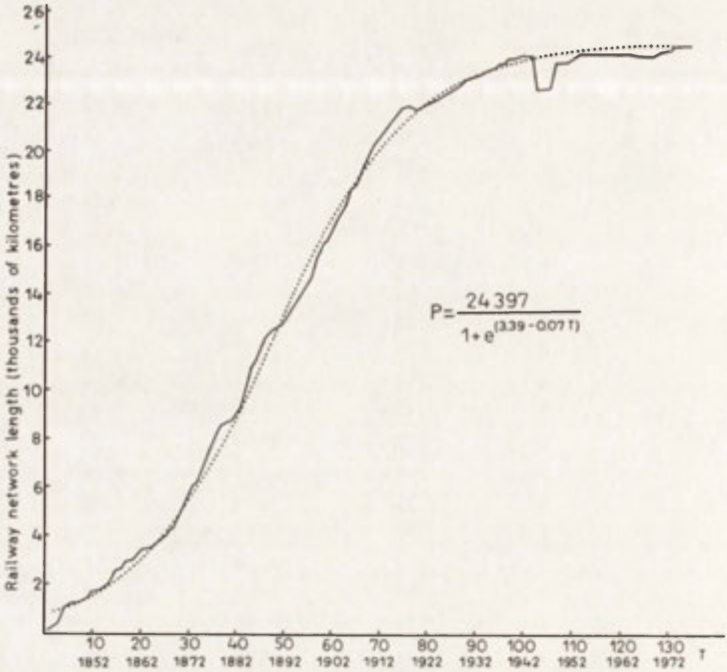


Fig. 1. The diffusion curve for the acceptance of railway network throughout the Polish territory, 1842–1977

The continuous line indicates the actual values, and the broken one – the values derived from the logistic function

throughout the present-day Polish territory displays a regular, almost ideal, course (b = 0.07), and a good fitting to the actual values (Fig. 1). A small deviation of the actual values curve from the logistic curve results from a space-time shift in the development of networks in each of the former sectors of partitioned Poland. Railway building was intensively promoted first in the Prussian sector, then in the Austrian one, and later still in what was called the Congress Kingdom of Poland.[4]

Let us now take a look at the upward trends of the railway network taken nation-wide and, later on, in the voivodship division. Whereas the general pattern of railway main lines (oriented towards Berlin) had been completed in western Poland by about 1860, railway building in the other two sectors was insignificant. In the Austrian sector, then called Galicia, only two major links were in use then – that between Cracow and Silesia, and so called 'northern railway' from Oświęcim via Cracow to Przemyśl; in the Kingdom of Poland the Warsaw–Vienna line with a limb to Łowicz were formed. For the next several years the railway lines were extended in the Prussian sector, somewhat later in the Austrian sector, as well. But very little has been done in that respect in the Congress Kingdom.

From 1880 to 1914, the railway-network density in the German sector was

4 The Congress Kingdom of Poland, 1815–1915, was created of a decision of the Vienna Congress (1815). The Kingdom embraced eight regions of total area 128 000 km^2, and had a population of about 3 300 000 in 1816 and 10 000 000 in 1900. There was a personal union between Russia and the Kingdom. In fact, the last one was so strongly connected with Russia that we call it also the former Russian sector (annexed territory).

further increasing, less so in Galicia. Contemporaneously with that, in the Russian part the railway main lines were still being under construction, including the Dęblin–Dąbrowa, the Narew lines as well as others in north-eastern Poland.

For military purposes, railway building during the First World War was the most intense throughout the territory of the Kingdom and especially in its borderland. The period of intensive investment activities ended during the First World War (the logistic curve gets flatter). In the inter-war period it became necessary to connect the networks of the different parts of Poland and of the industrial center of Upper Silesia with the Gdynia seaport as well. So, one can see the continuous increase in length of the network till the outbreak of the Second World War. After the damages suffered during the war most of the network has been rebuilt. The closures of nonprofit-making lines in Poland's northern and western territories in the latter half of the 1960s were smaller than offset by the extending of the network in the eastern and south-eastern voivodships. In result, a total length of railway network was rising slowly (Pisarski 1974).

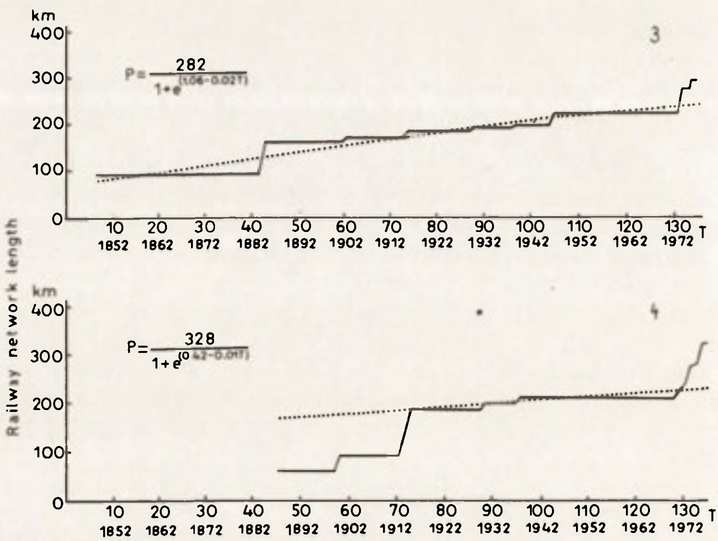
*

The values of the gradient (parameter *b*) have been used to distinguish the four types of regions (Fig. 2). Each of 29 voivodships belong to one or other of four types.

Type I (b = 0.01–0.02) includes the voivodships of Skierniewice, Piotrków Trybunalski (Fig. 3), Radom, Kielce, Tarnobrzeg (Fig. 4) and Zamość, as well as the

Fig. 2. Types of regions (voivodships) by mean rate of railway network growth

1 – type I (b – 0.01–0.02), 2 – type II (b = 0.03–0.04), 3 – type III (b = 0.05–0.06), 4 – type IV (b = 0.07–0.08), 5 – absolute decline of network length



Figs 3 and 4

Note to Figs 3–9. The diffusion curves for the acceptance of railway network for the selected spatial units (present-day voivodships)

The continuous lines indicate the actual values, and the broken ones – the values derived from the logistic function

voivodship of Konin, spatially separated from the others. They are almost entirely the territories comprised within the former Congress Kingdom. Except for the first two, all those voivodships started railway building more than 40 years later than Lower Silesia (the Wrocław–Olawa–Brzeg line was built in 1842). The mean growth rate there, especially in what today are the Kielce and Tarnobrzeg voivodships, was the lowest for all Polish territories. One characteristic feature was that railway building lagged behind a given area's economic development. The lack of rail transport was doubtlessly the cause of the stagnation, if not the economic collapse, of parts of that territory. For instance, the first railway line leading through the Old-Polish Basin was laid as late as in 1885. In the meantime that area was depressed, among others, because of transport difficulties (Lijewski 1977).

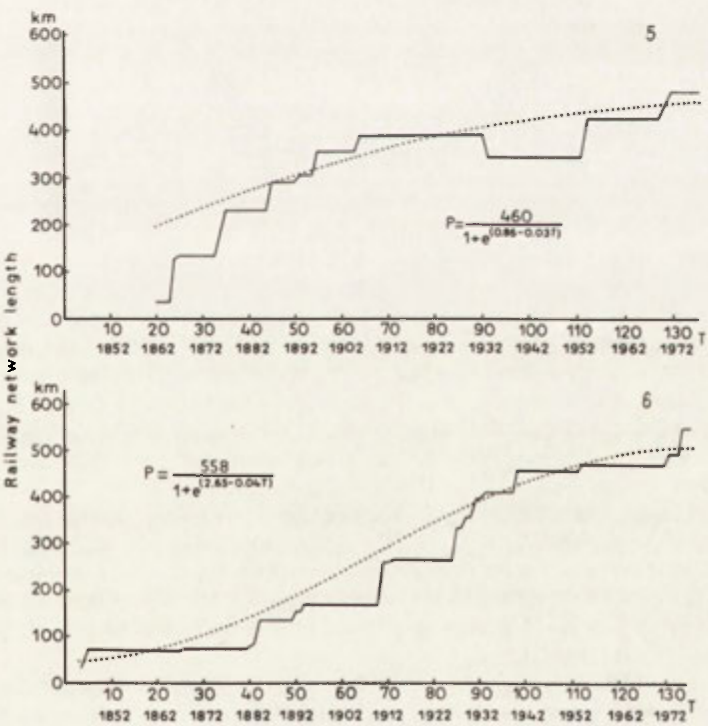
The unfavourable situation persisted, with a few exceptions, till the times of nowadays Poland. How insufficient rail transports then were, can be seen from the following fact: in connection with the intensive development of the mining industries (sulphur, gypsum, limestones), of the energy producing industries (among others, the Kozienice power stations), the chemical industry (Tarnobrzeg, Tomaszów Mazowiecki, Pionki), the engineering industries, after the last war the highway building has flourished on an unprecedented scale. This is especially true in the case of the Kielce, Radom and Tarnobrzeg voivodships. There, also new railway lines were built, among them the Tomaszów–Radom (1948–1949), the Kielce–Busko (1953), the Włoszczowice–Grzybów–Tarnobrzeg (1969–1973), the Zwierzyniec–Bilgoraj–Stalowa Wola (1971–1976), and the Piotrków–Bełchatów (1977) lines. It is also through that area that the Central Trunk-Line is already running as well as the 'sulphur-metallurgical' line from Hrubieszów to Huta Katowice, which has not been included in our analysis. The later line will provide, among others, transport services in the area.

The undevelopment of rail transports was still conspicuous nowadays in the

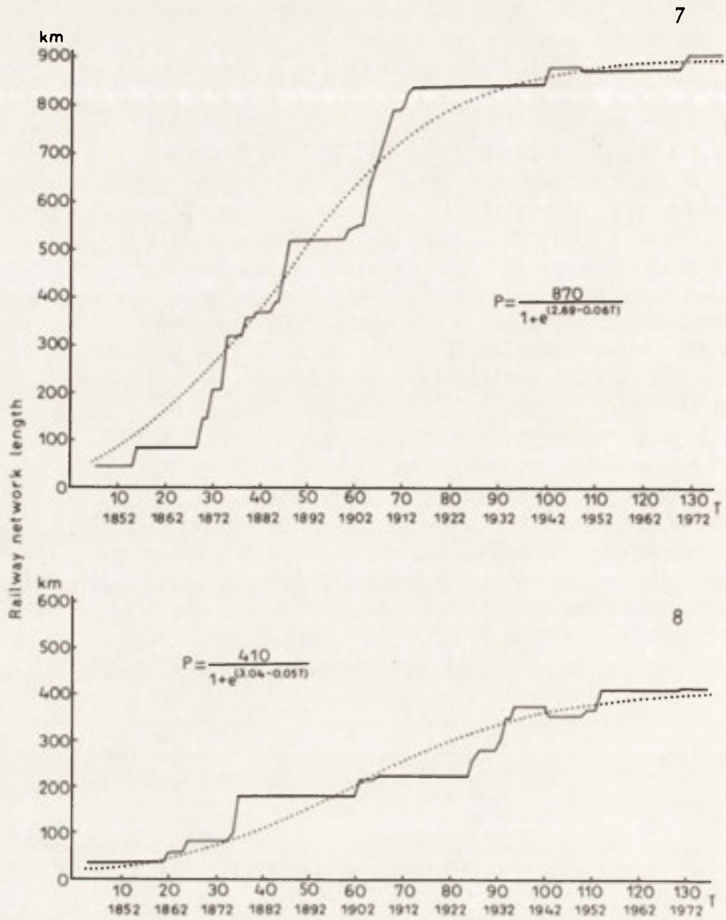
Konin voivodship where bulk commodities were often hauled by lorries, as for instance coal to the Adamów power station.

Type II (b = 0.03–0.04), represented by three compact areas in various parts of Poland, displays a slightly higher rate of railway-network growth. They comprise what today are the voivodships of: (1) Siedlce (Fig. 5), Ostrołęka, Łomża and Białystok, (2) Sieradz, Częstochowa (Fig. 6) and Katowice, and (3) Rzeszów and Przemyśl. If we disregard the absolute length of the network and its density, whose linkage with the level of economic development seems undisputable, the spatial distribution of Type II is at odds with Hypothesis 1, which says that the rate of railway networks spread depends mainly on the former incorporation to a foreign state organism. But in spite of it, to some extent at least, political and strategic factors have not to be depreciated, especially in the case of north-eastern areas. Many lines, such as for instance the Warsaw–Białystok–Kuźnica Białostocka line (1862) or the later one Siedlce–Siemiatycze–Siemianówka (1906), were laid mainly for political and strategic reasons, as evidenced by the fact that they bypass the settlements of that time. Centres such as Wołomin, Tłuszcz, Łochów, Łapy or others emerged later only, in result of the expansion of industries along the existing railway line.

The case of the Częstochowa voivodship (Fig. 6), and even more so that of the Katowice voivodship, points to the very intensive, though fairly regular, process of railway development which reached maximum lengths and densities in the spatial units under review. It was towards the coal basin that the first railway lines were built from all three sectors, a circumstance indicative of the dominance of economic motivations in laying the first railway lines (Lijewski 1977). Following



Figs 5 and 6



Figs 7 and 8

the split-up of Silesia into the German and Polish parts, new railway lines were laid in both parts in the inter-war period; the territory of the Częstochowa and the Sieradz voivodships was supplied with the Kalety–Wieruszów line in 1926 and with the Coal Trunk-line in 1930–1933. After the war, the building of belt-lines around the Upper-Silesian Industrial District (Lubliniec–Pyskowice, Zawiercie–Kochłowice, Tychy–Wesoła) was being continued; so was the extension of the railway nodes, for instance that of Częstochowa.

The same mean rates of railway development have been found for the other two voivodships classed with Type II: those of Rzeszów and Przemyśl. The building of railways had started relatively early there and was completed already before the end of the 19th century; it was only in the latter half of the 1950s that those railway networks were partly supplemented with new links (including the Rzeszów–Nowa Dęba one).

Type III (b – 0.05–0.06) is represented by four voivodship clusters: (1) Poznań and Kalisz, (2) Włocławek, Płock, Łódź-city, and Warsaw-city, (3) Biała Podlaska and Lublin, (4) Tarnów, Nowy Sącz, and Krosno. Development was taking place in them at the same mean rates but at differing network lengths. It was only in the present voivodships of Poznań (Fig. 7) and Warsaw-city (Fig. 8) that the railway network developments are represented by full logistic curves, while in the remaining ones they are only partly so. This follows from the incomplete developmental cycle of the network of undeveloped areas (Biała Podlaska, Lublin, Krosno). The motivations for the building of networks differed from case to case (economic, or political, or strategic ones) and usually one of these prevailed as the motivating factor in the region or even in the case of a single line. For instance, the network of the two south-eastern voivodships of Nowy Sącz and Krosno was built mainly for economic reasons (what was called the 'transversal' line bound to the development of the petroleum industry in the Carpathians), or for strategic reasons (as the N–S lines across the mountain range). Formed before 1890, that line survived virtually unaltered up today, though the significance of single routes has changed in the meantime (Lijewski 1977).

Type IV, that with the highest mean rate of railway-network development ($b = 0.07$–0.08), includes two voivodships only – those of Bielsko-Biała (Fig. 9) and Bydgoszcz. Both represent a relatively early beginning of railway building – just after 1850 – which subsequently has been continued till the end of the inter-war period. Since those days, however, no new railway line has been put to the use there. The high rate of network building was matched by intensive economic development, especially of the industrial output of the two regions.

In the remaining 20 voivodships there was an absolute decline, i.e. a contraction of network length at the end of the time series. That process cannot be represented by means of a logistic function.

With relatively few exceptions noted below, there are voivodships of the northern and western territories where the total length of the networks decreased considerably due to war damages and to the dismantling of many tracks just after the war. This is primarily true of the less economically advanced voivodships (Suwałki, Olsztyn, Elbląg, Słupsk, Koszalin), less so of the industrialized voivodships of Wałbrzych, Jelenia Góra, Opole, Wrocław, Legnica and Gdańsk. A decrease, though a lesser one, was also recorded for the railway networks of the voivodships that partly comprise the Regained Territories and partly the old ones (Piła and Leszno), mostly the old territories (Toruń and Ciechanów), and, in two cases, the old territories exclusively (Chełm and Cracow). But in the latter four voivodships closures of railway lines were insignificant.

How do the hypotheses listed at the outset stand a comparison to empirical observations? None has been fully confirmed, though none can be totally rejected, either. A corollary of all this: it seems to me that the spread rate of railway network is a result of many intertwined factors acting together or in contradictory

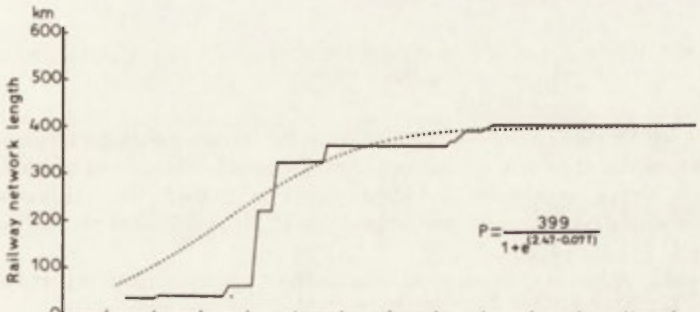


Fig. 9.

manner, either speeding up, or slowing down its growth, depending on a region concerned. Whereas historical factors do account for the high differentiation in railway-network densities on the territory of Poland (Lijewski 1977), one cannot overestimate their importance as regards the railway building growth. It is conventionally assumed (Hypothesis 1) that railway building had proceeded most rapidly in those Polish territories that had been incorporated into the Prussian sector. Our analysis has partly confirmed this opinion (for the Bydgoszcz and Poznań voivodships) in that we have to do there with the afore-mentioned space-time shift of network growth in the given areas. The only fact of belonging to a foreign organism does not predetermine the rate of network extension which depends on plenty of factors. The case of Polish north-western territories that belonged to Germany prior to the Second World War confirms this, too. For political reasons there were few cases of putting into use border lines which were to substitute links and/or nodes given to Poland in those days.

It is perhaps Hypothesis 2 that has got a relatively fullest confirmation. Economic and urbanization factors play almost a crucial role in determining the propensity to railway extension. This can easily be demonstrated by examples. It must be pointed out, though, that increase in network lenght may also occur in the less industrialized and/or urbanized areas with a railway line running through it to some major industrial center or district (the Coal Trunk-line in the Sieradz voivodship is a pertinent example in this context). Economic reasons can determine not only a high-density network building but also its fast growth. A good example of this is the Bielsko region, considerably different in the gradient value from the other south-eastern voivodships although the whole area had belonged to the former Austrian sector. Bearing this in mind, however, the actual high rates of railway development for reasons other than economic tend to attenuate the validity of Hypothesis 2.

Hypothesis 3 finds its confirmation with regard to less and moderately advanced regions of low-density railway networks that were built in few stages only (the Biała Podlaska, Krosno, Lublin, Nowy Sącz, or Sieradz voivodships) and which have not been extended to great length up to now even. But this is not always the case: it is known as a historical fact that many new routes were built in the 1870s in Greater Poland and Pomerania, two regions which had lagged behind Silesia in that respect. Yet, Hypothesis 3 has not been confirmed in the less advanced borderland areas of the former Congress Kingdom of Poland: about 1880 there was still no railway at all, and its development took a long time. That pattern of development seems to contradict a view that in areas where the innovation was adopted later the lessons were drawn from mistakes of 'pioneering' actions.

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SOCIO-ECONOMIC DEVELOPMENT AND THE TRANSPORT NETWORK IN POLAND

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One of the most important problems in studies of a country's spatial social and economic structure is an analysis of the relationships between the level of socio-economic development of areas and the transportation infrastructure, i.e. the state of transport networks in those areas.[1] The present spatial differentiation of the level of economic development in the country should correspond to a spatial differentiation of the transportation infrastructure. It is neither necessary non advisable to aim at a uniform spread of the transport network. An excessive density of the network, especially of higher quality, achieved through superfluous investment outlays on an expansion of the network can be just as detrimental to the functioning of the economy as insufficient investment in the field. An inadequately modelled road network causes immense damage, due both to a high share of the value of transport facilities in fixed assets and an unnecessary protraction of transportation.

However, owing to their great complexity, it is extremely difficult and often not feasible to fully investigate those relationships, which operate on the feedback principle. This is due to a differentiation of the means of transport as well as to methodological obstacles. Hence, two limitations have been imposed on the present paper. Firstly, the transport infrastructure is limited to the road network and, secondly, the paper does not consider feedbacks, focusing primarily on an investigation of the influence of the level of socio-economic development of areas on the transportation infrastructure.[2]

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[1] The term road infrastructure is commonly used to denote the state of surfaced roads (with improved and unimproved road surface, treated jointly) in the given area, measured by the index of road density (Lijewski 1977) or indices of the topological structure of the network.

This is the meaning of the term adopted in the present paper. A surfaced road is the minimum quality standard of roads which allows larger-scale motor transportation. Improved roads are considered separately within the category of surfaced roads.

[2] Although the interaction between the degree of economic development and the road infrastructure operates on the feedback principle, the strength of this interaction is not the same in both directions. The effect of economic development on the road infrastructure is considerably stronger than the effect of the road infrastructure on the economic development of regions. As Lachene's studies (1965) showed, the transport network is indispensable, but not sufficient to cause economic development. In other words, economic development of a given area will always result in greater transportation needs and an extension (and quality changes) of the transport network. On the other hand, the fact that some area has a well-developed network does not necessarily or may only slightly contribute to a further economic development of that area.

Despite of such a considerable limitation of the subject, it seems useful to conduct such an analysis. One may expect that certain isomorphisms between the transportation infrastructure and the spatial differentiation of the level of socio-economic development will be detected in the study, which will provide grounds to indicate the areas where definite changes in the density and alignment of the existing road network should be aimed at.

The fundamental goal of the present paper is to define spatial interdependences[3] between the road infrastructure and the level of socio-economic development in Poland. As an element of detecting regularities in the occurrence of socio-economic phenomena, such research is of a basic character. The findings may contribute to a better understanding of the way of functioning of the country's socio-economic system. The paper also offers a model of research which may be of use in geographical analyses conducted for the purpose of the spatial planning of the transportation infrastructure of the country and its regions. The reaching of this goal consists in a concretization of models which describe the interaction of socio-economic development and the transportation infrastructure.

As it has already been stated, the study covers only the road network, because of the following reasons:

(1) The road network provides virtually unlimited access for both passenger and freight transportation. The railway network, on the other hand, is accessible only at some points, and owing to various organizational limitations, it is far less accessible for freight conveyance than for passenger transportation.

(2) The unlimited accessibility of the road network is of special importance when network serves the spatially dispersed places where transportation needs develop and die out, thus mainly agriculture and rural settlement (Lissowska 1978) as well as for dispersed industry and small towns. This kind of economic activity and settlement generates transportation needs which are largely met by a short-distance, multi-direction transportation. Therefore, they are mainly satisfied by road transport and may be investigated with reference to small area units.

(3) The road network may be adapted to changes in the distribution of transportation needs much faster than the railway network.

The empirical studies were conducted on the national sçale. The four time sections considered were: 1960, 1965, 1970, and 1977. This made possible to draw conclusions on successive stages in the process of development of the investigated phenomena. Such an approach, called synchro-comparative, is unfortunately of limited reasearch value, as it does not allow a full reconstruction of the process of change or a description of its mechanisms (Chojnicki and Czyż 1978). The lack of a continuous time series of data in appropriate spatial disaggregation, especially as concerns the road network, as well as the 1975 change of the country's administrative division, not only prevented the use of the more valuable diachronic approach but also restricted the degree of generaliy of the conclusions drawn from the statistical analysis.

Owing to the change of Poland's administrative division, the present paper embraces two sets of reference units: poviats (according, to the administrative division valid until June 1975) and voivodships (according to the administrative division valid since June 1975).

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[3] The present study is principally limited to an examination of spatial interdependences between the road infrastructure and the level of socio-economic development of areas. However, it is possible to draw generalizations on the dependences between the processes of change of the two variables. It may be assumed that since every process consists of successive states, by way of investigating spatial relationships between those states it is possible to ascertain relationships occurring betweeen processes.

The utilization of different degrees of data aggregation (in reference units of varying size) led to an incomparability of the results, such as, for instance, correlation coefficients. However, the problem, encountered in most papers dealing with quantitative methods, has not been fully solved yet. Bearing that in mind, the author conducted the same analysis, so far as it was possible, for both sets of reference units.

In order to attain the assumed research goals, multiple regression analysis and, supplementarily, an analysis of principal components were employed.

The former poviats were initially adopted as the basic spatial units in the analysis of interdependences between the road infrastructure and the level of socio-economic development. The analysis was conducted for two time sections: 1960 and 1970.

The dependent variables were:

y_1 – the density of surfaced roads,

y_2 – the density of improved roads.

Following an initial analysis with the use of simple and multiple regression, the number of independent variables was reduced to three: x_1 – population per 100 km^2, x_2 – level of industrialization,[4] x_3 – average yield of four cereals per 1 ha as a measure of the development of agriculture.

An additional variable (x_{ad}) was introduced, namely the index of mean road density in units adjoining the investigated unit. Such a variable was introduced by Leinbach (1974) in equations describing the development of the road network in Malaysia in the years 1887–1968. A similar variable was also employed by Tobler (1970), only the latter considered just one adjoining unit at a time, the one with the greatest road density.

The purpose of using multiple regression was to answer the following questions:

(1) whether the variables y_1, y_2 are statistically dependent on the variables x_1, x_2, x_3 and, if so

(2) which of the two dependent variables is more strongly correlated with the independent variables.

Four multiple regression equations were computed for each of the two time sections. Judging by the results of studies by other auhors (e.g. Leinbach 1974), it was expected that the influence of the variable x_{ad} (mean road density in units adjoining the investigated unit) might be so big as to obscure the influence of the other independent variables. Thorefore, for each quality category of roads, the equations were computed separately with four and three independent variables, i.e. without the variable x_{ad}. The results of this part of regression analysis are presented in Table 1.

The level of explanation of all the models is high, even very high, ranging from 32 to 79%. As indicated by the values of the statistic and partial standardized regression coefficients, in equations with four independent variables the strongest influence on the independent variable is exerted by the variable x_{ad} (mean road density in surrounding units). The influence is the strongest in the case of roads with improved surfaces (y_2). Likewise, the level of explanation turned out to be higher for models which have the variable y_2 as the dependent variable.

As concerns the influence of the other independent variables, it varies from equation to equation. In the first 1960 model estimated for surfaced roads (i.e. $y_{1(60)}$),

[4] The variable x_2 is a synthetic index obtained through an analysis of the principal components. The interpretation of the component I is identical for both the investigated time sections; besides, it accounts for over 40% of total variation. The interpretation of the remaining principal components is different for each of the time sections, hence they have not been included in further study.

TABLE 1. Regression coefficients for the years 1960 and 1970. Poviat division

No.	Dependent variable	Regression coefficients original	Regression coefficients standard	Statistic t	Significance $xx = 0.01$	r	R^2 (in %)
1.	$y_{1(60)}$	$0.011\ x_3$	0.046	1.405		0.852^{xx}	72.6
		$0.126\ x_1$	0.064	1.608			
		$0.466\ x_{13}$	0.427	7.131	xx		
		$0.889\ x_{ad}$	0.734	12.633	xx		
2.	$y_{1(60)}$	$-0.019\ x_3$	-0.079	-1.508		0.673^{xx}	45.3
		$0.858\ x_1$	0.436	9.138	xx		
		$2.045\ x_{13}$	0.407	8.872	xx		
3.	$y_{2(60)}$	$-0.002\ x_3$	-0.017	-0.347		0.889^{xx}	79.0
		$0.180\ x_1$	0.195	4.698	xx		
		$0.145\ x_{13}$	0.061	1.269			
		$0.814\ x_{ad}$	0.726	26.663	xx		
4.	$y_{2(60)}$	$-0.017\ x_3$	-0.151	-2.988	xx	0.719^{xx}	51.7
		$0.619\ x_1$	0.671	16.148	xx		
		$0.591\ x_{13}$	0.250	5.161	xx		
5.	$y_{1(70)}$	$0.035\ x_3$	0.189	3.850	xx	0.787^{xx}	47.2
		$-0.171\ x_1$	-0.087	-0.335			
		$0.647\ x_{13}$	0.189	3.813	xx		
		$0.767\ x_{ad}$	0.622	17.040	xx		
6.	$y_{1(70)}$	0.067	0.364	7.141	xx	0.570^{xx}	32.5
		$-0.098\ x_1$	-0.050	-0.676			
		$1.377\ x_{13}$	0.399	8.151	xx		
7.	$y_{2(70)}$	$0.013\ x_3$	0.093	0.471		0.886^{xx}	78.5
		$0.116\ x_1$	0.076	1.782			
		$0.387\ x_{13}$	0.148	3.322	xx		
		$0.781\ x_{ad}$	0.686	24.622	xx		
8.	$y_{2(70)}$	$0.030\ x_3$	0.215	1.087		0.751^{xx}	56.4
		$0.427\ x_1$	0.273	6.559	xx		
		$0.142\ x_{13}$	0.437	18.219			

xx – significant at level $\alpha = 0.01$

r = correlation coefficient
R = determination coefficient

apart from the variable x_{ad}, the variable x_3 (agriculture) exerts a statistically significant influence (at the asumed level $\alpha = 0.05$) on the dependent variable. In the second model, the influence of the variable x_2 (industrialization) is somewhat bigger than that of the variable x_3.

As concerns the models estimated for improved roads ($y_{2(60)}$), in the first, apart from the variable x_{ad}, the greatest influence on the dependent variable is exerted by the variable x_2 (industrialization); the same holds true for the second model, the influence of all the variables being statistically significant (at $\alpha = 0.01$).

There remains a certain unexplained part of the regression. In order to find out what additional factors may influence the road infrastructure, maps of regression residuals were drawn. As the residuals were also expressed in standardized values, all the maps are comparable.

The interdependence between the density of improved roads and the features of socio-economic development of regions is bigger than the degree of interdependence between the density of surfaced roads and those features. A possible explanation is that in 1960 the density of improved roads was relatively small; at that time mainly inter-regional and some regional roads had improved surface. Most of the local roads at that time were surfaced roads. Hence, the strong correlation was found between x_3 (agriculture) and y_1 (surfaced roads) in the first equation (for $y_{1(60)}$). On the other hand, the uneven spread of improved roads corresponded to the uneven spread of industry as well as uneven urbanization.

As Table 1 shows, the relationships for 1970 are different. Determination coefficients in regression equations concerning surfaced roads (y_1) are lower than the corresponding coefficients for 1960. This should be attributed to the process of levelling the differentiation in the spread of surfaced roads in Poland, which was not accompanied by an equally strong levelling of the differentiation in the level of the country's socio-economic development.

As concerns the equation with four independent variables estimated for improved roads (y_2), the value of the determination coefficient is similar to that in the corresponding equation for 1960. In the equation with three variables for 1970, the determination coefficient is higher.

Hence, the conclusion can be drawn that the differentiation in the density of that quality category of roads increasingly corresponds to the differentiation of socio-economic development of areas.

The difference between multiple correlation coefficients computed for the two equations, i.e. for $y_{1(70)}$ and $y_{2(70)}$, is far bigger than between the corresponding 1960 equations.

As concerns the influence of each independent variable on the dependent variable, the influence of the variable x_3 (level of agriculture) is very clear. It is particularly remarkable in the case of improved roads (y_2). Similarly as in the analysis of the preceding period, in equations with four independent variables the predominant influence is exerted by the variable x_{ad} (mean road density in adjoning areas).

A similar analysis was carried out for 49 voivodships. Four time sections were investigated: 1960, 1965, 1970 and 1977, data for the years 1960, 1965, and 1970 being re-calculated to suit the new administrative division.

The list of independent variables was slightly changed, namely the variable x_2 was replaced by the variable $x_{2'}$ (people employed in industry and industrial crafts) as a measure of industrialization.

Like in the preceding case, regression analysis was carried out for two dependent variables: y_1 and y_2. The results obtained are presented in Table 2.

The level of explanation of the models is high, ranging from 53 to 86% for equations with four independent variables, and from 24 to 67% for equations with three independent variables. With the exception of 1960 models, the value of determination coefficients is higher when the density of improved roads is concerned. A number of conclusions may be drawn from an examination of the investigated relationships in individual time sections.

In equations with four independent variables estimated for 1960, the greatest influence on the dependent variable is exerted by the variable x_{ad} (mean road density in adjoining units). The influence of the other variables is negligible, partial regression coefficients being statistically insignificant on either of the adopted significance levels. The observed pattern of dependences is similar in both equations with three independent variables, the variable referring to industrialized level and population density being of the greatest importance.

In equations with four independent variables estimated for 1965, the strongest

TABLE 2. Regression coefficients for the years 1960, 1965, 1970, 1977. Voivodship division

No.	Dependent variable	Regression coefficients		Statistic t	Significance $xx = 0.01$	r	R^2 (in %)
		original	standard				
1	2	3	4	5	6	7	8
1.	$y_{1(60)}$	$-0.006\ x_3$	-0.059	0.410		0.896^{xx}	80.2
		$0.032\ x_8$	0.149	1.268			
		$0.704\ x_{13}$	0.151	1.374			
		$0.894\ x_{ad}$	0.711	10.378	xx		
2.	$y_{2(60)}$	$-0.004\ x_3$	0.089	0.620		0.876^{xx}	76.7
		$0.019\ x_8$	0.205	1.655			
		$0.058\ x_{13}$	0.029	0.238			
		$1.000\ x_{ad}$	0.748	10.294	xx		
3.	$y_{1(60)}$	$-0.058\ x_3$	-0.564	-3.961	xx	0.797^{xx}	63.5
		$0.174\ x_8$	0.814	6.895	xx		
		$1.807\ x_{13}$	0.387	3.529	xx		
4.	$y_{2(60)}$	$-0.029\ x_3$	-0.652	-4.493	xx	0.743^{xx}	55.2
		$0.081\ x_8$	0.876	7.057	xx		
		$0.578\ x_{13}$	0.286	2.375	xx		
5.	$y_{1(65)}$	$-0.015\ x_3$	0.178	1.243		0.847^{xx}	71.7
		$0.052\ x_8$	0.290	2.485	xx		
		$0.188\ x_{13}$	0.042	0.319			
		$0.883\ x_{ad}$	0.673	8.427	xx		
6.	$y_{2(65)}$	$0.004\ x_3$	0.082	0.574		0.866^{xx}	75.0
		$0.002\ x_8$	0.019	0.163			
		$0.099\ x_{13}$	0.038	0.295			
		$1.163\ x_{ad}$	0.830	6.980	xx		
7.	$y_{1(65)}$	$-0.045\ x_3$	0.137	3.729	xx	0.736^{xx}	54.2
		$0.167\ x_8$	0.462	7.980	xx		
		$0.907\ x_{13}$	0.462	8.000	xx		
8.	$y_{2(65)}$	$-0.025\ x_3$	0.514	3.588	xx	0.730^{xx}	53.3
		$0.092\ x_8$	0.889	7.512	xx		
		$0.616\ x_{13}$	0.239	1.839			
9.	$y_{1(70)}$	$-0.112\ x_3$	-0.156	-0.116		0.833^{xx}	69.4
		$-0.046\ x_8$	-0.206	-2.321	xx		
		$0.160\ x_{13}$	0.054	0.411			
		$0.916\ x_{ad}$	0.675	8.037	xx		
10.	$y_{2(70)}$	$0.008\ x_3$	0.092	0.960		0.927^{xx}	85.9
		$0.002\ x_8$	0.015	0.133			
		$0.488\ x_{13}$	0.217	2.042	xx		
		$0.987\ x_{ad}$	0.742	11.768	xx		
11.	$y_{1(70)}$	$-0.021\ x_3$	-0.273	-1.953		0.679^{xx}	46.1
		$0.130\ x_8$	0.751	6.561	xx		
		$0.482\ x_{13}$	0.164	1.239			
12.	$y_{2(70)}$	$-0.014\ x_3$	-0.238	-1.681		0.819^{xx}	67.1
		$0.084\ x_8$	0.634	5.611	xx		
		$1.058\ x_{13}$	0.471	4.429	xx		

1	2	3	4	5	6	7	8
13.	$y_{1(77)}$	0.025 x_3	0.311	4.134	xx	0.745^{xx}	55.5
		−0.014 x_8	−0.089	−0.647			
		0.760 x_{13}	0.237	2.644	xx		
		0.865 x_{ad}	0.604	6.623	xx		
14.	$y_{2(77)}$	0.023 x_3	0.337	2.550	xx	0.856^{xx}	73.3
		−0.004 x_8	−0.022	0.243			
		0.836 x_{13}	0.307	2.523	xx		
		0.867 x_{ad}	0.623	6.598	xx		
15.	$y_{1(77)}$	0.038 x_3	0.473	3.625	xx	0.486^{xx}	23.6
		−0.003 x_8	−0.019	−0.138			
		0.643 x_{13}	0.440	2.591	xx		
16.	$y_{2(77)}$	0.023 x_3	0.336	2.550	xx	0.643^{xx}	41.3
		0.025 x_8	0.192	1.524			
		1.048 x_{13}	0.385	2.912	xx		

influence on the dependent variable is exerted by the variable x_{ad}. Apart from x_{ad} in the first equation (for $y_{1(65)}$) one more variable is significant, namely x_2, and in the second, partial regression coefficients for the other variables are insignificant. Thus, the pattern of dependences is similar as in 1960, only the dependences are slightly weaker. Determination coefficients computed for surfaced roads and improved roads are similar. In the case of equations with three independent variables, the pattern of dependences is similar to the pattern detected in the preceding time period.

In all the equations estimated for 1970, the pattern of investigated interdependences and the significance of variables are similar to those found in the preceding two time sections. The correlation coefficient ($r = 0.967$) computed for the variable ($y_{2(70)}$) is remarkably high. Thus, the detected dependence is of an almost functional character (level of explanation of the model $R^2 = 86\%$).

The interdependences detected by means of regression analysis for 1977 have a similar pattern. In both equations with four independent variables, the greatest influence on the pattern of variation of the dependent variable is exerted by the variable x_{ad}. The variable x_3 comes second in importance. Besides, also the variable x_1 (population density) is significant in all statistical equations, whereas its influence in the models estimated for the preceding periods was insignificant.

Table 3 presents the standardized regression residuals for the equation $y_{2(77)}$ with three independent variables. The left column contains the voivodships in which theoretical values are bigger than actual ones, i.e. the network density is smaller than might be inferred from transportation needs. This column includes the voivodships with the biggest two urban and industrial agglomerations – Warsaw and Łódź. However, it must be borne in mind that the road network in areas adjoining the big agglomerations is already very dense and that these are mainly improved roads. Therefore, the network is mainly expanded by way of raising the traffic capacity of the existing roads, widening them or the construction of second lanes, for instance. This does not involve an increase in road density, but results in greater traffic capacity and improves traffic conditions. Besides, a large part of the traffic, especially passenger traffic (commutes to work and services) has been taken over by the railways, which compete, as it were, with motor transportation. This is the reason why the regression residuals are positive, i.e. the theoretical road density surpasses the actual one.

TABLE 3. Regression residuals by voivodships in 1977 for the dependent variable y_2 with 3 independent variables

Positive		Negative	
Warszawa	1.1	Bielsko-Biała	1.4
Biała Podlaska	0.2	Bydgoszcz	0.2
Białystok	2.5	Ciechanów	0.1
Chełm	0.9	Częstochowa	0.2
Elbląg	0.3	Jelenia Góra	1.4
Gdańsk	0.8	Kalisz	0.9
Gorzów	1.3	Konin	1.0
Katowice	0.1	Kraków	2.5
Kielce	0.2	Legnica	1.1
Koszalin	0.4	Leszno	0.8
Krosno	0.2	Lublin	0.0
Łomża	1.2	Nowy Sącz	0.0
Łódź	1.4	Opole	0.9
Olsztyn	0.7	Piotrków Tryb.	0.1
Ostrołęka	0.8	Płock	0.6
Piła	0.7	Radom	0.2
Poznań	0.5	Rzeszów	0.9
Przemyśl	0.9	Sieradz	0.4
Siedlce	0.9	Skierniewice	0.7
Słupsk	0.1	Tarnów	1.6
Suwałki	1.1	Toruń	0.4
Szczecin	1.6	Wałbrzych	0.8
Tarnobrzeg	0.5	Włocławek	1.6
Zamość	0.7	Wrocław	0.9
Zielona Góra	0.3		

Other voivodships with high positive values of standardized regresion residuals are the voivodships of Białystok, Łomża, Suwałki, Gorzów, and Szczecin. In the first three, the fact that improved road density is lower than theoretical results from a relative economic backwardness of the areas, which can be attributed to the above described historical conditions of the development of Poland's road network and the properties of natural environment (forests, waters). Besides, by far the greatest part of those voivodships 'socio-economic potential is concentrated in voivodship capitals, which does not necessitate an extension or modernization of the road network in the whole voivodship area.

When analysis regression coefficients computed for equations in the voivodship pattern, one will see that they decrease in time. This should be attributed to the levelling of disproportions in Poland's road density, which is not accompanied by an equally fast reduction of disproportions in the level of the economic development of voivodships.

The analysis conducted up till now does not investigate the temporal sequence of events, without which it is hardly possible to infer cause-and-effect relationships. The influence of socio-economic advancement of regions, i.e. new economic ventures, the increase of population, urbanization, and the level of agriculture, on the density of surfaced and improved roads is not immediate, the consequences are thus somewhat delayed. Therefore, additional studies providing for the effect of the time factor have been undertaken.

A linear lag regression model was employed for the purpose. The independent variables were the same as in the analysis of spatial relationships, i.e. population density (x_3), industrialization (x_1 – in the analysis referring to poviats, i.e. the value of the first main component, or x_1 – the number of people employed in industry and industrial crafts per 1000 inhabitants in the analysis referring to voivodships), and the average yield of four cereals as a measure of agricultural development (x_{13}). The model may be recorded as follows:

$$y_{it} = a + b_1 x_{3,t-d} + b_2 x_{1,t-d} + b_3 x_{13,t-d} + E \qquad i = 1.2$$

where: y_{it} – values of the dependent variable at time,
y_{t-d} – values of the dependent variable with time lag ($d = 5$ or 10 years).

The variables x_{t-d} are to explain the pattern of variation of the dependent variable at a later time; considered are two time intervals: 5 and 10 years. Such a recording of the model is based on the assumption that the level of socio-economic development of regions is the fundamental cause of further expansion and modernization of the road network. In other words, following an estimation of the unknown parameters, the equation would make possible to calculate theoretical road density if it was influenced exclusively by the independent variables considered in the given model (see Tinline 1970, Cliff and Ord 1971, McKinnon 1974, Leinbach 1974).

In the present study, lag regression analysis was carried out, similarly as in the preceeding chapter, for two sets of reference units. Bearing in mind the results obtained in the above mentioned studies, the author decided to include an additional independent variable in the equations, namely road density in the given spatial unit at a preceding period. In the literature on the subject, such a model is sometimes termed as autoregressive one. For each time section, two regression equations with three and four independent variables were estimated for surfaced roads and improved roads. The results of the analysis by poviats are presented in Table 4. The lag in this case was 10 years, i.e. the data on the level

TABLE 4. Lag regression analysis. Poviat division 1960 : 1970

No.	Variable	Regresion coefficients*		Statistic t	Significance $xx = 0.01$	r	R^2 (in %)
		original	standard				
1.	y_1	$0.098\ x_3$	0.447	9.172	xx	0.860^{xx}	73.9
		$-0.682\ x_1$	0.381	-7.541	xx		
		$0.743\ x_{13}$	0.162	3.503	xx		
		$0.680\ y_{1(60)}$	0.747	21.711	xx		
2.	y_2	$0.034\ x_3$	0.206	4.273	xx	0.875^{xx}	76.6
		$0.077\ x_1$	-0.057	-1.320			
		$0.963\ x_{13}$	0.278	6.422	xx		
		$0.927\ y_{2(60)}$	0.632	19.616	xx		
3.	y_1	$0.088\ x_3$	0.402	8.236	xx	0.673^{xx}	45.3
		$-0.088\ x_1$	-0.049	-0.973			
		$2.129\ x_{13}$	0.464	10.039	xx		
4.	y_2	$0.018\ x_3$	0.109	2.262		0.756^{xx}	57.1
		$0.494\ x_1$	0.365	8.472	xx		
		$1.512\ x_{13}$	0.437	10.084	xx		

of socio-economic development of areas referred to 1960, whereas the values of the dependent variable referred to 1970.

As can be seen in Table 4, determination coefficients indicate very strong dependences between the level of socio-economic development of areas in 1960 and road density in 1970. Depending on the number of independent variables included, the level of explanation of the formulated models ranges from 57 to 74%. Thus, all the estimated regression equations are statistically significant at least at the level $\alpha = 0.01$. Determination coefficients are higher in the case of regression equations estimated for improved roads (y_1 and y_2). This corroborates the results of the analysis of spatial interdependences for 1970, the differences being smaller.

In models with four independent variables, the most significant variable is this one which denotes road density in a preceding period, i.e. $y_{1(60)}$ or $y_{2(60)}$. Simple correlation coefficients between this variable and the dependent variable equal, respectively to:

$$r_{y_{1(60)}y_{1(70)}} = 0.792 \text{ and } r_{y_{2(60)}y_{2(70)}} = 0.821.$$

Thus, its influence on the level of explanation of regression models is crucial. Such high correlation coefficients indicate an uneven development of Poland's road network, especially the network of improved roads, in the years 1960–1970. Although, as stated above the decresing coefficients of variation indicate that the uneven spread of the road network is being levelled, the span between the extreme values of road density in poviats grew over that time. The disparity between poviats with the biggest and the smallest density of surfaced roads rose from 72 km/100 km^2 in 1960 to 80 km/100 km^2 in 1970. It rose even more in the case of improved roads, from 32 km/100 km^2 to 58 km/100 km^2, respectively. The length of roads continued to grow considerably in areas with big road density. This is particularly true of improved roads, and is corroborated by correlation coefficients.

As Table 4 shows, the influence of the other variables on the pattern of variation of the independent variable is different in individual regression equations. In the model which describes surfaced roads (y_1), all the variables are statistically significant, the variable x_1 (population density) being of the greatest significance, followed by x_2 (industrialization) and x_3 (agriculture). Thus, the pattern of dependences is similar as in the study of spatial relationships, only in the latter the variable describing industrialization level (x_2) was statistically insignificant.

An identical pattern of interdependences was obtained in both equations with three independent variables (y_1). The most significant variable was the one referring to the level of agriculture (x_3), followed by population density (x_1). Thus, the results of lag regression analysis corroborated the findings of the study of 1970 spatial relationships. Progress in agriculture was of the greatest importance for the development of surfaced roads. It should be noted that the model which provides for the time lag explains a larger part of variation of the dependent variable than the model which provides for spatial relationships only (45% and 32%, respectively).

In both regression equations estimated for improved roads (y_1 and y_2), the most significant variable (apart from the variable $y_{2(60)}$) is this one which describes the level of agriculture (x_3), followed by the level of industrialization (x_1). Thus, the results are identical as those obtained from regression analysis without the time lag. Besides, the value of determination coefficients is similar in both the analyses (with and without a lag).

Lag regression analysis was repeated for the voivodship division. As the findings proved to be similar or identical, they are not treated at length here.

Comparing the results obtained in both types of the models, one should note that similar levels of explanation were arrived at. Certain differences in the pattern of the investigated relationships between the reference units examined, slight as they were, resulted from the degree of data aggregation. Within one administrative division, the findings were virtually identical, both in lag regression analysis and in the analysis of spatial dependences. This observation is of practical importance, as it is often difficult to use data referring to different time sections due to a lack of appropriate statistical material.

Summing up the analysis, the following conclusions may be drawn:

– the strength of interdependences between the road infrastructure and the level of socio-economic development of areas is contingent on the quality of the examined road network. For all the multiple regression equations, higher determination coefficients were obtained in the case of improved roads than in the case of surfaced roads. Similar results were obtained for both levels of data aggregation (poviat division and voivodship division) as well as the analysis of spatial relationships and the analysis providing for a time lag;

– the structure of the investigated dependences changes in time. This is particularly clear when examining improved roads. In 1960 the variable describing the level of industrialization had the greatest influence, whereas in 1970 the variable which exerted the strongest influence described the level of agricultural development. In 1960 the density of improved roads grew mainly in areas of highly developed economy. Agricultural development, and the intensive modernization of agriculture in particular, necessitated an expansion and modernization of the existing local road network. The trend is clearly visible in equations formulated for 1970, in which the variable describing the level of agriculture exerts a predominant influence on the pattern of variation of the dependent variable. Also in regression equations valid for 1977, the most significant variable was the one referring to the level of agriculture.

The development of Poland's road network, both in space and in time, was found to be highly inert. This is evidenced by the results of regression analysis which included a variable describing mean road density in units adjoining the unit in question in the case of spatial relationships, and a variable describing the density of the given quality road network at a time preceding the investigated time in the case of models with a lag. In each of the equations which included these variables, their influence on the pattern of variation of the dependent variable proved to be predominant. The other independent variables describing the level of socio-economic development of areas only slightly contributed to raising the level of explanation of the models. Thus, the findings indicate a further uneven development of Poland's road network, especially the network of improved roads. This holds to be true especially for improved roads, which have expanded in the most economically active areas of the country, i.e. in the eastern regions, the central part of the country, and northwards to the Bay of Gdańsk.

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NATIONAL SYSTEM OF FREIGHT CONNECTIONS

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In geographical studies the mass of elements located physically in space is usually defined via magnitudes of: population, production, employment, capital, etc., i.e. of all those indicators in a given time unit which reflect the inertia and stability of objects considered. However, not only time and space, but also motion is a fundamental form of existence of the matter. Features of motion are defined by characteristics of objects causing it, and since the matter appears on various, qualitatively differing structural levels, one can speak of a hierarchy of motion forms.

The above statement is the starting point for empirical studies of the country-wide system of freight transportation connections. Analysis of this system makes possible to look at the settlement system construction not necessarily from the viewpoint of settlement centers having certain mass, but from the viewpoint of material motion caused by existence and growth of these centers within the geographical space.

Hence, according to the concept of Domański (1976), it was assumed that the contemporary settlement system is undergoing definite transformations, whose terminal state consists in structural changes, from a hierarchical, although irregular, setting, to a system in which integration of urban centers on national level and more-than-proportional growth of medium and bigger towns occur. If in the studies merely the economic aspect of this system is taken into account one can ask: on which stage of such trasformations Polish settlement system presently is, and what is the basis of its structure: big cities, regional centers or one dominating center. In the literature devoted to theoretical aspects of this question the significance of integration of big cities in the development of country's settlement system is emphasized (see Dziewoński 1973, p. 95).

The approach presented here suggests the necessity of invoking the force field theory in the analysis, assuming that freight relations depend upon the masses of the settlement centers and upon their distances. In other words, any flow between entities I_i and I_j can be interpreted as a function of economic potential of these entities and their distance:

$$R(I_i - I_j) = F\{G_{I_i}, G_{I_j}, D_{I_i - I_j}\}$$

where: R is the commodity flow, G: economic features, D: distance, F: functional transformation.

Gravitational model as developed by Ikle (see Chojnicki 1966, p. 61), corrected with the linear regression model was the basis for empirical studies. Model parameters obtained from the two regression equations constituted certain ideal reference point, and were compared with actual or aggregated data.

This approach makes two kinds of spatial configurations appear, as resulting from freight relations conditioned by masses and functions performed by individual centers within the national economic structure, these two kinds of configurations being: mobile and stable. In the first case actual flow magnitudes should be higher than those obtained from the model, while in the second case – the lower.

However, freight relations expressed in terms of shipment volume magnitudes might be determined by peripheral location of natural resources of Poland. If so, then application of regression models in the analysis of the intercenter relations does not guarantee the statistical significance of results. It is therefore more adequate to use monetary measures, in spite of the limited possibilities of transforming freight volumes into monetary measures.

The work reported here used available statistical material[1] concerning all freight connections in Poland, according to 100 aggregate spatial units. More precisely, the following data sets were used:

a. The set of spatial units grouped into two subsequent series:

– corresponding to areas of 10 biggest Polish cities of populations above 200 thousand inhabitants[2],

– corresponding to other spatial units represented by the main city within their territories.

It was assumed that one of the basic criteria of determining the 'representative' town of a territory is whether it is the center of a given agglomeration or whether it performs dominant functions with regard to sorrounding areas (see Morawski et al. 1974).

b. The set of features characterizing the mass of individual units, i.e. total population, employment in state and cooperative sectors, employment in material production, capital investment, global and net assets.

c. The set of physical distances among spatial units given as a symmetric matrix of $D_{l_i - l_j} - D_{l_j - l_i}$. This matrix was put together for a set of towns representing individual spatial units, with calculated distances expressed in kilometers.

d. The set of freight volumes for train and road transportation according to monetary values contained in a 100×100 matrix.

When constructing mathematical models of the shipment volume relations, two types of functions were used to approximate the data available:

1. Gravitational model: $f_1 = A_1 \cdot X_{1i} \cdot X_{2i}^{A_2}$, having theoretical foundation, was assumed to be the basic one in the study reported here.

2. Linear model: $f_2 = A_1 X_{1i} + A_2 X_{2i} + A_3$, to be used for comparative purposes with regard to the gravitational model. The linear relation assumed in this model is rarely encountered in the reality observed; as an approximation, however, it is a useful tool for verification of precision of the basic, gravitational model.

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[1] These are:

– flows of commodities transported with railways for 1970 according to 103 transportational spatial units; after aggregation of the three units constituting the Katowice agglomeration and of two units constituting the Gdańsk agglomeration (Gdańsk and Sopot, Gdynia – Three-cities) the number decreased to 100 (after Morawski et al., 1974),

– data on road freight volumes collected by the Road Transportation Institute in Warsaw for 1970 and presented in the 100×100 matrix.

The above flow magnitudes expressed in tons were summed up and then converted into monetary terms according to the volume value index for individual commodity group, as developed by Morawski (1967).

[2] Following areas were considered, according to their main metropolitan centers: Katowice (13 cities' area), Warsaw, Łódź, Gdańsk (3 cities), Cracow, Wroclaw, Poznań, Szczecin, Bydgoszcz and Lublin.

For functions f_1 and f_2 the normal distributions were assumed in the analysis in order to get the results of comparison of the two models as well as explanation of the greatest total variance assessing dispersion of the distribution. Ratio of this variance to the non-explained one was estimated via the F-Snedecor's test of the form $F_{(n_1,n_2)} = \frac{S_1}{S_2}$, where S_1, S_2 are respectively variances of n_1, n_2 degrees of freedom, and values of the F statistics are presented through the coefficient of adequacy (as introduced by the author):

$$\alpha = \frac{S(Y)}{S(Y-\dot{Y})},$$

where Y: true values, and $\dot{Y}$: model values.

Subsequently, relation of the coefficient of adequacy to the percentage p of explanation of the total variance was determined:

$$p = \left(1 - \frac{1}{\alpha^2}\right) 100\%$$

and critical values of α and p were established, so that below these values the results would be treated as statistically insignificant.

The study started with aggregation of socio-economic characteristics of the 100 economic units considered, done with the simple orthogonal regression algorithm, according to the formula

$$\min_{p,k} G = \sum_{i=1}^{q} d_i^2,$$

where $\bar{p}$, $\bar{k}$ are vectors and d_i – distances, G – constans.

Orthogonalization was performed in order to be able to generalize over the numerical data available through determination of an aggregate feature T_i. Because the analysis of connections was a two-stage one (before and after the data reduction) the primary characteristic used was the one having the highest correlation (0.975) with the aggregate feature T_i, this characteristic being the number of employed in state and cooperative sectors.

CONNECTION ANALYSIS BEFORE DATA REDUCTION

In the first stage of the analysis all freight connections in Poland were considered, national imports and exports, i.e. external flows, omitted. Fundamental question was the determination of parameters of the regression models for:

– the whole commodity transportation system of the country, represented through the matrix $M_{100\times100}$,

– connections among the biggest ten cities, being centers of spatial units, according to the matrix $M_{10\times10}$,

– active flows (exports) from the biggest cities to other spatial units, according to the matrix $M_{10\times90}$,

– passive connections, i.e. imports of big cities from other units, according to $M_{90\times10}$,

– other connections among spatial units, according to $M_{90\times90}$.

As indicated by Table 1, for the whole of the connection system ($M_{100\times100}$) the gravitation model performs quite well, and the values of coefficients α and p thereby obtained, although low, are statistically significant. Low values were

TABLE 1. Results of the analysis of freight flows according to the $M_{100\times100}$ matrix (gravitation model)

		Big cities	Other spatial units
		1, 2, ..., 10	11, 12, ..., 100
Big cities	1, 2, . . . 10	$\alpha =$ 1.204; $\alpha^{crit.} =$ 1.19 $p =$ 32%; $p^{crit.} =$ 28% $r =$ 0.705 $B_1 =$ 9.141 $B_2 =$ −0.221 $M_{10\times10}$	$\alpha =$ 1.223; $\alpha^{crit.} =$ 1.11 $p =$ 34%; $p^{crit.} =$ 17% $r =$ 0.614 $B_1 =$ 4.404 $B_2 =$ −0.811 $M_{10\times90}$
Other spatial units	11, 12, . . . 100	$\alpha =$ 1.374; $\alpha^{crit.} =$ 1.11 $p =$ 45%; $p^{crit.} =$ 17% $r =$ 0.709 $B_1 =$ 2.162 $B_2 =$ −0.659 $M_{90\times10}$	$\alpha =$ 1.134; $\alpha^{crit.} =$ 1.11 $p =$ 19%; $p^{crit.} =$ 17% $r =$ 0.506 $B_1 =$ 1.947 $B_2 =$ −0.553 $M_{90\times90}$
Total	1, 2, . . . 100	$M_{100\times100}$ $\alpha =$ 1.218; $\alpha^{crit.} =$ 1.04 $p =$ 33%; $p^{crit.} =$ 8% $r =$ 0.701 $B_1 =$ 0.210 $B_2 =$ −0.586	

obtained for distance coefficient B_2, appearing in the transformed gravitation model:

$$f_1 = A_1 X_{1i} X_{2i}^{A_2} = B_1 (G_i + B_3) D_i^{B_2} + B_4,$$

and B_2 equalled −0.5 to −0.7, which is an evidence of a relatively deep irrelevance of distances for freight connection functions. For the matrix $M_{10\cdot10}$ the values of α and p are also quite low. Out of all the partial matrices this one yields the highest economy coefficient B_1, and the lowest distance coefficient B_2. For such big cities as Katowice, Cracow, Wroclaw and Łódź the gravitational model is inadequate, as compared with reality: actual connection values for these towns exceed by far the model-based values.

The matrix $M_{10\times90}$ of active links of big cities with the country's hinterland, yields higher values of α and p than those obtained for the previous cases, and the distance coefficient obtained is the highest as well. Analysis of extremal values of regression sums of errors indicates regional structures appearing here. Examples are: westwards of Katowice, to the south of Poznań, around Gdańsk, etc.

The matrix $M_{90\times10}$ concerning passive links of big cities with the hinterland, yields the highest – out of the four partial matrices analyzed – values of coefficients α and p, which points out a good fit of the model to reality. As compared to the active connectivity structure this one shows, through magnitudes of B_1 and B_2, a weaker influence of hinterland on big cities than the other way round.

Consideration of regression rest sums leads also to conclussion, that the highest divergence from the model based profile occurs for southern region, with Katowice as its center.

The last of the matrices analyzed, $M_{90\times90}$, yields the lowest values of coefficients α and p. This matrix, representing the marginal connections, located outside the main stream of freight transportation structure span over the country, yields as well quite low distance coefficients, approx. -0.55.

This first stage of analysis does not exhaust the entire problem. Its results simply indicate the fact that the spatial-economic integration process is most distanctly pronounced in the southern part of Poland.

Closer explanation of this fact requires an application of data reduction to the statistical material analysed, so that connections having low shipment volume values would get eliminated from further considerations. This is so, because dispersion of connection values has negative influence on the results obtained with the gravitation model, and simultaneously it makes impossible application of the corrective linear regression model, which for this reason has given statistically insignificant results in the first stage of analysis.

CONNECTION ANALYSIS AFTER DATA REDUCTION

As the dispersed, low volume flows get eliminated from considerations, a reduced graph of actual connections and a matrix of flows, corresponding to it, is obtained. This reduction was performed with a simple algorithm implemented on the Polish computer Odra 1204. Paris of units were ordered according to the appropriate flow volumes and this portion of so created sequence was taken which accounted for 33% of total flow volume. This way only over 100 pairs were identified for the total of 5 000 pairs and the flow volumes beyond that number got essentially lower. Such result indicates strong concentration of flows over a limited number of transportation routes.

Once data reduction was performed, both regression models were called in again. This time both models gave statistically significant results. When comparing these results (see Table 2) one can assess relatively well the advantages of the gravitation model in representing the reality. There are some coefficients of the gravitation model, though, which are lower than for the linear one, notwithstanding the fact of statistical significance.

Hence, spatial relations occurring in a multilayer reality cannot be simply represented by a one, unique model corresponding to actual data, thereby expressing a law on certain spatial relations. That is why in further conduct of the regression study of country-wide system of commodity transportation relations the regression residuals were analysed.

TABLE 2. Results of the analysis of freight transportation connections according to the $M_{100\times100}$ matrix reduced down to M_{-}

Models	Coefficients		
Gravitation	$\alpha = 1.227$ $p = 34\%$ $r = 0.704$	$\alpha^{crit.} = 1.19$	$B_1 = 2.124$ $B_2 = -0.485$
Linear	$\alpha = 1.281$ $p = 39\%$ $r = 0.625$	$p^{crit.} = 28\%$	$b_1 = 1.404$ $b_2 = -4.729$

Four basic forms of residuals and their functions are distinguished in statistics, i.e. $V_1 = \dot{Y} - Y$, $V_2 = \dot{Y} - Y/Y$, $V_3 = Y/Y$, $V_4 = (\dot{Y} - Y)S_v$, where Y are observed values, Y are model-based values, S_v – standard error of estimation.

In the considered case it was the most appropriate to apply the residue function V_4, relating its values to model's accuracy and accounting for estimation of its error.

Results obtained from both regression models after the data reduction stage indicate the utility of analysing the standardized residue values, presented graphically against the four basic transportation flow classes. In the linear model the big actual flow magnitudes coincide with high residue values. This makes the Katowice agglomeration come to the forefront because of its actual strong, higher than the model-based, connections with the closest 'representative' cities, such as Cracow, Opole, Częstochowa, Nysa, Koźle (an inland harbour), and with the relatively distant Poznań. Generally speaking, linear regression is primarily related to the absolute power of existing connections (Figure 1).

The gravitation model reacts otherwise, reflecting subtle differences between the

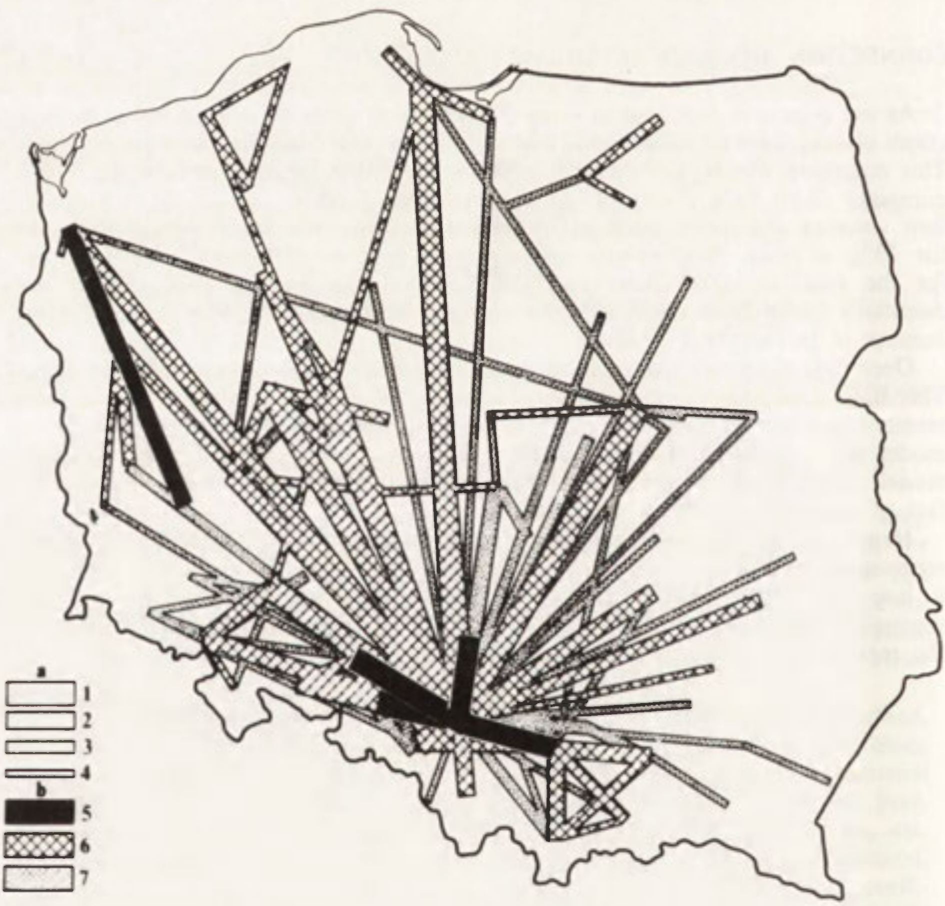

Fig. 1. Linear regression model: maximum values of freight connections and standardized residual values

a – two-way commodity links in monetary units, *zlotys*, after reduction of the 1–4 value classes of links, r – standardized residuals: 5 – exceeding the norm (> 11), 6 – within the limits of the norm (0 to + 10), 7 – within the limits of the norm (– 10 to 0)

Fig. 2. Gravitation model: maximum values of freight connections and standardized residual values. For explanation see Fig. 1

real and theoretical flows, mainly over these lines where the volumes of transported commodities constitute a low share in relation to country's total, Difference of results between the gravitational and linear models does not involve higher values of coefficients α and p in the gravitational model. This was caused by a gap between the theoretical (homogeneity) assumption and the economic reality determined by natural and economic factors. Having widened the study with the residue analysis the precision of the gravitational model, mentioned before, was deployed through the ability of accounting for these phenomena, which were beyond the grasp of the linear model.

The highest values of standardized residuals for the gravitational approach concerned not the main connections in the country. but rather the regional flows among the medium size cities located in the northern, north-western and western parts of Poland, as well as around the Upper Silesia (Figure 2).

Thus, obtained picture of freight relations existing in the country allows to draw the following general statements:

– positive extremal residue values indicating important deviation from the reference hypeplane given by the model based values are not encountered for the big cities

— the main set of these values, appearing along with maximum real flows, encompassing the southern part of Poland with Katowice, Cracow and Opole as the center, is an exception to the above rule; it could therefore be called the *southern subsystem*;

— both models, linear and gravitational, corroborate the existence of this subsystem: the first of them gives a spatial picture of a less diversified, but more compact, area of the real values higher than the theoretical ones; in other words — higher values of coefficients α and p for the linear regression are reflected in a less contrasted image of the standard residues;

— gravitational model, as opposed to the linear one, gives the more spatially diversified residual values, which makes possible to draw farther reaching conclusions;

— the results obtained indicate that there exist certain — stronger than theoretical — regional configurations within the country, related to such regional centers as: Poznań, Wroclaw, Gdańsk, Szczecin, Koszalin, Olsztyn, and Zielona Góra;

— all the big cities are connected directly with Katowice through flows consistent with the model-determined values;

— in the case of connections having higher magnitudes than those resulting from the model, occurring between the Katowice agglomeration and Wroclaw, Poznań, Gdańsk and Cracow, they have an indirect character, so that these connections do not concern the centers themselves, but their respective regions;

— the analysis does not reveal the industrial axis of upper and lower Vistula (towns of Puławy, Płock, Włocławek); this is caused by the strong foreign export-import links of these centers, these links being by virtue of principle omitted in the study presented here;

— among the other agglomerations not mentioned yet, Warsaw constitutes a regional connections subsystem according to model determined values, while Łódź and Lublin, on this level of generalization, do not develop significantly distinct regional settings; again this is a result of the foreign trade connections of these centres, omitted in the reported analysis;

— direct flows between Katowice and Warsaw, Wrocław, Poznań, Gdańsk although ones of the greatest in Poland in terms of their magnitudes, are, approximately, conform with the values determined with the models, hence they cannot be considered as integrating connections.

The structure of the analysed freight connections system can be represented by a hierarchical graph, which shows superiority or subordination of individual 'representative' towns, treated as basic elements of the transportation system of the country. This graph contains as many subgraphs as there are towns having their own trees of connections, operationally classified into classes I, II..., VII according to magnitudes of their actual flows. This graph can be referred to as marked graph, since in its pictoral presentation the arcs reflecting connections having higher than theoretical, model-determined magnitudes are shown in a different manner, i.e. with a heavier line (Fig. 3). Since in the national system of commodity connections the Katowice agglomeration is the *superior node*, then in the framework of the whole system three categories of relations can be distinguished, according to connections between the superior node and the other nodes. These categories are:

— direct connections between Katowice and individual 'representative' towns,

— indirect connections, realised through certain intermediate, 'contacting' points-centres being themselves nodes of higher order in the hierarchy of connections; in most cases these nodes are other bigger towns;

— connections independent from the Katowice superior node; these connections, around their centers create certain subgraphs of regional commodity links isolated within the whole system; this 'independence', however, results perhaps mainly from

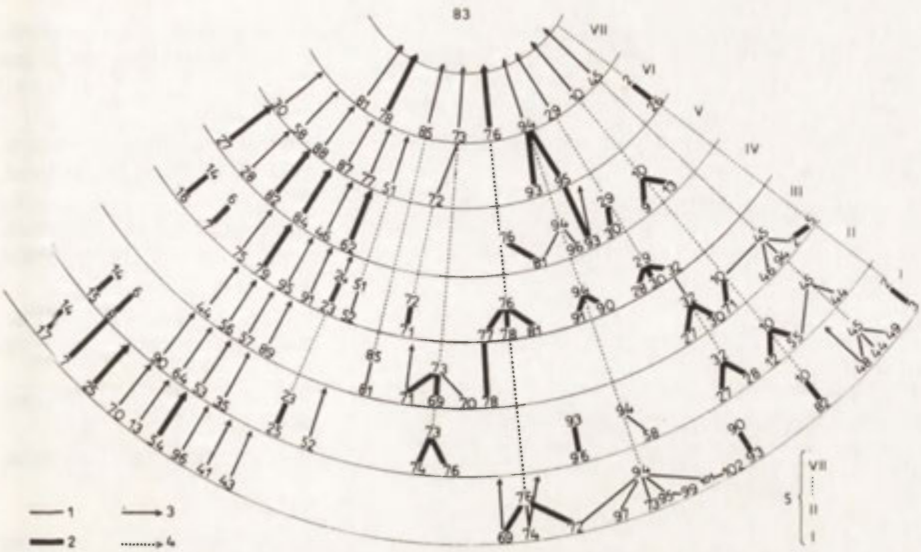

Fig. 3. Hierarchical graph of reduced flows according to matrix $M_{2:2}$

1 – arc of values equal to norm, 2 – arcs of values exceeding the norm (by standardized residuals); links with Katowice: 3 – direct, 4 – indirect, 5 – hierarchical levels (numbers according to towns given in the Appendix)

the reduction of the matrix $M_{100\times100}$ down to $M_{2:2}$ and it is possible that with lesser reduction it would not occur.

The commented graph contains, in its pictoral presentation, from left to right, the following entities (Fig. 3): simple subsystems isolated – or independent, then the complex system of direct links with the Katowice node, and finally the highly complex subsystem of indirect connections. The latter appears in the form of a number of trees, whose 'crowns' occupy the lower and middle levels of the flow hierarchy, while their roots belong to the highest, VII-th level of this hierarchy.

Connections among the particular trees, i.e. quasihorizontal integrating links are relatively rare, and therefore integration in the big cities class is weak, since these connections appear primarily on the lower hierarchical levels (III, II, I). An exception is provided by the Cracow and Opole regional subsystems, linked through a connecting point of level V.

This is sufficient to conclude that horizontal integration, i.e. without the intermediary of the Katowice agglomeration, is feeble, both in terms of the commodity flow intensities and in terms of the number of arcs. Simultaneously, the marked arcs representing actual flow volumes higher than the theoretical ones indicate that the mobile subsystems occur in the southern and western Poland, while heavy, 'immobile' subsystems with flow magnitudes lower than predicted by the model, dominate in the eastern part of the country.

CONCLUSSIONS AND POSTULATES

The results of the analysis reported here may now constitute a basis for forwarding a set of more concrete statements:

1. Katowice agglomeration plays a dominating role in the system of freight relations of Poland.

2. Other big cities do not form, as yet, an integrated settlement set or subset, which, however, does not rule out existence of certain integrating processes within the country.

3. Two such processes can be distinguished:

– one, having strong flow intensity, occurring between the big cities of western and southern Poland and the Katowice agglomeration, with connections realized indirectly through respective regional subsystems,

– second, with weak commodity flow intensities, constituting an incipience of a future subsystem of big cities, is being formed independently of the influence of Katowice agglomeration.

4. Economic links existing in Poland create various forms of subsystems having, respectively, highly complex, complex and simple character. They are, according to this classification of complexity:

– Katowice (i.e. southern) regional subsystem and all the regional subsystems as subordinated to the Katowice center,

– the Katowice supraregional subsystem and individual regional subsystem separately treated,

– local subsystems around isolated centers.

5. Within the whole of the national settlement system the individual subsystems play the equivalence or subordination roles:

– equivalence roles result from the contributions of individual subsystems into the compactness of the global systemic structure; it is the cooperation of the individual centers of subsystems on various hierarchical levels that makes the overall complexity increase as the integration proceeds;

– subordination roles result from relations of individual subsystems and their centers to units and systems of higher level.

6. The study has shown that subordination relations dominate over the country, and their reflections are complex and highly complex subsystems with low degree of mutual integration. They appear in the form of graph as well developed trees of regional connections, subordinated to the Katowice center.

7. 'Input' and 'output' (seaport) centers of the settlement system do not manifest, in spite of their productive specifics, any distinct difference of their connection structure, and they form definite regional subsystems.

On the basis of these specific statements the following general conclusions can be drawn. The main driving force of the increase in freight connections intensity, and thereby indirectly of the national settlement system development, is the so-called southern subsystem (Katowice, Cracow, Opole). Regional Wroclaw subsystem also gravitates in this direction. On the national level this southern subsystem has the strongest links with the middle-western and south-western parts of Poland, mainly with the medium-sized cities of dominating industrial functions. City agglomerations, besides those mentioned, have, in spite of their important mass, weaker connections than those predicted. This concerns, first of all, their 'internal' connections within their class, which is perhaps the result of the inadequate development of production specialization of these towns, and of the inappropriate work distribution over the country. On the other hand, great agglomerations have strong regional connections, since they constitute bases for the industrial production development on the economically subject areas. These connections do not form, however, independent constructs, for they are subordinated to influences of the southern subsystem.

Hence, in view of this evidence, the concept of the system of great cities, although substantially interesting, is not corroborated. It may be considered as a certain terminal state, reflecting the final stage of formation of the settlement system in Poland. The present spatial-economic structure of the country, consolidated with the recent capital investment decisions, makes it necessary, however, to modify somehow this image. Thus, considering solely the material production side of the system, it may be deduced that the actual terminal state of spatial-economic transformations may have the following form:

1. The integrated system of big cities shall be composed of two subsystems:
   - the one subordinated to the southern macro-node, and
   - the subsystem of other big cities, connected among themselves in certain sectors of economy, independent of the Katowice node.
2. The system of regional medium size centers shall be decomposed into the following subsystems with decreasing force of connections:
   - centers directly subordinated to the southern macro-node,
   - centers related to individual great agglomerations,
   - centers integrated 'internally' within their respective classes.
3. The system of other settlement centers shall be directly connected with:
   - the southern subsystem,
   - individual big cities,
   - regional centers of medium size,
   - within their classes, forming the nuclei of the future local integrated subsystems.

The above concept assumes that until the end of this century the integrating processes going on in the settlement system of Poland will continue with preservation of the existing hierarchy of towns. Integration within the individual classes shall have gradual character, starting with the biggest centers towards the smaller ones, the connections with the southern subsystem being always predominant.

APPENDIX

Numbers and names of towns representing individual transportational spatial units:
(1) Świnoujście, (2) Szczecin, (3) Gryfino, (4) Nowogard, (5) Stargard Szczeciński, (6) Koszalin, (7) Szczecinek, (8) Słupsk, (9) Wejherowo, (10) Gdynia, (11) Gdańsk, (12) Starogard Gdański, (13) Elbląg, (14) Olsztyn, (15) Iława, (16) Kętrzyn, (17) Szczytno, (18) Ełk, (19) Łomża, (20) Suwałki, (21) Białystok, (22) Bielsk Podlaski, (23) Gorzów Wlkp., (24) Zielona Góra, (25) Żary, (26) Głogów, (27) Piła, (28) Leszno, (29) Poznań, (30) Konin, (31) Krotoszyn, (32) Kalisz, (33) Chojnice, (34) Wyrzysk, (35) Bydgoszcz, (36) Świecie, (37) Toruń, (38) Inowrocław, (39) Lipno, (40) Włocławek, (41) Płock, (43) Ostrołęka, (44) Otwock, (45) Warszawa, (46) Żyrardów, (47) Garwolin, (48) Siedlce, (49) Kutno, (50) Sieradz, (51) Łódź, (52) Piotrków Trybunalski, (53) Skierniewice, (54) Końskie, (55) Jędrzejów, (56) Kielce, (57) Radom, (58) Ostrowiec Świętokrzyski, (59) Busko Zdrój, (60) Biała Podlaska, (61) Puławy, (62) Kraśnik, (63) Lubartów, (64) Lublin, (65) Zamość, (66) Chełm, (67) Zgorzelec, (68) Bolesławiec, (69) Jelenia Góra, (70) Legnica, (71) Oleśnica, (72) Wałbrzych, (73) Wrocław, (74) Kłodzko, (75) Kluczbork, (76) Opole, (77) Nysa, (78) Koźle, (79) Lubliniec, (80) Gliwice, (81) Rybnik, (82) Tarnowskie Góry, (83) Katowice, (84) Zawiercie, (85) Częstochowa, (86) Będzin, (87) Tychy, (88) Bielsko Biała, (89) Cieszyn, (90) Olkusz, (91) Chrzanów, (92) Oświęcim, (93) Nowy Targ, (94) Kraków, (95) Tarnów, (96) Nowy Sącz, (97) Tarnobrzeg, (98) Mielec, (99) Krosno, (100) Kolbuszowa, (101) Rzeszów, (102) Przemyśl, (103) Sanok.
Numbers 104–107 reflect the foreign trade and transit connections, not accounted for here (after Morawski et al., 1974, pp. 353–369).

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AN ATTEMPT AT A FUNCTIONAL CLASSIFICATION OF RURAL AREAS IN POLAND. A METHODOLOGICAL APPROACH

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The study is based on research into the spatial organization of rural areas, carried out in the Institute of Geography and Spatial Organization at the Polish Academy of Sciences.

It was undertaken in other to identify the principal characteristics of the spatial structure of rural areas, approached as multifunctional space, and to establish the principles of their classification made according to their main functions.

The main aim of the study is to establish the proper methodology. In the same way as in every classification or typology, the first task is to select proper diagnostic characteristics and their measures, theoretically correct and applicable in a cognitive procedure. The next task is to carry out in a proper way the normalization of the variables, expressing these characteristics, and finally to apply a proved method for grouping multifeatured units. The methods adopted should make it possible to utilize available statistical material and compare the results in time and space.

The cognitive aims are a scientific identification of the spatial structure of Poland's rural territories as regards their leading functions and an attempt at their classification. Such an identification may also be utilized in practical work for the purposes of integrated spatial planning of rural areas (J. Kostrowicki 1976)

To realize those aims it was necessary to solve a number of methodological problems. From the very beginning, from the very attempt to formulate the objective, subject and scope of research, the author had to face many methodological difficulties. These were partly discussed on the 1st Polish-Yugoslav Geographical Seminar (Stola 1978a) and in some studies concerned with methodological premises of research into the spatial organization of rural areas on the basis of Anglo-Saxon (Dietl 1979) and French literature (Stola 1976). The methodological concept of multifunctionality of rural areas, and also of their research and planning problems, were formulated in 1976 (J. Kostrowicki).

The indentification and delimitation of rural areas as such, both in the conceptual as well as spatial sense are rather difficult. Though definitions of rural areas from the point of view of population density, intensity of land use, or the origin of rural functions and character of their concentration, relationships between the pace of work and that of residence, etc. are very numerous, every one of them is only partially true (J. Kostrowicki 1976; A. S. Kostrowicki 1978; Stola 1978b). Therefore, a certain convention must be adopted which will stipulate what in specific research should be understood by a rural area. In the present study rural areas are territories situated between incorporated settlements, this is,

TABLE 1. Measures used in the study of the functional classification of rural areas

	Voivodships					Classes				
Poland	Warsaw	Kielce	Suwalki	Leszno, Walbrzych, Wroclaw	Characteristics	very low	low	medium	high	very high
1*					Density of population (capita/squ. km)	0–30	30–50	50–70	70–100	>100
2	1				Percentage proportion of agricultural land in total area	0–50	50–60	60–70	70–75	75–100
		1	1			0–40	40–60	60–70	70–80	80–100
				1		0–20	20–40	40–60	60–80	80–100
				2	Percentage proportion of socialized agricultural land in total agricultural land	0–20	20–40	40–60	60–80	80–100
3	2	2			Number of employed per 100 ha of agricultural land	0–25	25–30	30–40	40–60	>60
			2		Number of employed mainly in agriculture per ha of agricultural land	0–10	10–20	20–30	30–50	> 50
				3	Percentage proportion of commercial production in agricultural gross production	0–40	40–50	50–60	60–70	70–100
	3				Percentage proportion of forests in total area	0–10	10–20	20–30	30–50	50–100
		3	3			0–10	10–20	20–40	40–60	60–100
4	4	4	4		Number of beds in tourist and recreation objects	0–1	1–2	2–6	6–10	> 10
				4	per sq. km	0–2	2–4	4–6	6–10	> 10
	5				Number of people utilizing beds in tourist and recreation objects per 1000 inhabitants	0–100	100–400	400–800	800–1600	> 1600
					Percentage proportion of non-agricultural population	0–30	30–40	40–50	50–60	60–100
5	6				in total population	0–20	20–40	40–60	60–80	80–100
		5		5						
			5		Percentage proportion of people employed outside agriculture in the total number of employed	0–10	10–30	30–50	50–70	70–100

	7			6	Percentage proportion of people employed in industry and building in the total number of professionally	0 – 10	10 – 20	20 – 40	40 – 60	60 – 100
			6		active people	0 – 5	5 – 10	10 – 20	20 – 40	40 – 100
		6			Percentage proportion of people employed in industry and building in the total number of people employed outside agriculture	0 – 20	20 – 40	40 – 60	60 – 80	80 – 100
					Percentage proportion of people employed in welfare	0 – 4	4 – 8	8 – 12	12 – 20	> 20
	8		7	7	services per 1000 inhabitants	0 – 5	5 – 10	10 – 15	15 – 20	⩾ 20
6					Number of commuters to work in socialized economy per 1000 persons in productive age	0 – 200	200 – 300	300 – 400	400 – 800	800 – 1000
	9				Number of commuters to work per 1000 persons in	0 – 200	200 – 300	300 – 400	400 – 600	600 – 1000
		7	8		productive age	0 – 100	100 – 200	200 – 300	300 – 500	500 – 1000

* No. of the variables

however, an arbitrary decision which means in practice that the basic units in detailed research in Poland are rural and urban-rural communes; as regards the latter urban and rural areas are investigated separately. In macro-scale research the rural areas of the voivodships are the basic units.

A very important aspect in any classificational or typological procedure is the selection of such characteristics and their measures which have a marked influence on cognitive findings. This is particularly true of the study of rural areas, which since they are a multidimensional complex, object (system), can be classified either from a certain single aspect, like the density of population, size-structure of agricultural holdings, or in a more synthetic way, e.g. from the point of view of a selected function developing on these areas, like agriculture, recreation, etc., or finally from the point of view of many functions, i.e. treating rural areas as multifunctional space. Each method requires its own set of characteristics and their measures, since in every case one deals with a different material system, consisting of various elements interconnected by a chain of various cause-and-effect interrelations (Kolipiński 1980). Every time the set of characteristics should be thus established as to make the investigated object be represented in the possibly most objective way. Therefore, characteristics should be quantitative (Planck 1975), universal, if possible synthetic, representative, relatively few and their value should not change considerably from year to year. It is desirable that their measures could be worked out on the basis of available statistical data, and this dictates chiefly what measures should be used in a specific study. The selection of an optimal set of diagnostic characteristics must therefore be preceded by the investigation of various measures, representing a greater number of characteristics.

The first investigation was carried out on the macro-scale for Poland as a whole, that is for rural areas of the 49 voivodships. The spatial structure of the following three groups of functions was analysed: a) internal, of the biogenetic character (A. S. Kostrowicki 1978), or in other words superficially distributed like agriculture and forestry as well as recreation and tourism; b) external, of the technogenetic character, i.e. with a tendency to be distributed punctually, like industry with mining and building; c) services including proper services (trade, health service, etc.) and transport.

To make it possible to select diagnostic characteristics that would represent them some, 25 measures were investigated; these measures characterized the professional structure and employment of rural population, the structure of the main forms of land use, settlement, recreation, certain infrastructural facilities, and services (Stola 1978a). Since it has been assumed that the number of characteristics should be small and that the proportions between the numbers of measures representing various functions should be balanced, of all analysed measures only such were finally selected out that seemed to represent the functional differentiation of rural areas in the most adequate way. Namely: 1. Density of population (per sq. km), 2. Proportion of agricultural land in total area, 3. Employment in agriculture per 100 ha of agricultural land, 4. Number of beds in tourist and recreation objects per sq. km, 5. Percentage of non-agricultural population in total population, 6. Number of commuters to work in socialized economy per 1000 persons in productive age.

Since there were no examples to be followed not only as regards the optimal selection of characteristics and their measures but also as regards their normalization, in an attempt at the normalization of adopted variables, methods used so far in agricultural typology were adjusted (J. Kostrowicki 1976, 1978, 1980; J. Kostrowicki and Szczęsny 1972; Stola 1976, 1977). The normalization was based on the national divergences of their values arranged in five-class intervals; the value of every variable was investigated separately. The intervals were assigned to ranks from 1 to 5 (Table 1), which represented values from the lowest to the highest. For every investigated unit, i.e. the rural areas of the separate voivodships, the value

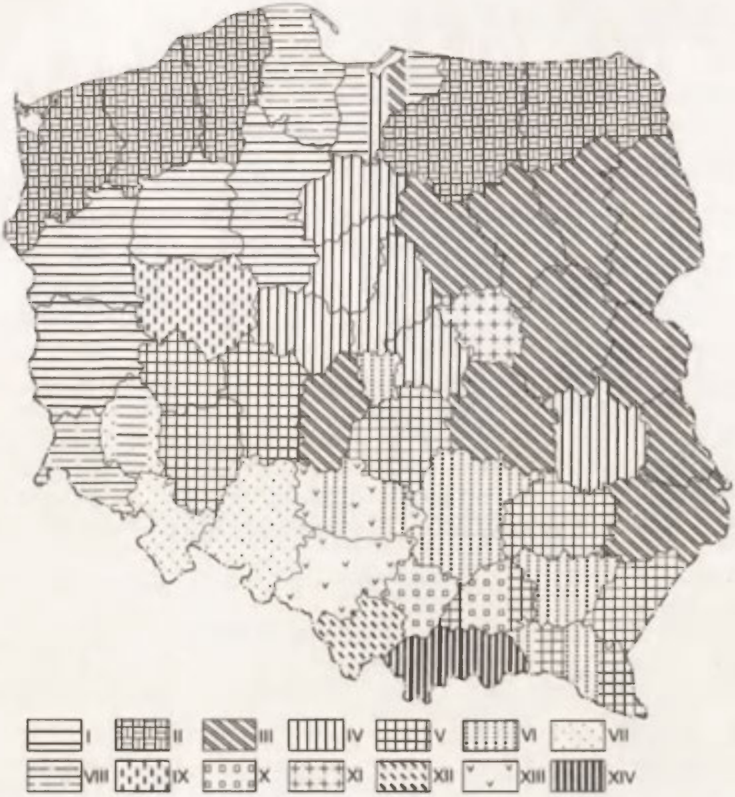

Fig. 1. Functional types of rural areas of Poland
I-XIV functional types described in the article

of every variable was expressed in a numeral way (rank) corresponding to the class of given characteristics on the national scale. The so expressed characteristics were the basic material for grouping the voivodships, which was made by means of the graph method (Szyrmer 1973) and the deviation method, often used in agricultural typology (J. Kostrowicki 1976); J. Kostrowicki and Szczęsny 1972; Stola 1977).

The degree of similarity of the system of variables, expressed as numerals (ranks of every voivodship was compared with similarly coded variables of the remaining 48 voivodships. The systems identical as regards the sets of ranks of characteristics or deviating no more than by 15% (i.e. up to 3) of the theoretically possible number (24) of deviations was acknowledged as the same category (type) on Poland's scale. The systems with a different number of deviatons were recognized as distinct categories (types) or transitory cases, when they resembled 2–3 of other types.

As a result, 8 functional types were singled out, grouping 38 voivodships; out of the remaining 11 voivodships 6 were identified as distinct types and 5 ones as transitory (Fig. 1), namely:

Type I (1, 2, 1–2, 2, 3, 2–3) representing each of the above mentioned functions with the agricultural and forest functions prevalent. It covers the southern part of Western Pomerania and the drainage basin of the middle course of Odra River.

Type II (1, 1–2, 1–2, 3–4, 2, 2) with the agricultural function prevalent, and recreation and forestry as secondary functions. It covers the coastal and lakeland voivodships (with the exception of Gdańsk and Elbląg).

Type III (1–2, 3, 3, 1, 1–2, 1) with the agricultural function prevalent over all other functions. It covers the 9 north-eastern voivodships.

Type IV (3, 4–5, 3–4, 1–2, 2–3, 1–2) with the agricultural function dominant. It covers the areas along the lower Vistula beneath Warsaw.

Type V (3, 3, 3, 1–2, 3, 3–2) with agricultural and industrial functions dominant. It appears on territories scattered over southern Poland.

Type VI (4, 3, 4–5, 1–3, 3, 3–5) with industrial and agricultural functions dominant, covers the voivodships of Łódź, Kielce and Rzeszów.

Type VII (3, 3, 2–3, 2–3, 5, 3–4) with the industrial function prevalent and agriculture as a secondary function. It covers two voivodships in Silesia only: Wałbrzych and Opole.

Type VIII (2, 2, 2, 4–5, 4–5, 4) with various non-agricultural functions prevalent (industry, recreation) and agriculture as a secondary function. Again it was identified in two voivodships only: Gdańsk and Jelenia Góra.

The six subsequent types were so unlike the other voivodships that in accordance with the methods used in the present study they could not be grouped together or acknowledged as transitory areas, and therefore should be recognized as distinct types:

Type IX (2, 3, 1, 3, 3, 4) with the agricultural function prevalent and secondarily industry (Poznań),

Type X (5, 4, 5, 3, 4, 4) with agriculture dominant and industry and recreation as a secondary function (Cracow),

Type XI (4, 2, 4, 4, 5, 5) with various non-agricultural (industry, construction, recreation, housing) functions prevalent and agriculture as a secondary function (Warsaw),

Type XII (5, 2, 5, 5, 5, 4) with industrial and recreational functions and a secondarily agriculture (Bielsko-Biała),

Type XIII (5, 2, 3, 2, 5, 5) with industrial functions highly dominant (Katowice),

Type XIV (4, 2, 5, 5, 3, 2) with agricultural and recreational functions and forestry as a secondary function (Nowy Sącz).

The remaining five voivodships were classified as transitory areas (see Fig. 1).

The classification attempt on the macro-scale was utilized as a basis for the selection of rural areas to be analysed in detail on the commune scale (rural and urban-rural communes). This research was aimed not only at testing on another scale the applicability of the methods of normalization and grouping the units under study but predominantly at improving the selection of diagnostic characteristics and their measures, the number and character of which depended on both the subject of the study and the availability of data. The cognitive aspect was also essential, i.e. the identification of the functional structure of the various categories of rural areas.

The following voivodships were investigated in detail: Warsaw (type XI according to the macro-scale classification), Kielce (VI), Suwałki (II), Wrocław and Leszno (V), Wałbrzych (VII),[1] and subsequently Cracow (X), Nowy Sącz (XIV), and Koszalin (II) (Jasiulewicz 1981).

[1] The functional classification of the voivodships of Leszno, Wałbrzych and Wrocław is based on material compiled by a group of researchers from the Laboratory of Regional Studies at the University of Wroclaw, headed by A. Zagożdżon; that of the voivodships of Cracow and Nowy Sącz was prepared by I. Kwiecień (Cracow) and A. Jackowski (Nowy Sącz) of the Institute of Geography at Jagiellonian University, who used analogical criteria and methods.

Since the scale of the analysis was more detailed, and functional structure of rural areas in each voivodship different, the number of investigated questions and the method of selecting diagnostic characteristics were also not the same; moreover, the normalization of characteristics (Table 1) and the classification were also modified.

In the analysis of the Warsaw voivodship (the city excluded), which on the macro-scale was singled out as a distinct type (XI), of a suburban character of a big agglomeration, two problems were given priority, namely that of the internal differentiation of the voivodship and the second one, which resulted from the first, of the basic functions of rural areas and their measures (Stola 1978a, 1979a 1980b). In such research, aimed at the detailed classification of rural areas, methodological knowledge gained in typological studies of communes or villages (Barberi 1960; Chiffelle et al. 1977; Gałęski 1969; Koziel 1978; Planck 1975; Stola 1979a, 1979b; Szczurówna 1978, and others) and also towns could be useful.

Since one of the main purposes of socio-economic development is to meet population's constantly growing needs, which are influenced to a great extent by the development of basic functions, identifying the interrelations between the given area and the external world, a study of rural areas from the point of view of the structure of basic and non-basic functions seems to be of interest. The basic functions should include in such case this part of traditionally 'rural' functions like agriculture, forestry and fishing, the products of which serve to meet external needs as a commercial production. Moreover, predominantly external functions in production and services, i.e. industry, building and external transport, subsequently functions of tourism and recreation, and in cases of commuting to work the function of housing, etc., could also be considered as basic functions. Non-basic functions are those forms of socio-economic activities, the products of which are intended to meet local needs, or which are aimed to render services to local population, like agricultural production for local consumption, handicrafts and industry for local needs, education at the local range, health services to local population, etc.

Since the character of each function is different, their measures are also different. Besides the measures based on population data, showing the percentage of people for whom a given function is the source of employment or livelihood, or in the case of service functions the number of people for whom services are provided, an important measure of the role of agriculture or forestry, for example, the area covered by these forms of land-use. Other important measures, besides employment, are the volume of production, calculated as a ratio of the area's total production, or in relation to the number of employed there, or as regards agriculture and forestry per ha of utilized land. The role of the function can also be measured by means of indices presenting their share in that area's created income.

To use the division into basic and non-basic functions and to select proper measures representing them may not be easy in the analysis because of lack of relevant statistical data. This, for example, was the case when the classification of the Warsaw voivodship was prepared. In that study, three groups of functions were analysed:

I Production functions of the biogenetic character, i.e. agriculture, forestry and aquaculture,

II. Production functions of technogenetic character, i.e. industry and building, and

III Services, i.e. recreation, transport, trade, housing etc.

A list of theoretically possible diagnostic characteristics was made in the form of a table (Stola 1980b) arranged according to the main production means (land labour, capital) and effects achieved (production, income). Subsequently, about 25 characteristics, included in the table, were analysed together with their measures; 9 of them were acknowledged as diagnostic characteristics though some of them only partly or roughly determined the role of the individual functions. The measures used were as follows: 1. Percentage proportion of agricultural land in total area, 2. Number of employed in agriculture per 100 ha of agricultural land, 3. Percentage proportion of forests in total area, 4. Number of beds in tourist and recreation objects per sq. km, 5. Number of people utilizing beds in tourist and recreation objects per 1000 inhabitants, 6. Percentage of people employed outside agriculture in the total number of employed, 7. Percentage proportion of people employed in industry and building, 8. Number of commuters to work per 1000 people in productive age, 9. Number of people employed in welfare services per 1000 inhabitants.

The first two measures provide information as regards the agricultural function, the third one on forestry and to a certain extent on potential conditions for the recreational development, the fourth and fifth – on the level of recreational development and indirectly on the role of the function of recreation in the life of local population, the sixth refers to the role of non-agricultural functions and indirectly informs on the percentage of agricultural population, the seventh is an important measure of external production functions, the eighth informs on commuting to work and indirectly also on the percentage of bi-professional population and the role of the residential function, the ninth is an important measure of social welfare services such as health service, education, etc.

The normalization of characteristics and the grouping of the basic units of the study according to their similarity, were carried out using the same methods as those used in the classification of Poland's rural areas on the macro-scale. As a result, 6 types were differentiated, which cover a total of 55 administrative units; the remaining 3 units were identified as transitory forms (Fig. 2).

The types are as follows: I. (2–3, 4–5, 1–2, 1–2, 1, 5, 4, 3–4, 2–3) of industrial and service functions and a secondary role of agriculture; it spreads over a majority of towns of the western part of the Warsaw voivodship; II. (1, 5, 4–5, 1, 1, 5, 3–5, 3, 3–4) with a dominance of non-agricultural functions, including forestry and a small proportion of agricultural land utilized intensively. It mainly appears in the north-western and north-eastern areas of the Warsaw voivodship; III. (3–5, 2–4, 1–3, 1, 1, 3–5, 3, 1–2, 3–4) of agricultural and industrial functions dominating, covers most of communes in the south-western part of the voivodship; IV. (1–3, 2–3, 2–4, 1–2, 1–2, 4–5, 3, 2–3, 1–3), also of agricultural and industrial functions but with a secondary role of forestry and recreation; it spreads mainly over north-western communes; V. (1–2, 2–3, 3–4, 4–5, 5, 5, 3, 3–4, 2–3) with functions of recreation, industry and agriculture; it was identified in some northern areas; VI. (1, 4–5, 3–4, 5, 2–3, 5, 4, 3–4, 3–4) with health resort functions and recreation, and a secondary role of industry and services; this category was found in three urban settlements: Otwock, Józefów and Konstancin-Jeziorna.

In the analysis of the rural areas in the Kielce voivodship, classified on the macro-scale as a territory with industrial and agricultural functions dominant (type VI.), 7 out of the total of 20 investigated characteristics (Table 1) were used (Stola 1979b).

The following types were identified: I. (4–5, 4–5, 1–2, 1–2, 1–2, 1–2, 1) with high dominance of agricultural functions, covers southern communes; II. (4–5, 3–4, 2–3, 1, 2–3, 1–3, 2–3) of agricultural functions with a secondary role of industry, which together with category III. (4, 3, 2, 3, 1, 3–4, 2–3, 3–4) of agricultural and industrial functions spreads over the central part of the voivodship, lying between the agricultural southern and the industrial northern areas; IV. (1–2, 3–4, 3–4, 1, 2–3, 1–2, 2–3) with agricultural and forest functions prevalent and a very high percentage of commuters to work, similarly as types II and III;

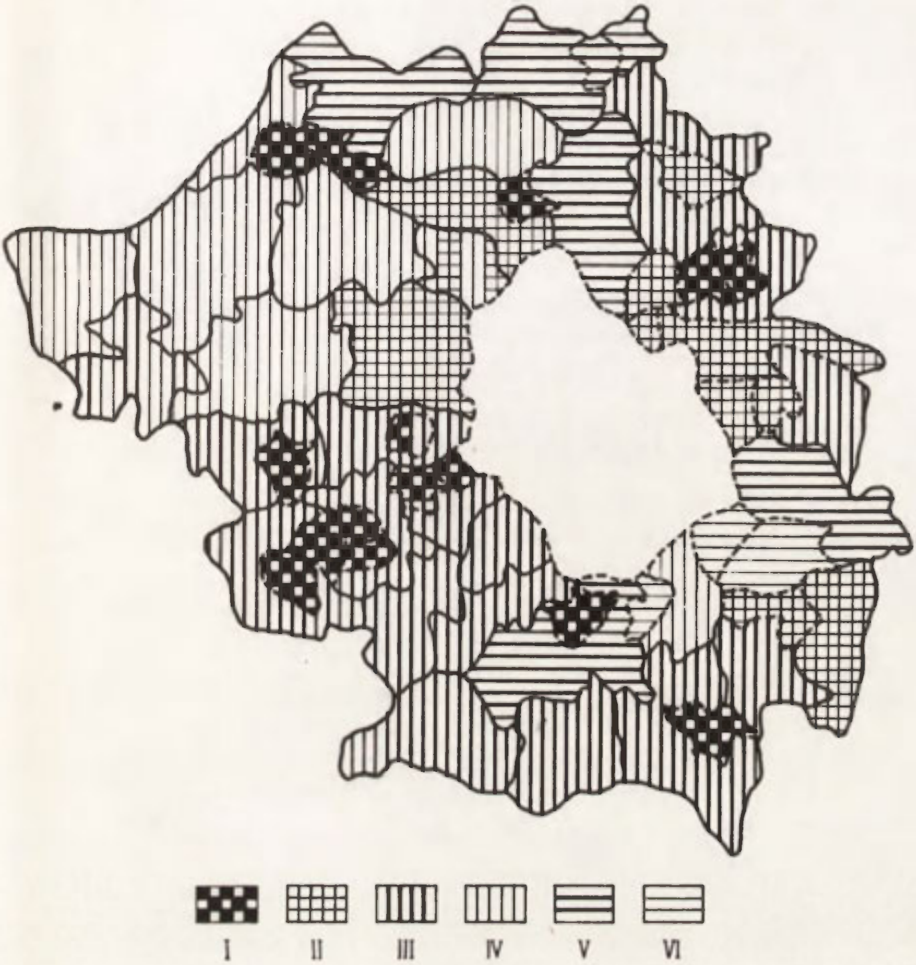

Fig. 2. Functional types of areas of Warsaw voivodship

V. (2–3, 3–4, 3–4, 1–3, 3–4, 3–4, 3–4) with industrial and agricultural functions, and a secondary role of forestry and sporadically of recreation, it appears in the northern areas in the vicinity of type VI. (1, 4–5, 5, 0–2, 4–5, 4-5, 4–5) with very highly developed industrial and a developed residential functions. Types VII. (3–4, 4, 1–2, 1, 5, 3, 4–5) and VIII. (2–3, 4, 1, 1, 4–5, 2–3, 3) represent only towns. Attention should be paid to the fact that the type with mixed, industrial and agricultural functions, which according to the macro-scale analysis characterized the whole of the voivodship, covers relatively small areas. The areas with either agricultural or industrial functions are prevalent features (Fig. 3).

The same conclusion can be reached on the basis of the study of the Suwałki voivodship, classified on the macro-scale as Type II with agricultural function prevalent and a secondary role of recreation and forestry, while on the basis of more detailed studies by communes, different types of rural areas have been identified there.

The attempts at the functional classification of rural areas, carried out so far,

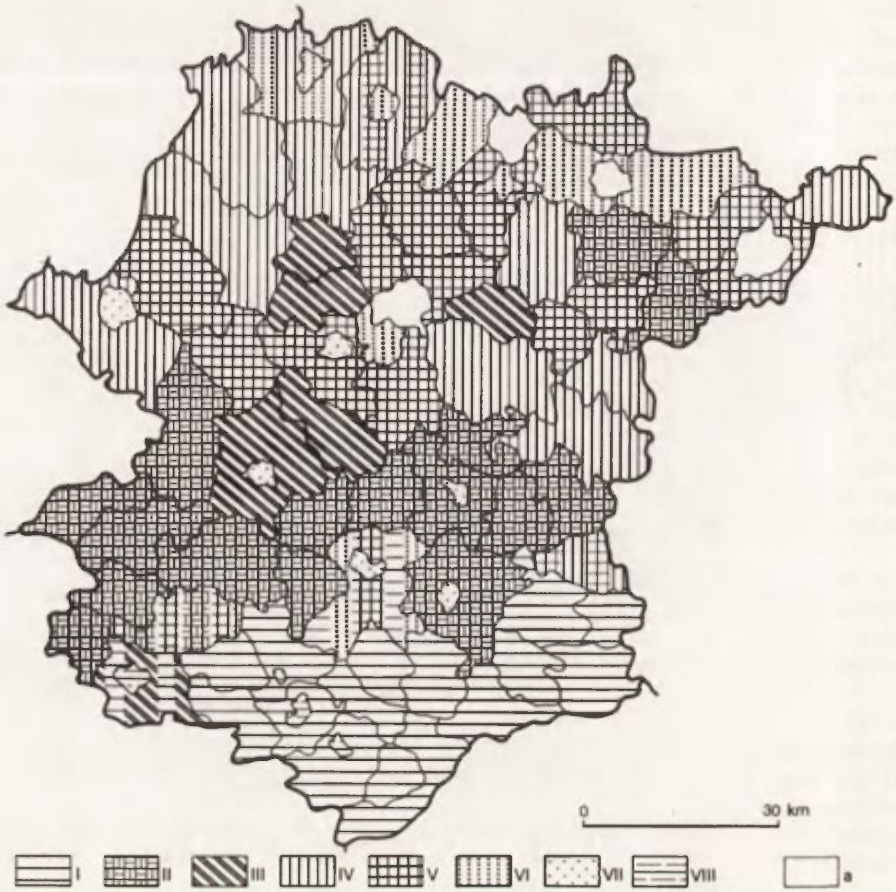

Fig. 3. Functional types of rural areas of Kielce voivodship
a – towns not being communal centres

corroborate the assumption of the complexity of the functional structure of those areas; the applied methods appeared to be adequate in the detailed research. The next attempt was therefore aimed at testing whether or not the criteria and methods adopted before could also be used in a simultaneous investigation of areas lying in various voivodships.

To carry out the study three voivodships of south-western Poland were selected (Fig. 1): Leszno, Wałbrzych and Wroclaw. In the macro-scale research they were classified as type V of agricultural and industrial functions (Leszno and Wroclaw) and type VII of industrial functions and a secondary role of agriculture (Wałbrzych). Altogether there were 91 communes and 47 towns (the seats of communes), i.e. 138 research units together in the three voivodships. The clasification was based on 7 variables (Table 1).

Certain changes were introduced to the normalization of some measures (Table 1): measures expressed as percentage (e.g. proportion of agricultural land in total area, the proportion of non-agricultural population in total population) were grouped into 5 equal classes, i.e. at every 20% (0–20, 20–40, etc.). This division, which is not determined exactly by the value of the national average, seems to be

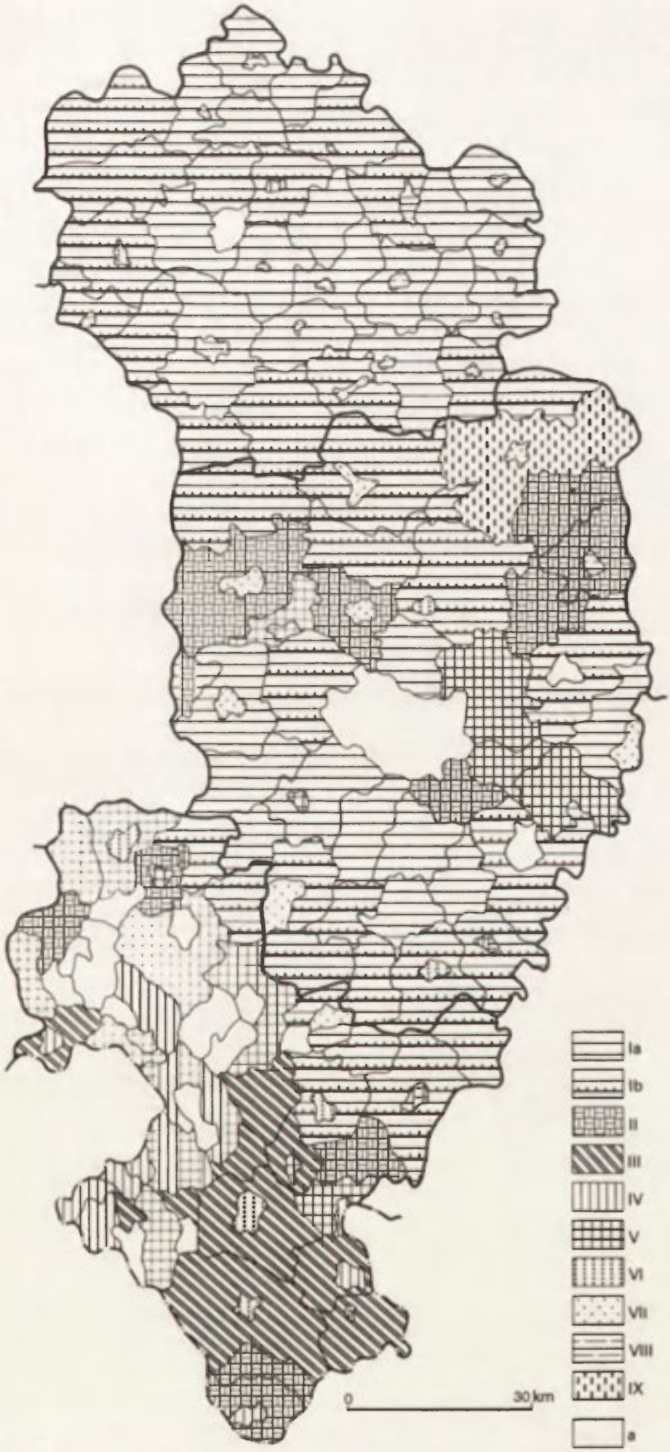

Fig. 4. Functional types of rural areas of the Leszno, Wałbrzych, and Wroclaw voivodships

a – cf. Fig. 3

TABLE 2. Diagnostic characteristics (and measures) of functions in rural areas

No.	Functions	As regards:	
		Land	Labour
	I. Bioproductive		
1.	Agriculture	+ Percentage proportion of agricultural land (in the total area). + Percentage proportion of agricultural land in socialized farm (in the total area of agricultural land).	+ Employment in agriculture (% of employed in total number of profesionally active). Percentage proportion of agricultural population in total population. Labour inputs (number of employed/100 ha of agricultural land, per farm).
2.	Forestry	+ Percentage proportion of forests in the total area.	Employed in forestry (% in total number of professionally active).
3.	Fishing	Percentage proportion of waters in the total area.	Employment in fishing (% in total number of profesionally active).
	II. Technoproductive		
4.	Industry	Percentage proportion of industrial and mining land in the total area.	+ Employment in industry (% of employed in total number of profesionally active according to places of employment and residence. Number of employed in industry per sq. km).
5.	Building		Employment in building (% of employed in total number of professionally active).
	III. Services		
6.	Recreation		Employment in recreation (% of employed in tourism and recreation in total number of profesionally active).
7.	Transport		+ Employment in transport (% in total number of profesionally active).
8.	Housing		+ Commuting to work (% of commuters in total number of profesionally active. Number of commuters per 1000 inhabitants).
9.	Other[1] (beyond local range)		+ Employment in service functions beyond local range (Secondary education and over, sanatoria, hospitals, etc. in % or per 1000 inhabitants).

[1] Important in a study of rural areas, including also towns: seats of commune.

\+ More important measures

Capital	Effects: production	Effects: income
+ Level of investment (value of fixed assets/100 ha of agricultural land, per farm) or capital inputs (machines, tractors, working capital per ha of agricultural land).	Land productivity (gross or net production/ha of agricultural land). Labour productivity (gross or net production per employed). Degree of commercialization (% of commercial production in gross production). + Level of commercialization (commercial production per ha of agricultural land). Commercial production per one employed.	+ Income created in agriculture as percentage of total income.
	+ Productivity of forests (forest production/ha of afforested area).	+ Income created in forestry as percentage of total income.
	Level of commercialization (commercial production/ha).	Income created in fishing as percentage of total income.
Level of investment (value of industrial investment per sq. km).	+ Productivity of industry (industrial production/sq. km, per employed, per inhabitant).	+ Income created in industry as percentage of total income.
		Income created in building as percentage of total income.
+ Level of investment on recreation (number of beds per sq. km, or per 1000 inhabitants. Number of second homes per sq. km).		+ Income created in tourism and recreation as percentage of total income.
Investment on transport (length of roads beyond local importance/sq. km).		Income created in transport as percentage of total income.

useful and may be applied in comparative analyses not only referring to time (dynamic) but also to space extended outside Poland's boundaries.

The grouping of multifeatured units and the classification were made by means of the same methods as used in previous research.

Altogether the 8 types of the areas containing 138 research units were singled out, 5 of which were identified as intermediate and 1 as a distinct type (Fig. 4). The largest area is occupied by type I (4–5, 2–3, 3–4, 1, 2–3, 2–3, 1–2) with agricultural functions dominant, a high (Ia) or medium (Ib) commercial individual agriculture prevalent, and a secondary role of technogenetic functions. The type spreads over 40% of investigated units, namely all the communes in the Leszno voivodship and most in the Wroclaw voivodship, but only 5 communes in the Wałbrzych voivodship. Type II (3–4, 2–4, 2–3, 1, 4, 3–4, 2–3) of agricultural and industrial functions characterizes mainly the central part of the Wrocław voivodship. Type III (2–3, 2, 2, 2–3, 3–5, 2–3, 1–2) of industrial, agricultural and recreational functions marks out the mountainous, southern part of the Wałbrzych voivodship. Type IV (2–3, 1–2, 2–3, 5, 5, 3–5, 3–4) of recreational and industrial functions was identified also in the mountainous south-western parts of that voivodship. Type V (3–4, 3, 2–4, 1, 4, 5, 1–3) of industrial functions and a secondary role of agriculture, is relatively most common in the western, intensively urbanized part of the Wałbrzych voivodship and in the communes lying along the Odra, above Wroclaw. The remaining three categories with mixed functions characterize most towns, which are seats of rural communes, and IX – distinct type.

To sum up: the spatial structure on a detailed scale was identified and functions were classified in the rural areas of 9 voivodships, containing 348 communes out of the national total of 2070, and 120 towns (seats of communes), which makes a total of 468 research units on an area of ca 55 thous. sq. km, i.e. over 17 per cent of the Polish territory Therefore, since territories under investigation were so marked as regards internal differences in their functions and covered such large areas, we may assume that they are sufficiently representative of the differentiation of the functional structure of Poland's rural areas. Besides the interesting results of cognitive nature, the research has in general corroborated that the adopted criteria and applied methods can be effectively used in a classification of various territories on various scales. It has also been proved that in Poland's rural areas – out of the three functions singled out: I. Productive of the biogenetic character, i.e. bioproductive (J. Kostrowicki 1982);[2] II. Productive of the technogenetic character (technoproductive), and III. Services (non-productive functions) – agriculture and forestry, industry as well as recreation and housmg are the most important as basic functions, both as regards the frequency of their occurrence and their involvement in external needs (Table 2). In addition, there are also some functions, occurring sporadically and therefore not fulfilling the conditions of generality, which should also be listed among the basic functions, like transport (mainly railways), health service (e.g. specialized, hospitals), and secondary and higher education, as well as some other services (e.g. to

[2] The division into three groups is similar to the classification of land-use systems, prepared by J. Kostrowicki (cf. his article in this volume) who singles out: (1) Bioproductive systems, i.e. such in which the biological factor (e.g. gathering, hunting, fishing, crop cultivation and animal breeding) plays the most essential role, (2) Technoproductive systems, i.e. those in which technology plays the basic role, like exploitation or processing of mineral, vegetable or animal raw materials and their semi-products, (3) Non-productive systems, mostly services.

agriculture). These functions play an important role in the studies of urban-rural communes, when the areas of the commune and the town (which is the commune seat) are analysed separately. In general, these functions accompany the other basic functions, predominantly productive. Thus, services, with the exception of recreation and housing, are largely non-basic. Irrespective of that the existence of such functions should not, however, be forgotten in detailed research including also towns which are seats of urban-rural communes, in which certain services are their basic functions.

The described studies have made it possible to select from the theoretically possible diagnostic characteristics and their measures (Stola 1980a, Table 1) a set of characteristics (Table 2) representing the basic functions singled out according to the main means of production (land, labour, capital) and gained effects (production, income). It should, however, be made clear that though the shares of individual functions in production or created income may perhaps be of greatest significance, it would be very difficult to work out their measures, which could be used in research, detailed (on the commune scale) studies in particular. Therefore characteristics referring to 'land', i.e. the percentage of the function (agriculture, forestry) in the total area of the investigated unit, as well as those referring to 'labour', i.e. showing the ratio of population for which the given function is the source of employment or livelihood, have almost exclusively been used in all attempts to prepare functional classification of selected voivodships.

Finally, it could be stated that the list of possible characteristics of rural areas presented in Table 2 makes it possible to consider what could be a relatively optimal set of diagnostic characteristics to be applied in the functional classification of Poland's rural areas on various scales. Apart of the cognitive aims, such a classification could be of importance for any planning of rural areas.

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TYPES OF AGRICULTURE IN EUROPE A PRELIMINARY OUTLINE

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The present paper brings in a preliminary outline of the typology of European agriculture based on the material collected for the Types of Agriculture Map of Europe.

The first draft of that map, with several gaps and inconsistencies, was presented for discussion to the section of 'Economic Geography' of the 24th International Geographical Congress, held in Tokyo in 1980. The second improved draft of the map was submitted to the International Cartographic Congress in Warsaw in 1982 (Kostrowicki 1982a). The third and final draft of the map which has been finished 1983 will serve as a basis for its printed form. It is aimed that the printed map is shown to the 25th International Geographical Congress in Paris in 1984.

Many scholars from various countries contributed to the elaboration of that map. M-mes J. Bonnamour and Ch. Gillette sent the material for France; M-me B. Dumortier for Ireland; the late Mrs B. Tschudi and subsequently A. Thormodsaether provided the material for Norway; O. Janson for Sweden; K. M. Jensen for Denmark; B. Cori with his group for Italy; and A. Gatzoyannis for Greece. The material worked out by G. I. Gorbunova and others (1979) was used for the USSR. The following members of the Department of Agricultural Geography, Institute of Geography, Polish Academy of Siences went abroad to collect materials for other countries: B. Gałczyńska (Bulgaria), R. Kulikowski (Netherlands, Spain), W. Stola (Belgium, Portugal), R. Szczęsny (Austria, Switzerland, GDR, Finland, Rumania), and W. Tyszkiewicz (Czechoslovakia, Hungary, Yugoslavia, Great Britain). For some other countries (Albania, F. R. G., Italy and parts of Yugoslavia) various statistical yearbooks had to be used to compile necessary data.

So many people from abroad have helped in collecting materials that it is impossible to name them here. All of them, however, deserve our most sincere thanks.

All the collected material was then elaborated by the mentioned members of the Institute plus A. Dziewulska. Subsequently, the materials were computed by B. Jurkiewicz from the Computer Centre, Polish Academy of Sciences. The map was drawn by W. Jankowski and J. Zarzycki from the same Institute. Everything which had been computed was grouped into types according to the typological method by the present author.

The material collected was far from being complete, uniform and not always fully reliable. A lot of time and effort had then be used to check it, to express it in a comparative form, and to fill the gaps, sometimes with estimates that, of course, do not reflect reality in full.

Irrespective of the fact that from the very beginning it had been decided that the whole material should be completed in about 1975, because of some delays, the earliest material became obsolete and had to be gathered once more. Finally, whole data used for the identification of the types of agriculture of Europe represent the period between 1975–1980.

Quite early it was also decided that the material should be collected for the administrative, or equivalent, agricultural units of the highest order. However, since considerable differences in size existed between such units – in some countries they were too large (USSR, FRG) in some others too small (Yugoslavia); consequently efforts were made either to group them into larger ones or to split them into smaller units of a lower order. The influence of the size of basic units on the identification of types was discussed elsewhere (Kostrowicki 1982a).

1. METHOD AND TECHNIQUES OF THE INVESTIGATION

In conformity with the method that had been worked out by the IGU Commission on Agricultural Typology, the identification of types was based on 27 variables (Table 1) representing the most important social, operational, production

TABLE 1. Classes of world ranges of agricultural attributes

No. of the variable	Classes				
	1 very low	2 low	3 medium	4 high	5 very high
1.	– 20	20–40	40–60	60–80	80–
2.	– 20	20–40	40–60	60–80	80–
3.	– 20	20–40	40–60	60–80	80–
4.	– 20	20–40	40–60	60–80	80–
5.	– 2	2–8	8–50	50–200	200–
6.	– 5	5–20	20–100	100–1000	1000–
7.	– 100	100–1000	1000–10 000	10 000–100 000	100 000–
8.	– 3	3–15	15–40	40–150	150–
9.	– 2	2–8	8–15	15–30	30–
10.	– 6	6–15	15–35	35–90	90–
11.	– 10	10–30	30–80	80–200	200–
12.	– 10	10–25	25–50	50–80	80–
13.	– 10	10–30	30–70	70–130	130–
14.	– 10	10–30	30–80	80–160	160–
15.	– 5	5–20	20–45	45–100	100–
16.	– 5	5–20	20–45	45–100	100–
17.	– 40	40–100	100–250	250–800	800–
18.	– 20	20–60	60–180	180–600	600–
19.	– 20	20–40	40–60	60–80	80–
20.	– 3	3–12	12–30	30–80	80–
21.	– 0.1	0.1–0.2	0.2–0.4	0.4–0.8	0.8–
22.	– 10	10–20	20–40	40–60	60–
23.	– 20	20–40	40–60	60–80	80–
24.	– 20	20–40	40–60	60–80	80–
25.	– 20	20–40	40–60	60–80	80–
26.	– 20	20–40	40–60	60–80	80–
27.	– 20	20–40	40–60	60–80	80–

and structural attributes of agriculture, normalized on the basis of the world ranges of each of these attributes, reduced to 5 classes and presented in codes (for details see Kostrowicki 1977, 1980, 1981). As a result of the present study it has been found out that one additional variable, representing the orientation of livestock breeding, should perhaps be introduced to the structural attributes.

Then, the codes for every basic unit under study were compared by computer with the model codes for the types of the 1st, 2nd and 3rd order, established earlier on the basis of over 1000 investigated cases covering most of the world.

When the investigated units did not differ from the model codes by more than the arbitrarily adopted minimum of deviations (11 for the types of the 3rd order, 22 – for the 2nd order and 33 for the 1st order i.e. by 1/10, 2/10 and 3/10 of the possible variance, respectively), they were considered as the same type. Those units that exceeded the adopted maximum were grouped according to their similarity and then described as new types. However, there were many cases when the distance between the code of the investigated unit and two or more model codes was smaller than the adopted minimum. In such a case the unit was treated as a transitional one between two or more types. The degree of transition was measured by means of the successive products technique (Kostrowicki 1976; Tyszkiewicz 1980; Stola 1983) with no more than 4 products involved (e.g. the transition between two types could be 3 : 1, 2 : 2 or 1 : 3). When the distance between the investigated unit and one model code was large though still below the adopted maximum, at the same time with the other model code slightly above that limit, but by no more than 25 per cent of the distance between the former and the model code, the "25 per cent tolerance clause" was introduced that made it possible to take such distances into account. In fact, this applies only to the cases when the distance between the unit and one model code is more than 9 and less than 14 from another model code ($10+0.25\times10 = 12.5$; $11+0.25\times11 = 13.7$). There are some cases, however, when the codes for some internally very diversified units exceed the adopted limit and cannot be grouped in any sensible way into new types. Then, some greater tolerance ought to be shown, if closer investigation of a given unit proves that several types of a very different character occur there side by side.

A full list of the types of agriculture of the 1st and 2nd order, described to date, as well as that of the types of the 3rd order, identified in Europe, together with their codes is presented in Table 2. All codes of the types described earlier have been reviewed, and some revised following an analysis of the distances between them and the types of a higher order.

2. TYPES OF AGRICULTURE OF EUROPE

As it is stated above, the identification of every type of agriculture is based on 27 variables. They are too numerous to form a proper name for each type, which should not be too long and awkward in use. Therefore, the name of each type is formed after its most conspicuous characteristics. To make their names still more handy, a symbol is given to each type – one capital letter for the types of the 1st order, one capital and one small letter for the 2nd order and one capital and two small letters for the types of the 3rd order. Most of those letters are derived from their characteristics such as **E(e)** – extensive, **T** – traditional, **l** – large-scale, **i** – intensive, **s** – specialized, **m** – mixed, **a** – animal, etc.

All the six types of world agriculture of the 1st order described earlier have been identified in Europe, namely: 1. Traditional Extensive Agriculture (**E**), 2. Traditional Large-Scale Agriculture (**L**), 3. Traditional Intensive Agriculture (**T**), 4. Market-

TABLE 2. Model codes

Order	Symbol	Code
I	**E**	5321311 – 1111121 – 1221111 – 133331
	L	1551354 – 2211132 – 2334422 – 132342
	T	1241222 – 4412242 – 4422221 – 114221
	M	1151233 – 2154343 – 4455544 – 122331
	S	1115555 – 3243242 – 3333433 – 124221
	A	1133445 – 3000003 – 3045535 – 151551
II	*En*	4211201 – 1100121 – 1221112 – 141451
	Ef	5321221 – 1111111 – 1221111 – 115111
	Et	2441211 – 2211132 – 2311211 – 132221
	Ll (*Tl*)	1551354 – 2211132 – 2333323 – 124331
	Lp (*Tp*)	1351444 – 4411142 – 3323434 – 333213
	Ti	1241212 – 5311452 – 5511221 – 114111
	Ts	2241222 – 3212231 – 2222325 – 313113
	Tm	1151222 – 4423143 – 3321321 – 124231
	Ms	1151333 – 3113341 – 4433444 – 511114
	Mi	1151212 – 5145451 – 5545555 – 215111
	Mm	1151222 – 3154143 – 4444443 – 122331
	Ml	1151355 – 2154341 – 4455544 – 213223
	Me	1151254 – 1152132 – 1255525 – 134221
	Se	1115343 – 3232131 – 2222321 – 124221
	Sm	1115555 – 2143143 – 3333432 – 133331
	Si	1115555 – 5422343 – 4522232 – 114111
	Sh	1115545 – 4155441 – 4434554 – 215111
	Ss	1115555 – 2133442 – 3344535 – 411214
	Sc	1115555 – 1142131 – 1234515 – 115111
	Sg	1115554 – 4434342 – 2312423 – 141233
	Ar	1133455 – 1000001 – 1033515 – 151551
	Ad	1133415 – 5000005 – 5055555 – 101551
III	*Etm*	1341221 – 3311132 – 2321221 – 133221
	Llm(*Tll*)	1251354 – 2211132 – 2333424 – 143341
	Tir (*Tmr*)	1151211 – 4411244 – 2211211 – 114111
	Tiu (*Tmu*)	1151112 – 4432454 – 3322321 – 214111
	Tmh	1251211 – 4511343 – 2311111 – 122341
	Tme	1151111 – 3423134 – 2211111 – 123331
	Tmb	1151222 – 3412133 – 3332232 – 122341
	Tmm	1151222 – 3323143 – 3323321 – 113231
	Tmo	1151111 – 3223142 – 4422133 – 113331
	Tmc	1241212 – 4422243 – 3423332 – 224221
	Tmy (*Tmj*)	1151111 – 4434244 – 3311223 – 214222
	Tmg	1151121 – 3243132 – 2322432 – 332232
	Tmf	1151112 – 4254141 – 3322332 – 513112
	Tmk	1151112 – 4423144 4421233 – 132451
	Mso	1151122 – 2143132 – 3334534 – 411115
	Mif	1151222 – 3154341 – 4445544 – 515111
	Miv	1151223 – 3145351 – 5534554 – 114111
	Mig	1151314 – 5155551 – 5555555 – 115111
	Mmr	1151233 – 2154142 – 3343433 – 123221
	Mmc	1151222 – 4254242 – 4434443 – 213222
	Mmf	1151112 – 3243343 – 3433433 – 324221

Order	Symbol	Code
	Mmv	1151123 – 2255243 – 5555552 – 114121
	Mmp	1151111 – 4254454 – 4422342 – 313341
	Mmz	1151122 – 2243342 – 2333322 – 141232
	Mmt	1251122 – 3153243 – 4443341 – 313231
	Mmm	1151222 – 3255144 – 4444442 – 122331
	Mmh	1151112 – 4454254 – 5533442 – 142451
	Mmg (*Tma*)	1151232 – 2223143 – 3433333 – 131351
	Mmw	1151122 – 3155145 – 3343333 – 151251
	Mma	1151233 – 2154144 – 4544444 – 141451
	Mmi	1151222 – 3155355 – 5545553 – 212451
	Mlm	1151355 – 2154143 – 4455542 – 123331
	Mlc	1151254 – 2154441 – 4455543 – 113112
	Mel	1151132 – 1143132 – 2244522 – 222222
	Mem	1151254 – 1152132 – 2355533 – 133331
	Meb (*Mmb*)	1151143 – 1143142 – 2355424 – 141451
	Mae	1151142 – 1155542 – 1544514 – 151551
	Sem	1115443 – 3233133 – 2333321 – 133331
	Sec	1115443 – 3232231 – 2222422 – 124121
	Sep	1115343 – 2142132 – 2333422 – 222222
	Smw	1115555 – 2142142 – 2223422 – 114331
	Smm	1115555 – 2144143 – 3434432 – 132341
	Smy (*Smj*)	1115454 – 2154141 – 1332423 – 143221
	Smg	1115453 – 1154242 – 1433412 – 152331
	Smc	1115555 – 3233242 – 3333432 – 223221
	Smu	1115555 – 3144143 – 3344534 – 114222
	Smi	1115555 – 2154443 – 4455543 – 122222
	Sma	1115555 – 2253142 – 2322424 – 143551
	Smd	1115454 – 3155144 – 4444443 – 113351
	Sgt	1115555 – 4444342 – 2312423 – 141233
	Shy (*Shj*)	1115444 – 3144341 – 3333534 – 323111
	Shv	1115555 – 4154342 – 4433545 – 115111
	Shg (*Shh*)	1115545 – 5155551 – 5555555 – 115111
	Ssf (*Shf*)	1115555 – 3133241 – 3344535 – 515111
	Ssc	1115555 – 2154442 – 3334535 – 332114
	Scm	1115555 – 1141131 – 1333413 – 154441
	Scc	1115555 – 1142131 – 2233525 – 115111
	Arr	1151354 – 1000001 – 1022515 – 151551
	Aro	1115555 – 1000001 – 1034515 – 151551
	Add	1151323 – 5050005 5055555 – 101551
	Ado	1115555 – 5050005 – 5055555 – 101551

Oriented Agriculture (**M**), 5. Socialized Agriculture (**S**), and 6. Highly Specialized Livestock Breeding (**A**).

Though distances between the model codes representing **L**, **T**, **M** and **S** types hardy exceed the adopted maximum distance between the types of the 1st order (33 deviations), distances between the two other types (**E** and **A**) and the remaining types are by far much greater.

Type **E**, i.e. Traditional Extensive (Primeval) Agriculture, is characterized by tradtional land-tenure systems (common ownership or labour or share tenancy), low inputs of labour and low land and labour productivity, very weak connections with the market in terms of both purchases of technical means of production and sale of agricultural produce, and therefore it is a subsistence or semi-subsistence orientation which at present is characteristic of many developing countries. This type of agriculture was quite common in Europe in the past, having survived in its most developed form (*Et*) until the mid-19th century and in some East European countries until the inter-war period. Following the collectivization in the thirties it was eliminated from the USSR and after the Second World War from most of the countries of East Central Europe. It survived in North Eastern Poland up to the early sixties (Biegajlo 1960, 1964) and in Southern Yugoslavia up to the present day.

Type **L** – Traditional Large-Scale Agriculture (Latifundia) differs from the former and the next one by a large scale of operation and therefore by more closer connections with the market. For centuries this type was connected with type **E** and some subtypes of type **T**, having formed together some kind of dual economy like, for instance, the European manorial system built on strong interrelations between great landowners and small peasants, based on villein services, or various forms of labour or share tenancy.

At present, this type of agriculture in its classic form is rare but in various transitional forms it is still practiced in a number of developing, mainly Latin-American, countries. As far as Europe is concerned, it belongs together with type **E**, to the past. Like the previous one, it disappeared from East European countries in the interwar period, or just after the Second World War, following the land reform and collectivization; from most of West European countries much earlier, following the development of agriculture and from most of Southern Europe following land reforms carried out either in the interwar period, or after the Second World War. In the transitional form between **L** and **M** it has survived only is some parts of Southern Europe.

On the other hand, Traditional Intensive (Peasant) Agriculture (**T**), while also eliminated from most of Europe either by agricultural development or collectivization, plays still an important role in some countries of East-Central and Southern Europe. This is a small-scale agriculture characterized also by weak connections with the market, limited purchases of means of production, and limited sales on the market of what is left in the form of surpluses after feeding the operator, his family and farm animals. At present, it is still small-scale, family farming, based on either owner-operator form of land tenure, or more evolved forms of land tenancy, which, as far as the productive results are concerned, do not differ much from the owner-operators one.

This type, quite common in most of the Third World countries, is still characteristic of some countries of Eastern and Southern Europe, where it is represented by a number of types of the 2nd and 3rd orders differing in their intensity, productivity, commercialization, orientations of production, etc. Several transitional types from the **T** to the **M** type have also been identified in some less developed regions of Central and Northern Europe.

The most characteristic features of type **M** – Market Oriented Agriculture are its close connections with the market. Such agriculture purchases practically all means of production on the market and not only sells most of its produce there but its whole activities are oriented towards the market, fluctuating with changes of demand for agricultural products, prices etc. In such a situation the size of a farm influences other agricultural attributes only slightly. Therefore, this type includes both small and large farms, forming different types of the 2nd and 3rd order alongside with differences in intensity, productivity and orientation of production.

On the other hand, Socialized Agriculture (**S**) differs from the other types of agriculture not only by its social attributes (which are only 4 out of 27) but also by its scale of operation (it is fundamentally very large-scale farming) as well as by none or a slight orientation toward the market. It is a commercial agriculture in the sense that most of agricultural produce is delivered off farm at fixed prices, mostly to state or cooperative agencies which distribute it among various state factories or supply directly to state or cooperative storage facilities. All means of production are also purchased from state agencies. The whole system (called sometimes the redistributive system) influences greatly the productivity of agriculture.

This type is characteristic of the socialist countries but in a more or less transitional form it can also be found is some developing or developed countries as various cooperative (*ejidos collectivos* in Mexico) or state farms (e.g. in Algeria, see Szyrmer's paper in the same volume), developing however in different social environment.

In type **A** – Highly-Specialized Livestock Breeding in view of the dominant importance of operational and technical characteristics the importance of other attributes is smaller. This type combines all forms of large-scale, commercial, livestock breeding systems, irrespective of their social characteristics, intensity, productivity, etc. such as highly specialized livestock ranching as well as highly-specialized animal (feed lot) farms.

As far as its distribution in Europe is concerned, type **A** in its most intensive form of animal farms can be found scattered in almost any country of Europe, whether capitalist or socialist, while in its extensive form only on the marginal semi-arid lands of south-eastern part of European Russia, or in the northernmost parts of capitalist and socialist Europe.

As mentioned above, between these types of the 1st order there are many transitional forms (types of a lower order) that resemble, at the same time, two or more types of the 1st order.

As far as their distribution is concerned, three types of the 1st order at present dominate the European scene: **M**, **S** and **T** while the others have survived only on some marginal lands, or are scattered around, covering only limited areas. Altogether, within the 6 types of the 1st order described above, 18 types of the 2nd order and 61 of the 3rd order have been identified in Europe to date.

The codes that characterize those types (Table 2) provide very rich information on any type described by them. However, in view of lack of place all those types are characterized below only in a very general way. It ought to be understood as well that all the quantitative characteristics based on codes (5 very high, 4 high, 3 medium, 2 low, 1 very low) are relative, and represent the references to the world range of each of the characterized attributes.

E. Traditional Extensive (Primeval) Agriculture

This type of agriculture has been identified in Europe only in its most developed form, transitional between types **E** and **T** i.e. by type *Et* of the 2nd order and type *Etm* of the 3rd order, i.e. Current Fallow Mixed Agriculture. This type, described from North-Eastern Poland in the fifties (Biegajlo 1960, 1964) has disappeared since as a result of farm consolidation.

L. Traditional Large-Scale (Latifundia) Agriculture

Also this type of traditional agriculture has almost entirely disappeared in Europe. It has survived only in the transitional form between **L** and **M** types of the 1st order as type *Mel* identified in central Spain, eastern and central Portugal and in some parts of Southern Italy.

T. Traditional Intensive (Peasant) Agriculture

Two types of the 2nd order (*Ti* and *Tm*) and 12 types of the 3rd order have been identified in Europe within Traditional Intensive Agriculture.

Traditional Labour Intensive Crop Agriculture (*Ti*), characteristic of South and East Asia has been identified in its two forms transitional between *Ti* and *Tm*, namely low productive and almost subsistence agriculture – *Tir* and more capital intensive, partly irrigated, medium productive, semi-subsistence to semi-commercial agriculture – *Tiu*. The two types are characterized by very small holdings, high labour and animal power inputs, and crop (mainly food crop) orientations. Both types described originally from Northern India, have been identified in some parts of Yugoslav Macedonia.

Traditional Mixed Agriculture (*Tm*) is much more common in Europe; 10 types of the 3rd order differing by their intensity, productivity, commercialization and orientation, whether fully mixed, mixed with crop growing or with animal breeding prevalent, have been identified within this type.

Tmh is the closest to the *Ti* type; it represents a very small-scale, labour (and animal power) intensive, low productive, semi-subsistence mixed agriculture with animal products prevailing in commercial production. This type, originally described from the South-Asian mountains, has also been identified in Yugoslav Macedonia.

Much less labour intensive (current fallow) but slightly more capital intensive, very small-scale, low productive, subsistence mixed agriculture *Tme* has also been described from Macedonia.

Much more popular in Europe is the *Tmb* type, i.e. a medium labour intensive (current fallow), low capital intensive, medium productive agriculture with animal products prevailing in commercial production.

Described originally from the Polish North-East it has also been identified in various parts of Yugoslavia but as well in Rumanian private farming.

The most common in Europe is, however, the *Tmm* type representing a medium labour intensive, low capital intensive agriculture with medium land productivity, low labour productivity and medium commercialization. It covers considerable areas in central Poland, and Yugoslavia and has also been identified in some parts of Austria, Italy, northern Spain and Portugal.

A special case is the *Tmo* type representing part-time farming. Very small farms dominate here, with medium inputs of labour, low to medium capital inputs, high land productivity, low labour productivity and very low to low commercialization. Drawing most of their income from extra agricultural sources, the farmers grow some crops and breed animals to meet their own needs. In such farms women become often principal farm operators. The type has been described from the suburban zones of Poland and identified also in Yugoslavia.

Four types of traditional mixed agriculture with crop growing prevalent have been indentified in Europe, mainly in Southern Europe, namely the *Tmc* type – a highly labour intensive agriculture with high inputs of animal power, medium to high land productivity, low labour productivity, medium commercialization (semi-commercial) with a dominance of food crops including fruits. It has been described from Yugoslavia, Italy, Spain and Portugal. This type of agriculture was more common earlier. With agricultural development it is now disappearing, being replaced by some more commercial types, transitional to **M** or already of the **M** type. Among them the following ones could be mentioned: *Tmy*, described mainly from Yugoslavia, is a very small-scale, labour intensive agriculture, with considerable use of animal power, high density of animal population, low to high capital inputs, medium land productivity, very low labour productivity, low commercialization, high proportion of food crops (including fruits); *Tmg* described mainly from Greece but identified also in parts of Italy and Spain, is a medium labour and low capital intensive agriculture, with low productivity of total land but high of cultivated land, low labour productivity, medium commercialization, with considerable proportion of perennial crops, including both fruits and industrial crops (olives) and a high proportion of permanent grasslands. Next is the *Tmf* type, which is a transitional form to the *Ms* type, described mainly from southern part of continental Italy. This is a very small-scale, highly labour intensive, but also high capital intensive agriculture, with medium land and low labour productivity, medium commercialization, very high orientation toward crop growing, mainly perennial crops, mostly fruits but also industrial ones (olives).

Only one type of traditional agriculture with animal breeding prevalent has been identified in Europe: this is the *Tmk* type described from the Polish Carpathians, from where it has expanded northward. It has also been identified in some mountainous parts of Yugoslavia, the Rumanian mountains, as well as in some parts of northern Spain. It is a very small-scale agriculture with high inputs of labour and animal power, low to medium capital inputs, high land but low labour productivity, very low to low commercialization (semi-subsistence), low proportion of food crops and a very high proportion of animal products in commercial production.

M Market Oriented Agriculture

Many more types of lower orders have been identified in Europe within Market Oriented Agriculture, i.e. 5 types of the 2nd and 24 types of the 3rd order Here a small-scale mixed agriculture (*Mm*) clearly dominates over the other types such as large-scale, intensive or extensive agriculture (*Ml* and *Me*) and highly specialized crop agriculture (*Ms* and *Mi*).

The first in the last group (*Ms*) is *Specialized Perennial Industrial Crop Agriculture*, more typical of tropical countries where it combines what is called modern plantations and a small-scale specialized crop agriculture connected with them by origin. In Europe, however, only one form of agriculture highly specialized in perennial industrial crops (olives) growing has been described from Jaen province of Spain as belonging to this type. This *Mso* type represents a small-scale agriculture with low inputs of labour, medium capital inputs, medium land and labour productivity, very high commercialization and high specialization in olives and/or some fruit crops growing.

Intensive Specialized Crop Agriculture (*Mi*) represented by 5 types of the 3rd order is more common in Europe. The first one, *Mif*, Specialized Fruit Trees Growing, transitional between *Ms* and *Mi* type, is a small-scale agriculture with medium inputs of labour and high capital inputs, high land and labour productivity, very high commercialization and high specialization, mainly in growing various fruit crops. It is most characteristic of South Europe. But even there, due to the large size of basic units of research – as a dominant type, it has been identified only in some parts of Italy, southern France and Spain.

The next one – *Miv*, representing a highly productive and very highly commercial agriculture, specialized in vegetable growing (market gardening), while quite common in most countries of Western and Central Europe, for the reasons stated above has not been found dominant in any of the investigated units.

This is even more true of the *Mig* type, representing a highly industrialized horticulture, very productive and very commercial, highly specialized in crops grown in more or less artificial environment (green houses, hot-beds etc.), which irrespective of their importance do not cover large areas and therefore do not dominate on the territories of the basic units of research.

Within *Mixed Agriculture* (*Mm*) – 13 types of the 3rd order have been identified, differing in their intensity, productivity, commercialization and production orientation.

Out of the types of mixed agriculture with crop production prevalent, the *Mmr* type is the least intensive. It is a small to medium-scale agriculture with low inputs of labour but high capital inputs, medium land productivity, high labour productivity and very high commercialization but medium specialization. The type initially described from central France, has also been identified in Western Spain and Italy. The following *Mmc* type is more labour intensive with high land productivity but medium labour productivity and high commercialization but medium specialization. Formerly more widespread, this type, closer to traditional agriculture, is now disappearing following a general agricultural transformation. It has been identified mainly in Italy but also in parts of Spain and Portugal. The *Mmf* type described mainly from Italy, southern France, southern Spain and Portugal is also characterized by medium labour inputs, medium to high capital inputs, partial irrigation, medium productivity of total land but high productivity of cultivated land, medium labour productivity, high commercialization, medium specialization, with a high proportion of food crops, mainly fruits. The most intensive in this group is the *Mmv* described from the Netherlands, characterized by low inputs of labour, but very high capital inputs, very high productivity and commercialization but a low degree of specialization is oriented chiefly toward crop production, mainly vegetables.

Out of fully mixed agriculture i.e. in which the proportion between the crop and animal production oscillates around 50 : 50 (2–3, 3–3, 3–4 in codes) the following types could be listed.

The *Mmp* type transitional from Traditional Agriculture should be mentioned first; described from northern Portugal it has been also identified in some parts of north-western Spain, parts of Italy and Yugoslavia. This is a very small-scale, highly labour intensive, but also highly capital intensive, highly irrigated agriculture, with high land productivity but low labour productivity, medium commercialization, low specialization with a high proportion of perennial crops but also highly developed livestock breeding; the next is the *Mmz* type, described from numerous countries of South Europe: Spain, Italy, Greece, Yugoslavia but also from southern Switzerland and Austria. It is a low labour intensive but medium capital intensive agriculture with low productivity of total land but medium productivity of cultivated land, medium labour productivity, medium commercialization and a low degree of specialization. In spite of a high proportion of permanent grasslands crop production slightly prevails over animal production. The *Mmt* type described from central Italy (Tuscany) but also identified in Spain and eastern Austria as well as in some suburban zones elsewhere, is small-scale farming with medium inputs of labour, high capital inputs, high land and labour productivity, medium commercialization and a very low degree of specialization with slight prevalence of crop products including fruits.

The *Mmm* type is most common in central Europe: the Federal Republic of Germany, Belgium, parts of the Netherlands, northern Austria and Switzerland but also north-western France (Brittany), south-eastern England, parts of Denmark, southern Sweden, Norway and Finland as well as in west-central Poland and parts of northern Yugoslavia. It is characterized by medium inputs of labour, very high capital inputs, high density of livestock, high productivity and commercialization and a low degree of specialization.

Out of the types of mixed agriculture with livestock breeding prevalent two types, differing mainly in intensity, represent a transitional stage between the Traditional and the Market-Oriented Agricultures. The first *Mmh* type, close to the *Thk* type, described from northern Spain, is very labour intensive, still with a high use of animal power, but at the same time with high capital inputs, high density of livestock, medium land productivity, low labour productivity but high commercialization and low specialization with marked prevalence of animal over crop production. The next *Mmg*, much more widespread in Northern and Central Europe formerly, has been identified chiefly in some less developed, mainly mountainous areas of central and northern Europe: the Alps, Massif Central, Pyrenees but also Scandinavian mountains. It is a small- to medium-scale agriculture with low labour inputs, low to medium capital inputs, medium density of livestock, medium land and labour productivity, medium commercialization and specialization.

With general agricultural development the *Mmg* type is being transformed into the next *Mmw* type, which in turn is changing into the still higher developed *Mma* type. At present, the *Mmw* type still covers large areas in Austria, Switzerland, northern Italy, north-western Yugoslavia, parts of Spain and Portugal as well as in France, Belgium, Ireland, Norway, Sweden and Finland. It is characterized by medium inputs of labour, very high capital inputs, very high density of livestock, grazed over large tracts of permanent grasslands, medium land productivity, high labour productivity, medium commercialization, medium specialization and high dominance of animal goods in commercial production. The next *Mma* tvpe is the most common in Britain but appears also in Sweden, Switzerland, northern Italy, north-western Yugoslavia, parts of Spain and Portugal scale of operation, lower inputs of labour, lower density of livestock population but higher land productivity, higher commercialization, higher specialization as well as higher proportion of animal production in gross production.

The most intensive in this group is, however, the *Mmi* type identified both in the Netherlands and Northern Italy (mainly Lombardy). It is a small-scale agriculture with medium inputs of labour, very high capital inputs, very high density of livestock, very high land productivity, high labour productivity, very high commercialization, but medium specialization, a high proportion of animal products in gross production and very high in commercial production.

The next type of agriculture of the 2nd order is *Large-Scale Intensive Agriculture* (*Ml*). This type of agriculture is more common outside Europe: in North America, South Africa, New Zealand, some parts of Australia. In Europe, it is represented by two types of the 2nd order.

The first is the *Mlm* type, Large-scale Mixed Agriculture, which is a transitory form from *Mm* to *Ml* types. It is a large-scale agriculture, with low labour and high capital inputs, medium density of livestock, high land productivity, very high labour productivity and commercialization, but a low degree of specialization. It has been identified mainly in France and Britain but also in Ireland. The other one is type *Mlc*, Large-Scale Crop Agriculture, which differs from the above by a considerable importance of irrigation, very low density of livestock, and higher specialization in various crops, mainly food crop products. It has been identified mainly in central France (Paris Basin).

Large-Scale Extensive Agriculture (*Me*) is also most common outside Europe, in the western United States and Canada, as well as in Australia. In Europe it is represented by three types of the 2nd order, namely the *Mel*, *Mem* and *Meb* types.

The first one (*Mel*), mentioned earlier, is of transitional character between the Traditional Large-Scale Agriculture – Latifundia (**L**) and the Market-Oriented Agriculture (**M**). It is a medium-scale agriculture with very low inputs of labour and animal power, high mechanization but medium chemical fertilization, low intensity of cropland use (fallow), low livestock density, very low land productivity, high labour productivity and high to very high commercialization, but a low degree of specialization, mainly in crop products, including industrial crops and fruits.

This type has been described from central parts of Spain and the neighbouring eastern parts of Portugal, it has been also identified in southern Italy.

The second one (*Mem*), Large-Scale Extensive Mixed Agriculture, is characteristic of some parts of the United States and other non-European Countries. In Europe, it is of very rare occurrence. It is characterized by very low inputs of labour, very high mechanization but low chemical fertilizing, low cropland use (fallow), low to medium land productivity, very high labour productivity and commercialization and high specialization in some crop and animal products.

The third one (*Meb*), Large-Scale Extensive Agriculture Specialized in Livestock Breeding, transitional from *Mm*, has been described from northern Britain (Scotland) and Ireland. It is a medium- to large-scale agriculture with very low inputs of labour, medium to high capital inputs, low density of livestock, low productivity of total land, but high of cultivated land, very high labour productivity and commercialization, a medium degree of specialization mainly in livestock breeding.

Mae is in fact a combination of highly intensive crop growing and extensive livestock grazing that characterizes Iceland as a whole. In fact, a highly intensive crop cultivation in greenhouses which could be classified as a *Mig* type is carried on there separately from livestock (mainly sheep) grazing on permanent pastures, represented by the *Arr* type.

S. Socialized Agriculture

Within this type of agriculture, 6 types of the 2nd order and 20 types of the 3rd order have been identified in Europe.

The first type, *Incipient Socialized Agriculture* (*Se*), represents socialized agriculture in its early stage after collectivization. The size of holdings varies according to the size of the former landed estate that was nationalized or the village *terroir* that was collectivized. Labour inputs are still relatively high and inputs of animal power still play an important role, while those of production means are rather low. Thus, productivity is lower as well as commercialization and the degree of specialization. The production orientations vary but food crops play the most important role. That type of agriculture predominated in the USSR after the Revolution and in most of other socialist countries of Europe for some time after the Second World War.

Three types of the 3rd order have been distinguished within Incipient Socialized Agriculture. The most common of them *Sem*, i.e. Incipient Mixed Agriculture was identified in the late seventies only in Rumania. It is a large-scale collective farming with medium inputs of labour, low inputs of animal power, medium capital inputs, low intensity of cropland use, medium density of livestock, low to medium land productivity, medium labour productivity and commercialization and very low specialization. The second one – *Sec*, still less frequent in Europe, is Incipient Agriculture with Crop Growing Prevalent, differing from the previous one by lower density of livestock, lower productivity but a higher degree of commercialization and, of course, by a higher proportion of crops, mainly food crops. This type in its decaying stage has been noticed in some southern parts of the USSR and in Rumania.

To the same type of the 2nd order falls the collective farming that spontaneously arised during the so called 'carnation revolution' in Portugal – *Sep*. It is a medium to large scale agriculture with low inputs of labour, high mechanization but low chemical fertilization, with low intensity of cropland use (fallow), low productivity of total land, but medium productivity of cultivated land, medium labour productivity, high commercialization, low degree of specialization and prevalence of crops over animal production.

The most common within Socialized Agriculture is however *Socialized Mixed Agriculture* (*Sm*), within which 9 types of the 3rd order have been identified, differing in labour and capital inputs, productivity and production orientations.

Within the group of fully mixed agriculture (around 50 : 50) the most extensive is the *Smw* type, widespread in the north-central part of the USSR where it forms a large belt from eastern Byelorussia to the Ural Mts, with the most typical form along the upper Volga River and its tributaries. It is characterized by low inputs of labour, high mechanization but low chemical fertilization, low density of livestock, low productivity, but high commercialization, a low degree of specialization and a high proportion of food crops.

Type *Smm*, occurring practically in all European Socialist countries is particularly common in the west-central USSR, Hungary, Czechoslovakia and Poland. It is characterized by low labour but high capital inputs, medium to high productivity, high commercialization but a low degree of specialization with a prevalence of animal products in commercial production.

Type *Smy*, identified in various parts of Yugoslavia, is a large-scale agriculture with low inputs of labour but high capital inputs, very low productivity of total land and medium of cultivated land, medium labour inputs and commercialization, medium specialization with crops prevalent over animal production.

Type *Smg* represents an unusual Yugoslav combination of socialized farming that results from the nationalization of mountain pastures formerly held in common by the villagers. Those pastures are now only partly used by socialized farms, being mostly rented to individual farmers. As large tracts of those mountain pastures have been statistically merged with collective and state farms this specific 'pseudo-type' can be described as medium- to large-scale agriculture with very low inputs of labour and very low labour productivity per total agricultural land, very high mechanization and high fertilization as well as productivity of cultivated land, medium labour productivity and high commercialization. With those large tracts of pastures eliminated, most of such farms would not differ much from the other types of socialized agriculture, identified in Yugoslavia (particularly *Smy*).

Type *Smc* is a very large-scale agriculture with medium inputs of labour and low inputs of animal power, medium capital inputs, medium productivity and high commercialization, a low degree of specialization with crop growing prevalent. More common in South-Eastern Europe, it has been identified mainly in Rumania and Bulgaria. The next type – *Smu*, differing principally by higher capital inputs, higher labour productivity, commercialization and specialization, higher importance of food crops but also industrial crops (sugar beets, sunflower) is most characteristic of rich chernozem lands of the Ukraine. The next one – *Smi* differing chiefly by a higher degree of irrigation, lower labour inputs, higher productivity and higher importance of non-food crops because of its scattered occurrence, could hardly be marked on the map. Described from the southern part of the USSR, it has been identified also in some countries of South-Eastern Europe.

Among the types of Socialized Mixed Agriculture with Animal Production Prevalent the following can be mentioned. Type *Sma*, prevailing over large territories of northern Russia but also identified in its middle part, particularly in the areas of poor soils, is very large-scale farming with low inputs of labour and animal power, very high mechanization but medium chemical fertilization, low density of livestock, low to medium land productivity, low labour productivity but high commercialization and high specialization in livestock breeding (cattle).

The next type – *Smd*, described from the GDR, where during the last decades it has covered almost the whole country, it has also been identified in parts of Czechoslovakia, Hungary and Poland. It is characterized by medium inputs of labour, but very high capital inputs, high productivity and commercialization but medium specialization with animal products prevailing over crops.

It is interesting that no type of agriculture transitional between the low intensive *Sma* type and the high intensive *Smd* has been identified in Europe to date.

A specific type of the 2nd order which though very close to *Sm*, but sufficiently differing to be treated as a separate one, is *Sg* that has been recently described (see B. Gałczyńska in the same volume) from southern Bulgaria. It is characterized by a combination of a very labour and capital intensive use of cultivated land situated in the mountain valleys (mainly under tobacco growing) and an extensive use of large tracts of mountain pastures by livestock grazing.

The next type of the 2nd order is *Sh – Socialized Horticulture*. Three types of the 3rd order have been included here. The *Shy*, described from Yugoslavia is the least intensive of them. It is a medium- to large-scale agriculture with medium inputs of labour but high capital inputs, medium productivity but very high commercialization and high specialization in crops, mainly fruits (grapes, various stone fruits). The next type, *Shv*, identified in many countries, could hardly be marked on the map because of the large size of the basic units. It is an intensive agriculture with high land productivity, medium labour productivity and very high commercialization, specialized principally in the production of vegetables (parallel to the type *Miv*). Also the *Shg* type – parallel to *Mig*, i.e. a highly industrialized agriculture specialized in vegetables growing under glass (green houses), in spite of its frequent occurrence in all European socialist countries could not be marked on the map.

Socialized agriculture, highly specialized in fruit production, appears to be closer in distance to the next type of the 2nd order – *Ss*.

In general, the *Ss* type – *Specialized Perennial Crop Agriculture* is a very large-scale agriculture, highly specialized in various perennial crops. Within this type of the 2nd order two quite different types of the 3rd order have been described. The first is just the intermediary one between *Sh* and *Ss* – the *Ssf* type, i.e. a medium labour and capital intensive agriculture with medium land and high labour productivity, but very high commercialization specialized in perennial (mainly fruit) crops growing. Though quite common in most countries of East Central and Eastern Europe, it could not be marked on the map either. The second is the *Ssc* type, i.e. a low labour intensive, but highly capital intensive, irrigated agriculture with medium to high land productivity, medium labour productivity and a very high degree of commercialization and specialization, chiefly in industrial, mainly perennial crops such as cotton, tea, etc. This has been described from the Central Asian republics of the USSR but also identified in the Transcaucasian republics, particularly in Azerbaydzhan.

The next *Sc* type of the 2nd order – *Extensive, Specialized Crop Agriculture* is characterized by very low labour inputs, medium capital inputs, low land but medium labour productivity, high commercialization and specialization in temporary food (mainly grain) crops. Two types of the 3rd order have been described here.

The first one – *Scm*, an intermediate form between *Sm* and *Sc*, combines extensive crop growing (usually with fallow), mainly grains, with livestock grazing on the neighbouring large tracts of rough pastures. It has been described from the Eastern margins of European Russia. The second, *Scc* type is a highly specialized grain crop growing. It has been described from the Central Asian republics of the USSR but also identified in south-eastern, semi-arid margins of European Russia.

A. Highly Specialized Livestock Breeding

This type is represented by two types of the 2nd order – *Ar* and *Ad*. *Ar* is a large to very *Large-Scale Agriculture Specialized in Livestock Grazing*. It is characterized by very low inputs of labour. very low density of livestock per unit area, very low land productivity, medium labour productivity, very high commercialization and specialization.

Within this type of the 2nd order two types of the 3rd order have been identified, differing mainly in social attributes and the size of holdings. The first, *Aro*, is a socialized, very large-scale, very extensive agriculture with very low land productivity, medium labour productivity, very high commercialization and specialization in herding various animals (cattle, sheep, horses) grazed on semi-arid steppes. It has been described from Central Asia but also identified, along the northern coasts of the Caspian Sea as well as in another form, the code for which has not been sufficiently described, as a reindeer breeding in the North of the USSR. The second, – *Arr*, is a market-oriented livestock grazing, known from North America, Australia, etc. In Europe, it has been identified only as reindeer grazing in the northernmost parts of Finland and Norway.

The last, *Ad* type is *Highly Industrialized Livestock Breeding*, characterized by very high labour and capital inputs, very high productivity, commercialization and specialization in breeding various species of animals (pigs, poultry, cattle). In one of the two distinct types of the 2nd order, differing mainly in social attributes (*Add* and *Ado*), is dispersed almost in every country of Europe. However, due to the small size of such enterprises and large areas of basic research units, it could not be identified on the basis of the material collected.

3. CONCLUSIONS

First some statistics. As far as the types of the 1st order are concerned, about 30% of the units under study are within the adopted distance of 33 deviations from the model code of Market-Oriented Agriculture (**M**), about 24% within the same distance from Socialized Agriculture (**S**) and Large-Scale Traditional Agriculture (**L**), about 20% from Traditional Intensive Agriculture (**T**). Only 1.5% of units are close to Extensive Traditional Agriculture (**E**) and 0.4% to Highly Specialized Livestock Breeding (**A**).

Following a similar analysis of the types of the 2nd order (maximum 22 deviations) it has been found that the most common of all the types is mixed agriculture, i.e. Market-Oriented Mixed Agriculture (*Mm*) – 26.8%, Socialized Mixed Agriculture (*Sm*) – 19.0% and Traditional Mixed Agriculture (*Tm*) – 14.8% of all units, then Incipient Socialized Agriculture (*Se*) – 9.3%, Socialized Dual Purpose Agriculture (*Sg*) – 8.9%, Socialized Specialized Extensive Crop Agriculture (*Sc*) – 4.5%, Socialized Specialized Industrial Crop Agriculture (*Ss*) – 3.5%, Socialized Intensive Crop Agriculture (*Sh*) – 3.1%, then Market-Oriented Extensive Crop Agriculture (*Me*) – 2.9%, Socialized Labour Intensive Agriculture (*Si*) – 2.4%. Market-Oriented Specialized Crop Agriculture (*Ms*), Market-Oriented Intensive Crop Agriculture (*Mi*) and Market-Oriented Large-Scale Agriculture (*Ml*) participate each in 1.5–1.6 of all units, while Traditional Extensive Current Fallow Semi-Subsistence Agriculture (*Et*) in 1.4% and Traditional Labour Intensive Agriculture (*Ti*), Traditional Specialized Agriculture (*Ts*) and Large-Scale Traditional Mixed Agriculture (*Ll*) in 0.2–0.3% each; and Highly Specialized Extensive Herding – 0.1%. Only four 2nd order types, described to date, are not represented in Europe at all, i.e. Nomadic Herding (*En*), Shifting Cultivation (*Ef*), Traditional Plantations (*Lp*) and Highly Industrialized Livestock Breeding, the last one for the reasons explained above.

When the percentages of the types of the 2nd order presented above are summed up to make types of the 1st order, some striking differences can be disclosed in comparison with the proportion presented above. While the percentages for types **E** and **A** are similar (1.4 : 1.5 and 0.1 : 0.4 respectively), the proportion of Market-Oriented Agriculture is almost the same (34.4 : 33.4), the proportion of Socialized Agriculture (**S**) is much higher (50.7 : 24.1), while that of Traditional Intensive Agriculture (**T**) lower (15.3 : 20.0) and that of Traditional Large-Scale Agriculture (**L**) much lower (0.2 : 23.9). From these differences it might be concluded that between Socialized Agriculture and Traditional Intensive Agriculture on one side, and Large-Scale Traditional Agriculture on the other – there is perhaps still room for some new types of the 2nd order of Traditional Large-Scale Agriculture transitional character.

A similar statistical analysis of the frequency of the 3rd order types reveals that within the adopted maximum of 11 deviations the greatest number of research units are classified as types *Mmm* (14.6%), *Mma* (10.8%), *Smm* (10.5%), *Mmw* (6.2%), *Smc* (5,4%), *Mmt* (4.6%), *Smw* (4.3%) then *Mmg*, *Mmz*, *Sma*, *Smd* (each 3.6–3.7%).

Summing up again the types of the 3rd order according to the types of the 2nd order we can see a still higher concentration in the mixed types: 48.5% of the investigated units falls to the *Mm* type, 32.2% to the *Sm* type and 9.6% to the *Tm* type. These three types cover together over 90 per cent of all investigated units. At the same time, when summing up the former into types of the 1st order, 55% of those units fall to type **M** – Market-Oriented Agriculture (34.4% and 33.4% in the former groupings), 34.7% to type **S** – Socialized Agriculture (50.7% and 24.1%, respectively) and 10.3% to type **T** – Traditional Intensive Agriculture (15.3 and 20.0%). Very few units are close to the types that belong to the **E** or **A** types. As one can see from the above, the results of the last grouping are closer to the proportions within the types of the 1st order, than those resulting from the grouping of the types of the 2nd order.

Another problem derives from a very high concentration of the mixed types, which in most cases does not seem to reflect reality, but results from the large sizes of the investigated units. Only in the case when such a unit is internally uniform, the identified type reflects a real situation. As the method tends to treat each unit in the same way as agricultural holdings, the internally diversified units are also treated as representing mixed farming. In fact, most of them represent a combination of various types of specialized agriculture. It is particularly true of Market-Oriented Agriculture which by definition is more specialized than the other types and which in Europe represents mostly small farms. From this statement a conclusion may be drawn that within Market-Oriented Mixed Agriculture only those that represent fully mixed agriculture, i.e. such where the proportion between crop and animal production oscillates around 50 : 50, certainly can be classified as a mixed type, while most of the others, particularly those that represent more developed agricultures, can be classified as specialized in either crop or animal production. Particularly the units classified as types of mixed agriculture, in which livestock breeding is prevalent, i.e. *Mma*, *Mmi* or even *Mmw*, can be considered as representing agriculture specialized in livestock breeding, which, however, has not been identified in Europe to date. In the same way the units classified as the types of mixed agriculture with crop growing prevalent, such as the *Mmf*, *Mmv* and even *Mmr* types can be treated as those, in which specialized types such as *Mif* or *Miv* dominate rather than *Mmf* or *Mmv*. It is certain than those mixed crop-oriented types can occur alongside with the fully mixed and specialized types.

The same can be said about Socialized Mixed Agriculture (*Sm*), which, however, due to the large size of holdings represents reality better than the combination of a greater number of small holdings.

This aspect has been taken into account in the subsequent attempt at the agricultural regionalization of Europe.

On the basis of the dominance of the combinations of individual types of agriculture the following six agricultural regions are proposed (see Fig. 1).

I. The Northern Region, in which Market-Oriented Agriculture with Livestock Breeding Prevalent (*Mma*, *Mmw*, *Meb*) together with transitional forms from Traditional to Market-Oriented Agriculture (*Mmg*), highly dominates over Market-Oriented Mixed Agriculture, located mainly in lowlands or in a close proximity to urban markets. This region covers, first of all, Scandinavian countries, including Denmark, then Great Britain and Ireland as well as some northern outskirts of continental Europe, northern parts of the FRG, the Benelux countries and France (Normandy).

II. The West-Central Region is characterized by a dominance of Market-Oriented either small- or large-scale Mixed Agriculture (*Mmm* or *Mlm*), with the types characteristic of the former region (*Mmg*, *Mmw*, *Mma*) in the mountainous areas

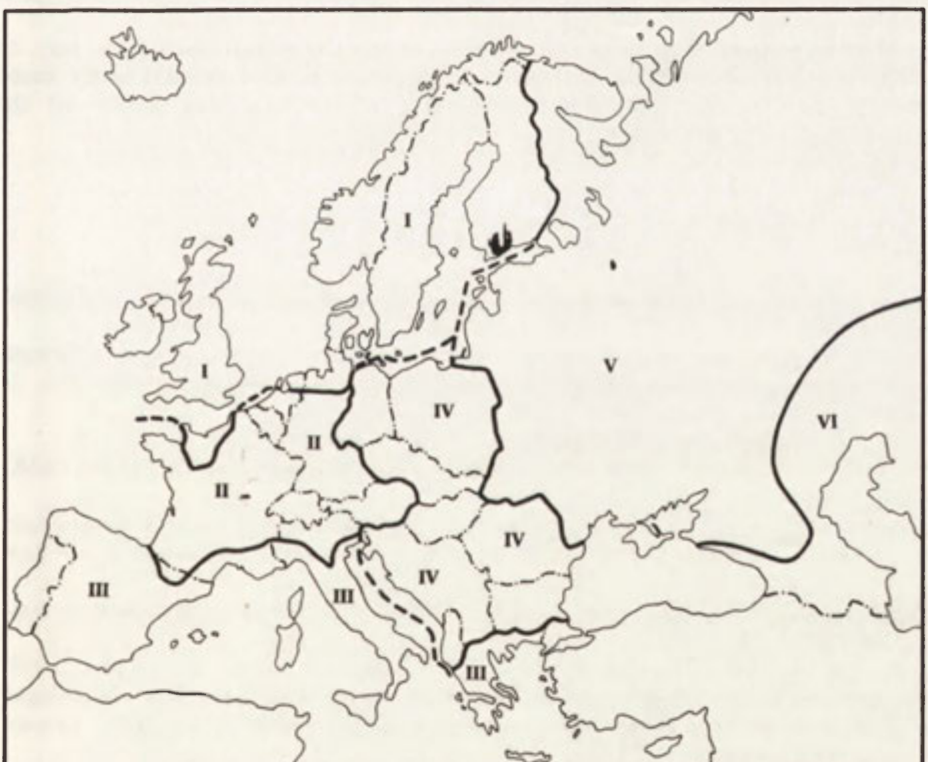

Fig. 1. Agricultural regions of Europe

I–VI – for explanations see p. 147–148 of the text.

(Alps, Massif Central) as well as the highly intensive *Mmi* and *Mmv* types in the Netherlands and Lombardy. This type is extended from the Elbe River and Upper Danube to the Atlantic Ocean, covering most of the Federal Republic of Germany, Austria, Switzerland, some northern parts of Italy, and Central France.

III. The Southern Region, because of varied natural conditions and a different level of development, is internally much more differentiated. Alongside with a quite large proportion of Traditional Agriculture, Market-Oriented Agriculture with crop growing prevalent dominates there, together with agriculture specialized in crop (mainly fruit crop) growing. The region extends from northern Portugal and Spain through Southern France, and most of Italy to Greece.

IV. The East-Central Region, in which three types of agriculture of the 1st order occur in various proportions and with various degrees of development, i.e. Traditional Agriculture, Market-Oriented Agriculture, and Socialized Agriculture, covers all socialist countries of East-Central and South-Eastern Europe, situated between the Baltic, Adriatic and Black Seas.

V. The Eastern Region, in which Large-scale Socialized Agriculture clearly dominates, covers the whole European part of the USSR.

It is quite possible, however, that south-eastern margins of European Russia, including Caucasus might be treated as a part of a larger region (VI) covering also the Central Asian republics of the USSR, in which socialized intensive, irrigated agriculture (*Sg*, *Ss* and the other) is interspersed with more extensive agricultures (*Sc* and the other), practised on non-irrigated land, including livestock grazing (*Aro*).

Within each of those large agricultural regions the several subregions may be delimited. That, however, could not be done before a more detailed study based on the map, is completed, which is the aim of the team that carries out the whole study.

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ESSAI DE TYPOLOGIE DE L'AGRICULTURE AUTOGÉRÉE ALGÉRIENNE

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L'étude présentée ici a pour objectif la distinction des types d'agriculture autogérée algérienne (à l'aide de la méthode élaborée par la Commission de Typologie Agricole de l'Union Géographique Internationale). Dans la partie préliminaire du travail, après une vue d'ensemble du secteur analysé, on présente la méthode appliquée et la base statistique de l'étude. La deuxième partie contient la typologie préliminaire et la description des types obtenus. La comparaison de cas étudiés aux types mondiaux, établis par la Commission – clôt le travail.*

SECTEUR AUTOGÉRÉ EN AGRICULTURE ALGÉRIENNE

Le secteur autogéré[1] est né en 1962 avec l'indépendance de l'Algérie et l'abandon par la plupart des colons français de leurs propriétés. Les ouvriers agricoles algériens des anciens domaines français, qui d'ailleurs pendant la période coloniale ont constitué une couche sociale privilégiée, ont continué à travailler en profitant, eux-mêmes, de la production et en gérant de fait ces domaines. Cet état a été institutionalisé en mars 1963. En même temps le gouvernement a mis l'autogestion ouvrière sous son contrôle. Le système de la gestion des exploitations en question a évolué entretemps. Surtout plusieurs décrets, pris par

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* Je voudrais remercier Monsieur le Professeur J. Kostrowicki de ses opinions et ses remarques qui m'ont beaucoup aidé dans ce travail.

[1] Parmi les travaux plus récents, on peut citer à titre d'exemple: S. Bedrani: L'agriculture algérienne depuis 1966, Etatisation ou privatisation, Office des Publications Universitaires, Alger 1981, 414 p.; A. Hersi: *Les mutations des structures agraires en Algérie depuis 1962*, Office des Publications Universitaires, Alger 1979, 206 p.; M. Raffinet et P. Jacquemot: *Le capitalisme d'Etat algérien*, Maspéro, Paris 1977, P. Marthélot: Le remodelage des exploitations agricoles en Algérie, *Geographia Polonica* 29, 1974, pp. 419–425; G. Duprat: *Le socialisme algérien d'autogestion rurale*, PUF, Paris 1973; H. Ahmad: *Les formes collectives des exploitations agricoles en Algérie et en Tunisie*, Paris 1973; C. Chaulet: *La Mitidja autogérée*, SNED, Alger 1970, 3 vol.; M. Rosciszewski: Kierunki ewolucji rolnictwa w krajach Maghrebu, *Prace Geograficzne* nr 88, PWN, Warszawa 1970, 128 p. (résumé en anglais: Trends of agricultural evolution in Maghreb's countries); T. Tidafi: *L'agriculture algérienne et ses perspectives de développement*, Maspéro, Paris 1969, 223 p.

le chef de gouvernement le 15 février 1969, ont redéfini la gestion et le fonctionnement des exploitations autogérées[2].

Le secteur autogéré est maintenant un des trois secteurs de l'agriculture algérienne, outre le secteur privé et le secteur de la Révolution Agraire. Ce dernier, proche du système coopératif, est né en novembre 1971 avec la deuxième phase de la réforme agraire.

L'assemblée générale des membres du collectif de travailleurs, qui est d'après la loi l'organe suprême d'une entreprise autogérée, prend les décisions concernant toutes les questions-clés de l'exploitation et élit le président, le conseil de gestion et le conseil de travailleurs. Mais la terre ainsi que les bâtiments et les autres moyens de production appartiennent à l'Etat. Celui-ci en accorde la jouissance pour une durée illimitée aux collectifs des travailleurs. Ces collectifs ne disposent pas du droit de vente ou du bail de la terre ni des bâtiments. Ils sont responsables de la bonne conservation des moyens de production, qui leur sont confiés, ainsi que du développement de l'entreprise. La loi limite aussi le droit pour les travailleurs de disposer des revenus de l'exploitation. Le travailleur qui quitte son travail au sein de l'exploitation cesse automatiquement d'être membre du collectif et perd tous ses droits à la gestion et aux profits de l'exploitation.

Le contrôle sur l'exploitation est assumé par le ministre de l'agriculture. Il indique des objectifs généraux et approuve le plan des cultures, nomme et révogue le directeur. Le directeur doit en principe réaliser les décisions de l'assemblée générale et du conseil de gestion mais il dispose du droit de veto en cas de contradiction entre ces décisions et la loi ou les dispositions du ministre. Le directeur dispose aussi d'une certaine influence sur la composition du collectif car c'est lui qui indique le nombre et les qualifications des personnes à coopter au sein du collectif.

On peut admettre que c'est le modèle yougoslave qui a inspiré les auteurs des lois réglant le fonctionnement du secteur autogéré en Algérie. Ils ont essayé de concilier l'autogestion des travailleurs avec le contrôle et la planification centrale. La réussite n'est pas complète. Les membres des collectifs se considèrent souvent comme des salariés et leurs avances mensuelles comme des salaires.

Outre les travailleurs constituant le collectif, il y a ceux qui ne sont pas les membres du collectif et par conséquent sont traités comme des journaliers. Mais pratiquement beaucoup parmi eux sont devenus permanents. On peut tirer cette conclusion du fait que le nombre moyen de jours de travail des ouvriers saisonniers par année est de 225 contre 310 jours de travail pour les ouvriers permanents-membres du collectif[3]. Le rôle des journaliers est très important; leur effectif (100 000) était égal à l'effectif de permanents.

L'évaluation de l'importance du secteur autogéré dépend de la base retenue. Il contrôle seulement 1,0% de la superficie du pays, mais 6,0% de la superficie agricole utilisée. Quand on soustrait de la SAU la superficie des pacages et parcours exploités d'une façon très extensive, qui constituent 80% de la SAU en Algérie, la part du secteur autogéré passe à 27,4%. Il ne faut pas oublier que ce secteur contrôle les terres ayant appartenu aux colons français, donc le plus fertiles, les mieux aménagées (p.ex. 43,5% des terres irriguées appartiennent au secteur autogéré) et les mieux situées.

Le secteur autogéré possedait au 31 décembre 1978 47,8% des tracteurs utilisés

[2] Collection des ordonnances et décrets concernant le secteur autogérée: *Secteur socialiste agricole*, Direction de la Reforme Agraire, MARA, Alger (sans date), 140 p.

[3] Tous les chiffres, sauf les cas mentionnés, concernent la campagne 1976/77; pour leurs sources, voir ci-dessous.

par l'agriculture et consommait 57% des engrais chimiques en 1977/78. En 1978, la part de l'agriculture autogérée était de 42% dans la production de céréales, de 53% pour les légumes secs, de 42% pour les pommes de terre, de 37% pour les tomates, de 88% pour le vin, de 56% pour les raisins de table, de 87% pour les agrumes. La part de ce secteur dans la production commercialisée a été encore plus élevée.

Les exploitations autogérées dominent autour de grandes villes: 70 à 80% de la SAU dans les wilayate d'Alger et d'Oran. Mais elles n'existent pas dans trois wilayate du Grand Sud: Béchar, Adrar et Tamanrasset (Tabl. 1).

En 1976/77 le secteur autogéré était constitué de 2071 exploitations. Une exploitation moyenne disposait de 1160 ha de SAU, de 50 travailleurs permanents

TABLEAU 1. Pourcentage du secteur autogéré dans la superficie agricole utile en 1978

N°	Wilaya	%
1.	Alger	78,4
2.	Blida	65,2
3.	El Asnam	23,7
4.	Médéa	7,1
5.	Bouïra	14,0
6.	Tizi Ouzou	8,0
7.	Oran	71,0
8.	Sidi Bel Abbés	59,1
9.	Tlemcen	28,7
10.	Saïda	6,3
11.	Tiaret	21,1
12.	Mostaganem	35,9
13.	Mascara	38,5
14.	Béjaïa	6,9
15.	Jijel	14,6
16.	Skikda	24,4
17.	Annaba	41,8
18.	Guelma	20,9
19.	Constantine	38,8
20.	Sétif	29,6
21.	M'Sila	0,2
22.	Batna	10,3
23.	Oum El Bouaghi	12,4
24.	Tébéssa	1,3
25.	Djelfa	1,0
26.	Laghouat	0,04
27.	Ouargla	0,01
28.	Biskra	1,8
29.	Béchar	–
30.	Adrar	–
31.	Tamanrasset	–

Remarque: Calculs à base des données de *Statistique agricole*, Série B 1978, MARA, Alger, pp. 8–11.

et 50 travailleurs saisonniers (environ 85 PAT: personne-année-travail), de 9 tracteurs, 1 ou 2 moissonneuses-batteuses et d'un camion. En ce qui concerne la taille des exploitations les différences étaient bien significatives et visibles même au niveau des wilayate. En 1976/77, la SAU moyenne d'une exploitation variait de 26 ha dans la wilaya saharienne de Laghouat à 2700 ha dans la wilaya céréaliére de Tiaret, située sur les Hautes Plaines. Une exploitation moyenne des Hautes Plaines disposait de 20 à 60 travailleurs mais une exploitation située aux alentours d'une grande ville, de 100 à 140 travailleurs.

L'apport national moyen de travail était de 7,9 PAT pour 100 ha de SAU. En ce qui concerne l'apport du capital, la traction était presque totalement motorisée. Mais on trouvait un tracteur pour 120 ha de SAU (et un tracteur en état de marche pour 150 ha de SAU). L'âge moyen d'un tracteur dépassait 7 ans. La consommation en engrais chimiques atteignait environ 45 unités fertilisantes pour 100 hectares de terre cultivée.

En 1976/77, l'agriculture autogérée occupait 2 405 000 ha dont 92,1% de SAU, 4,0% de surfaces forestières et 3,9% d'autres surfaces (superficies couvertes par les bâtiments, les voies de communication, ainsi que celles utilisées pour d'autres fins non agricoles et les terrains improductifs non susceptibles d'être cultivés ou pacagés). Dans l'ensemble de la SAU (environ 2 217 000 ha), les cultures permanentes apparaissaient pour 13.4%, les cultures herbacées pour 53,7%, les jachères pour 24,9%, les pacages et parcours pour 8,0%.

Parmi les cultures permanentes, la vigne avait l'extension la plus importante (60,9% de la superficie plantée). Viennent ensuite les agrumes avec 13,4%, puis les oliviers avec 11,8%. Les cultures herbacées étaient dominées par les céréales: 72,0% de la superficie; 4,7% de la superficie des cultures herbacées étaient occupés par les légumes secs, 4,7% par les cultures maraîchères, 1,1% par les cultures industrielles, 17,6% par les cultures fourragères. Parmi les céréales, on cultivait avant tout le blé (80% de la superficie et 85% de la production) et l'orge (15% de la superficie et 11% de la production). Leurs rendements étaient de 7 quintaux à l'hectare. La plupart des céréales étaient cultivées en assolement biennal avec jachère. Les cultures maraîchères importantes étaient les pommes de terre avec 36% de la superficie totale des cultures maraîchères et 39% de la production (rendement moyen 53 q/ha), les tomates avec 13% de la superficie et 27% de la production (rendement moyen 98 q/ha) ainsi que les melons et les pastèques (16% de la superficie et 7% de la production). Les cultures maraîchères successives n'étaient pas très répandues: le rapport entre la superficie de récolte et la superficie réelle était 1,13/1.

L'élevage joue un rôle secondaire. En 1976/77 l'effectif moyen du troupeau était de 6 unités de gros bovins pour 100 ha de SAU. Les espèces dominantes étaient les bovins (100000 têtes environ) et les ovins (500000 têtes environ). Les autres orientations de l'élevage sont insignifiantes. L'élevage des porcins n'existe pas en égard aux dogmes religieux.

Le degré de commercialisation était très élevé: en 1976/77, il était dans les 3/4 des wilayate de 90 à 100% et dans le 1/4 restant, de 80 à 90%. Les fruits et les cultures industrielles ont été commercialisées à 100%, les céréales à 99,8%, les cultures maraîchères à 99,2%, le lait à 97,2%, les legumes secs à 96,2%.

MÉTHODE

Pour distinguer les types d'agriculture en Algérie, on a appliqué la méthode élaborée par la Commission de Typologie Agricole de l'Union Géographique

Internationale présidée par J. Kostrowicki [4]. Cette méthode repose sur cinq éléments essentiels:

1. liste des critères qui constituent les assises de la typologie,
2. technique de comparaison des critères,
3. liste des étalons (modèles) des types mondiaux d'agriculture,
4. technique de comparaison des unités étudiées aux étalons,
5. règles d'affectation des unités étudiées aux types mondiaux.

La liste des critères est composée de vingt sept critères divisés en quatre groupes:

I. Critères sociaux:
  A. Structure foncière:
    1. Pourcentage de SAU en possession communautaire traditionnelle.
    2. Pourcentage de SAU en métayage ou en location contre une prestation de travail.
    3. Pourcentage de SAU en propriété privée.
    4. Pourcentage de SAU en possession collective ou d'Etat.
  B. Taille des exploitations:
    5. Nombre de travailleurs par exploitation.
    6. SAU par exploitation.
    7. Production globale [5] par exploitation.

II. Critères techniques:
  8. Nombre de PAT (personne-année-travail) pour 100 ha de SAU.
  9. Animaux de trait [6] pour 100 ha de TC (terre cultivée).
  10. Parc de matériel de traction en chevaux-vapeur pour 100 ha de TC.
  11. Consommation d'engrais chimiques en unités fertilisantes pour 1 ha de TC.
  12. Pourcentage de TC irriguée.
  13. Coefficient d'intensité d'utilisation de la terre labourable (surface récoltée par surface réelle de la terre labourable).
  14. Cheptel vif en unités de gros bovins pour 100 ha de SAU.

III. Critères de production:
  15. Productivité de la terre (production globale par hectare de SAU).
  16. Productivité de la terre cultivée (production globale par hectare de TC).
  17. Productivité de travail (production globale par PAT).
  18. Production commercialisée par PAT.
  19. Degré de commercialisation (pourcentage de la production commercialisée dans la production globale).
  20. Production commercialisée par hectare de SAU.
  21. Coefficient de spécialisation [7].

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[4] J. Kostrowicki: The types of agriculture map of Europe, *Geographia Polonica* 48, pp. 79–91+4 cartes; J. Kostrowicki: A hierarchy of world types of agriculture, *Geographia Polonica* 43, 1980, pp. 125–148; J. Bonnamour, Ch. Gillette: *Les types d'agriculture en France*, Essai méthodologique, CNRS, Paris 1980, 184 p.; J. Kostrowicki et W. Tyszkiewicz (eds.), Agricultural Typology, *Geographia Polonica* 40, 1979, 260 p.

[5] La valeur des productions globale et commercialisée a été évaluée en unités conventionnelles élaborées par J. Kostrowicki (voir les travaux cités ci-dessus). A titre d'exemple: 1 q de blé = 1 unité, 1 q de pommes de terre = 0,4 unité, 1 q d'agrumes = 0,7 unité, 1 q de dattes = 1,5 unité, 100 l du lait = 1 unité.

[6] En unités conventionnelles élaborées par J. Kostrowicki: chameau = 2 unités, cheval = 1 unité, mulet = 0,8 unité, âne = 0,3 unité.

[7] Voir J. Kostrowicki: The typology of world agriculture, in: C. Vanzetti (ed.), *Agricultural Typology and Land Use*, Verona 1975, pp. 429–480; J. Szyrmer: Stopień specjalizacji rolnictwa, *Przegląd Geograficzny* 47, 1975, 4, pp. 117–135 (résumé en anglais: The degree of agricultural specialization).

IV. Critères structuraux:

22. Pourcentage des cultures permanentes dans la SAU.
23. Pourcentages des près, prairies et pâturages dans la SAU.
24. Pourcentage des cultures alimentaires dans la SAU.
25. Pourcentage des productions animales dans la production globale.
26. Pourcentage des productions animales dans la production commercialisée.
27. Pourcentage des cultures industrielles dans la production globale.

En vue de rendre possible les comparaisons réciproques des unités ainsi que les comparaisons des unités aux étalons des types mondiaux, on normalise les valeurs de tous les critères à l'aide d'un barème. Toutes les modalités existantes ou même possibles de chaque critère en agriculture mondiale sont divisées en cinq classes[8]. La valeur normalisée est égale au numéro de la classe à laquelle appartient la valeur observée; elle varie donc de 1 à 5. Ainsi chaque unité étudiée peut être décrite par un code composé de 27 chiffres, chacun exprimant la valeur normalisée d'un critère.

Les étalons des types mondiaux sont décrits de la même façon que les unités. Après l'analyse de plus d'un miller d'exemples pris dans toutes les régions du monde et en tenant compte des suggestions et critiques de chercheurs participant aux travaux de la Commission, son président J. Kostrowicki a créé un système hiérarchique mondial des types d'agriculture. Il contient des types de trois ordres. Chaque type est décrit par un étalon sous forme de code. Le système est composé de six types d'ordre I, d'une vingtaine de types d'ordre II et plusieurs dizaines de types d'ordre III, dont le nombre s'élargit grâce aux études de différents cas de l'agriculture mondiale. Chaque type d'ordre III appartient à un type d'ordre II et celui-ci à un type d'ordre I. Chaque type est représenté par un symbole composé d'une (ordre I), deux (ordre II) ou trois (ordre III) lettres. Dans le dernier cas, la première lettre correspond au type d'ordre I et la seconde au type d'ordre II auxquels ce type d'ordre III appartient[9].

On compare les unités aux étalons des types mondiaux à l'aide de la distance taxonomique. La Commission a retenu la formule suivante de la distance:

$$D_{kl} = \sum_{j=1}^{n} |a_{kj} - a_{lj}|$$

où D_{kl} – distance taxonomique de l'unité k au type l,
a_{kj} – valeur normalisée du critère j dans le code de l'unité k,
a_{lj} – valeur normalisée du critère j dans le code de type l.

Cette formule est appliquée aussi au calcul de la distance d'une unité à l'autre.

Les unités sont affectées aux types d'ordre I, II et III dont elles se rapprochent le plus du point de vue taxonomique. Mais la distance de l'unité au type auquel elle est affectée ne peut dépasser 33 dans le cas du type d'ordre I, 22 pour l'ordre II et 33 pour l'ordre III. Les unités qui ne peuvent être classées à cause de l'éloignement dépassant les limites retenues, doivent être traitées comme les représentants de nouveaux types, non décrits, et élargissent la liste des types mondiaux.

ASSISES STATISTIQUES

L'étude présentée ici concerne la campagne 1976/1977, donc la période entre le 1 octobre 1976 et le 30 septembre 1977. Cette campagne est la plus récente

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[8] Voir J. Kostrowicki: The types..., op. cit. et J. Kostrowicki: A hierarchy..., op. cit.

[9] Voir J. Kostrowicki: A hierarchy..., op. cit.

pour laquelle des données assez complètes aient été publiées. L'enquête sur le secteur socialiste agricole (*Résultats de la campagne 1976–1977*. Statistique agricole. Série: Etudes et enquêtes) publiée à Alger par le Ministère de l'Agriculture et de la Révolution Agraire a servi comme source principale des données. Les sources secondaires ont été consituées par d'autres publications du Ministère de l'Agriculture ainsi que les publications du Ministère de la Planification et de l'Aménagement du Territoire[10].

On a utilisé les données par wilaya. La wilaya est une unité principale du découpage administratif de l'Algérie. L'agriculture autogérée existe dans 28 des 31 wilayate. La SAU du secteur autogéré varie de 26 ha dans la wilaya de Laghouat à 319 000 ha dans la wilaya de Sidi Bel Abbès.

La source principale a fourni des données suffisantes pour le calcul des valeurs de tous les critères sauf le n° 10 (parc de matériel de traction) et le n° 11 (consommation d'engrais chimiques). Le potentiel de la traction a donc été estimé à l'aide des données portant sur les effectifs de tracteurs selon les classes de puissance et les effectifs des moissonneuses-batteuses. Pour la consommation en engrais chimiques, toutes les wilayate ont été affectées à la troisième classe mondiale d'après la consommation moyenne nationale. Il est possible que quelques wilayate littorales puissent appartenir à la quatrième classe et quelques wilayate des Hautes Plaines, à la deuxième classe. Mais à cause du manque de données, tous les classements basés sur des estimations incertaines ne seraient pas moins arbitraires et ne contiendraient pas moins d'erreurs que la solution retenue.

Les valeurs observées de 27 critères pour 28 wilayate ont été calculées d'après les recommandations de la Commission et normalisées selon le barème de classes établi par elle. Ainsi on a obtenu les codes pour toutes les wilayate (Tabl. 2). Ces codes ont constitué l'assise des opérations ultérieures.

TYPOLOGIE PRÉLIMINAIRE

La typologie préliminaire a été établie sans aucun rapport avec les étalons des types de la Commission. C'était la typologie des unités étudiées "isolées" du monde. Les types ont été distingués seulement à partir de ces unités. Les distances taxonomiques entre les unités (wilayate) (Tabl. 3) ont été calculées à l'aide de la formule citée ci-dessus. A partir de ces distances on a classé les unités à l'aide de quatre méthodes de groupement: méthode du voisin le plus proche, méthode du voisin le plus éloigné, méthode de Berry, méthode de Hubert[11]. Ces méthodes donnent des résultats hiérarchiques – chaque méthode donne plusieurs solutions, chacune à un autre niveau du découpage, plus ou moins détaillé. D'autre part la même méthode peut donner plus d'une solution au même niveau. On a obtenu ainsi un éventail des solutions.

Le choix de la solution optimale – du découpage optimal – a reposé sur deux principes retenus:

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[10] Surtout *l'Annuaire statistique de l'Algérie 1979*, MPAT, Alger, 448 p.+ annexes; *l'Annuaire statistique de l'Algérie 1977–78*, MPAT, Alger, 379 p.+ annexes; *Statistique agricole*, Série B, 1979 MARA, Alger, 72p.; *Statistique agricole*, Série A, 1979, MARA, Alger, 19 p.; *Statistique agricole*, Série B, 1978, MARA, Alger, 71 p.

[11] L. L. McQuitty: Hierarchical syndrome analysis, *Educ. Psych. Measur.* 20, 1960, pp. 293–304; B. J. L. Berry: *A method of deriving multifactor uniform regions*, 1961; S. C. Johnson: Hierarchical clustering schemes, *Psychometrika*, 32, 1967, pp. 241–254; L. Hubert: Monotone invariant clustering procedures, *Psychometrika*, 38, 1973, pp. 47–62.

TABLEAU 2. Codes de wilayate

N°.	Wilaya	Code
1.	Alger	1115443 – 4153342 – 2312532 – 213111
2.	Blida	1115443 – 3153342 – 2222522 – 314111
3.	El Asnam	1115444 – 2143242 – 2233523 – 223111
4.	Médéa	1115453 – 2143131 – 1122513 – 133121
5.	Bouïra	1115453 – 2143141 – 1223522 – 223221
6.	Tizi Ouzou	1115443 – 3153242 – 2223432 – 314221
7.	Oran	1115443 – 2143141 – 1212522 – 324111
8.	Sidi Bel Abbès	1115453 – 2143131 – 2223523 – 324111
9.	Tlemcen	1115453 – 2143141 – 2223522 – 224111
10.	Saïda	1115453 – 1133141 – 1123513 – 123221
11.	Tiaret	1115454 – 1133131 – 2244525 – 133111
12.	Mostaganem	1115453 – 2143141 – 2222522 – 324111
13.	Mascara	1115453 – 2143231 – 1222523 – 333111
14.	Béjaïa	1115443 – 3153242 – 2222523 – 313121
15.	Jijel	1115343 – 2143131 – 1223523 – 233111
16.	Skikda	1115443 – 2143141 – 2223523 – 223111
17.	Annaba	1115443 – 3153242 – 2222522 – 223221
18.	Guelma	1115453 – 2143131 – 2233524 – 123111
19.	Constantine	1115353 – 1143131 – 1233524 – 133111
20.	Sétif	1115353 – 1143131 – 1133514 – 133221
21.	M'Sila	1115353 – 1133331 – 1122513 – 142111
22.	Batna	1115353 – 1133131 – 1234524 – 142441
23.	Oum El Bouaghi	1115353 – 1133131 – 1123513 – 123221
24.	Tébéssa	1115343 – 2143131 – 1123513 – 123221
25.	Djelfa	1115352 – 1143131 – 1112513 – 142441
26.	Laghouat	1115333 – 2153541 – 4423545 – 515111
27.	Ouargla	1115333 – 4153542 – 4433544 – 515111
28.	Biskra	1115453 – 2133211 – 2333525 – 251111

1. Le découpage acceptable est celui où tous les groupes obtenus s'accordent avec les règles de la Commission concernant les types mondiaux d'ordre III. La distance taxonomique de chaque unité à l'étalon du groupe ne peut donc dépasser 11. L'étalon d'un groupe est construit à partir des moyennes de valeurs normalisées de chaque critère pour toutes les unités (wilayate) appartenant à ce groupe.

2. En vue de minimaliser le nombre de groupes parmi les solutions obéissant au premier principe, il faut retenir celle qui a le nombre de groupes le plus bas. Ces principes permettent un découpage en groupes assez homogènes et peu nombreux.

Aucun des découpages en 2 et 3 groupes n'obéit au premier principe. Parmi les découpages en 4 groupes, il y en a un, obtenu à l'aide de la méthode du voisin le plus éloigné. On a obtenu ainsi les quatre types principaux de l'agriculture autogérée algérienne. Et notamment:

Type **D**: Laghouat, Ouargla.

Type **L**: Alger, Blida, Tizi Ouzou, Béjaïa, Annaba, Tlemcen, Sidi Bel Abbès, Oran, Mostaganem, Mascara, El Asnam, Bouira, Jijel, Skikda.

Type **C**: Guelma, Constantine, Tiaret, Biskra.

Type **H**: Tébéssa, Oum El Bouaghi, Sétif, M'Sila, Médéa, Saïda, Batna, Djelfa.

Le Tableau 4 contient les codes des types.

En mesurant l'homogénéité des groupes à l'aide de la distance interne moyenne

TABLEAU 3. Matrice des distances taxonomiques entre les wilayate

Nº. de wilaya	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
28	23	23	15	18	18	25	21	15	16	20	13	18	14	21	15	15	21	12	14	18	16	18	20	21	25	28	31	
27	18	18	22	33	29	20	26	24	25	33	32	25	27	20	26	24	24	25	27	31	33	37	33	30	42	5		
26	21	19	23	30	26	21	23	21	22	30	29	22	24	21	23	21	25	24	26	30	30	36	30	27	39			
25	28	28	24	11	17	28	20	20	21	13	22	21	17	24	16	20	22	19	15	11	11	9	11	12				
24	20	18	12	5	7	16	12	10	11	5	16	13	11	14	6	8	12	9	9	5	11	15	3					
23	23	21	15	6	8	19	15	11	12	2	13	14	12	17	9	11	15	10	8	4	8	12						
22	31	29	21	16	16	27	23	19	20	14	13	22	18	25	15	19	23	14	10	10	14							
21	21	19	17	8	16	25	17	15	16	10	15	16	10	19	11	15	19	14	10	10								
20	25	23	15	6	10	21	17	13	14	6	11	16	12	19	9	13	17	8	4									
19	21	19	11	8	10	21	13	9	10	10	7	12	8	17	5	9	17	4										
18	17	15	7	8	8	17	11	5	6	10	7	8	8	13	7	5	13											
17	8	6	8	13	7	6	10	12	9	13	20	9	11	4	12	8												
16	12	10	4	9	5	12	6	4	3	9	12	5	7	8	4													
15	16	14	8	7	7	16	8	6	7	11	12	9	5	12														
14	8	4	8	13	11	6	10	10	11	15	20	9	9															
13	15	11	9	6	8	15	7	5	8	12	13	6																
12	13	7	9	10	6	11	3	3	2	12	15																	
11	24	22	12	13	15	24	18	12	13	13																		
10	21	19	13	6	6	17	13	11	10																			
9	13	9	7	10	4	11	5	3																				
8	16	10	8	9	7	12	6																					
7	12	8	10	11	7	12																						
6	10	6	12	19	11																							
5	15	13	9	8																								
4	19	17	13																									
3	12	10																										
2	6																											
1																												

Remarque: Les numéros de wilayate sont les mêmes que dans les Tableaux 1 et 2.

TABLEAU 4. Codes de types

Type	Code
D	1115333 – 3153542 – 4433544 – 515111
L	1115443 – 2143141 – 2223522 – 223111
C	1115453 – 1143131 – 2233524 – 133111
H	1115353 – 1133131 – 1123513 – 133221

(la moyenne de toutes les distances taxonomiques liant chaque couple d'unités appartenant au même groupe), on a trouvé aussi la solution retenue comme la meilleure de toutes les solutions au niveau de 4 groupes. D'autre part les groupes obtenus ont des niveaux d'homogénéité similaires.

Parmi les découpages plus détaillés il y en a un qui donne aussi les niveaux d'homogénéité de groupes similaires. C'est le découpage suivant:

Type **D**: Laghouat, Ouargla.

Type **L**: Soustype **LA**: Alger, Blida, Tizi Ouzou, Béjaïa, Annaba.
Soustype **LO**: Oran, Tlemcen, Sidi Bel Abbés, Mostaganem, Mascara, El Asnam, Bouira, Jijel, Skikda.

Type **C**: Soustype **CC**: Constantine, Guelma, Tiaret.
Soustype **CB**: Biskra.

Type **H**: Soustype **HH**: Tébéssa, Oum El Bouaghi, Sétif, M'Sila, Médéa, Saïda.
Soustype **HB**: Batna.
Soustype **HD**: Djelfa.

Le Tableau 5 contient les codes des soustypes, le Tableau 6, leurs étendues et la carte (Fig. 1), leur répartition en espace.

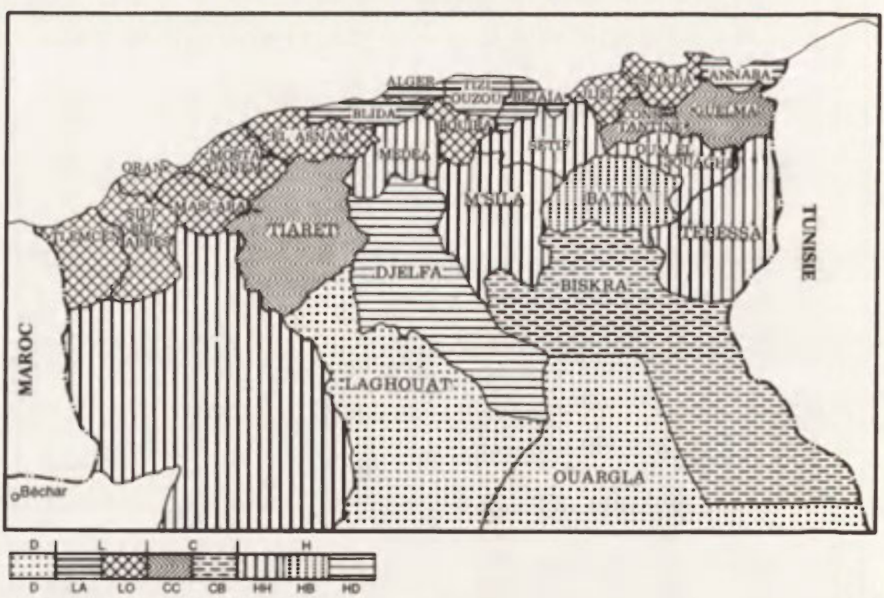

Fig. 1. Types de l'agriculture autogérée

D, L, C, H = types; D, LA, LO, CC, CB, HH, HB, HD. = soustypes

TABLEAU 5. Codes de soustypes

Soustype	Code
D	1115333 – 3153542 – 4433544 – 515111
LA	1115443 – 3153242 – 2222522 – 313111
LO	1115453 – 2143141 – 2223523 – 223111
CC	1115453 – 1143131 – 2233524 – 133111
CB	1115453 – 2133211 – 2333525 – 251111
HH	1115353 – 1133131 – 1123513 – 133221
HB	1115353 – 1133131 – 1234524 – 142441
HD	1115352 – 1143131 – 1112513 – 142441

TABLEAU 6. Etendue, des types et soustypes

Type	Sous-type	ha SAU	ha SAU	%	%
D		378	378	0.0	0.0
L		1 222 208		55,1	
	LA		208 472		9.4
	LO		1 013 736		45.7
H		457 330		20.6	
	HH		411 238		18,5
	HB		38 213		1,7
	HD		7 879		0.4
C		537 468		24,3	
	CC		518 565		23,4
	CB		18 903		0.9
Algérie		2 217 384	2 217 384	100,0	100.0

Remarque: SAU – superficie agricole utile.

DESCRIPTION DES TYPES [12]

TYPE D

Il existe dans deux wilayate sahariennes (Laghouat et Ouargla) avec un climat aride et une densité de population très basse (au-dessous de 3 pers./km²). Cette population est concentrée dans les oasis. L'agriculture, dominée par le secteur privé, se présente sous deux formes:

1. une forme intensive, basée sur la culture des dattes dans les palmeraies irriguées autour des oasis,
2. une forme extensive, basée sur l'élevage extensif des animaux sur de pauvres pâturages, combinée ça et là avec une céréaliculture extensive.

Dans ces deux wilayate, le secteur autogéré est limité presque exclusivement à la forme intensive.

Les exploitations autogérées y étaient relativement petites avec des SAU moyennes

[12] Les types ont été decrits en démontrant surtout les différences entre eux. Les termes: bas, moyen, élevé, petit, grand constatent la position par rapport aux autres types de l'agriculture autogérée algérienne et non la position dans le cadre de l'agriculture mondiale. Tous les chiffres concernent la campagne 1976/1977. La valeur de la production est calculée en unités conventionnelles de J. Kostrowicki – voir note 5.

de 26 et 70 ha et un nombre de travailleurs faible: 15 et 43. C'était l'agriculture la plus intensive de tous les types: la mieux équipée en main d'oeuvre (environ 60 PAT pour 100 ha de SAU) et en matériel de traction (respectivement 200 et 400 CV pour 100 ha de terre cultivée); près de 100% de la SAU étaient irrigués.

C'était une agriculture très spécialisée (coefficients de spécialisation respectifs 0.76 et 1,00) en dattes qui constituaient 87% et 100% de la production commercialisée et qui couvraient 94% et 100% de la SAU. Elle se caractérisait par la productivité de la terre la plus élevée: 54 et 70 unités conventionnelles pour 1 ha de SAU. Quant à la productivité du travail, ces deux wilayate se haussaient aussi aux premiers rangs nationaux. Pratiquement la totalité de la production était commercialisée.

TYPE L

Il s'étend sur le Tell avec son relief accidenté et son climat méditerrannéen. La densité de population y est assez élevée (près de 150 pers./km^2). Quatorze wilayate appartenant à ce type occupent seulement 3% du territoire de l'Algérie mais agglomèrent 60% de sa population. La part du secteur autogéré dans l'agriculture est plus élevée ici qu'ailleurs. Ce type est composé de deux soustypes: **LA** occupe la partie centrale et une portion de la partie orientale du Tell, **LO** occupe la partie occidentale et le reste de la partie orientale.

Les exploitations du soustype **LA** étaient peu étendues mais à main d'oeuvre nombreuse. Quant à la superficie, si l'on fait exception du type **D**, c'étaient les plus petites avec des moyennes respectives compris entre 300 et 600 ha SAU. Mais en ce qui concerne la main d'oeuvre ces exploitations étaient les plus grandes: en principe l'une d'elles avait entre 110 et 140 travailleurs.

Du point de vue de l'intensivité, ce soustype se trouvait à la seconde place après le type **D**. L'équipement en main d'oeuvre était de 15 à 30 travailleurs par 100 ha SAU (et même dans la wilaya d'Alger 46 travailleurs); l'équipement en matériel de traction, de 95 à 130 CV par 100 ha de terre cultivée; l'équipement en cheptel vif, de 15 à 20 unités de gros bovins par 100 ha SAU; 10 à 30% de la terre cultivée étaient irrigués; le coefficient d'intensité de l'utilisation de la terre labourable était de 70 à 100.

C'était l'agriculture la plus polyculturale en Algérie (coefficients de spécialisation de 0,10 à 0,25). Les cultures permanentes y jouaient le rôle principal en couvrant respectivement de 15 à 40% de la SAU. Les agrumes occupaient la première place et entraient pour 20 à 45% dans la formation de la production globale (sauf à Blida où la viticulture avec 20% de la production globale était une branche importante). Un rôle assez important y était joué par les cultures maraîchères, surtout les pommes de terre et les tomates. Par contre l'importance des céréales était relativement restreinte — de 5 à 20% de la production globale.

Par rapport aux autres types, la part de la production animale était significative — de 15% à 30% de la production (surtout l'élevage laitier des bovins).

En termes de productivité de la terre, le soustype **LA** ne cédait qu'au type **D**: la production globale moyenne d'un ha de SAU était de 9 à 18 unités; celle d'un ha de terre cultivée, de 10 à 20 unités et la production commercialisée d'un ha de SAU, de 8 à 15 unités. Par contre la productivité du travail y était la plus basse: de 40 à 80 unités de production globale et de 30 à 60 unités de production commercialisée par travailleur. Le degré de commercialisation, lui aussi, était le plus bas (78 à 86%). Cela peut s'expliquer par le rôle de l'élevage.

Les exploitations du soustype **LO** étaient plus grandes en ce qui concerne la superficie (de 800 à 1200 ha SAU), et moins grandes quant à la main d'oeuvre (généralement de 80 à 110 travailleurs par exploitation), par rapport au soustype **LA**. Ce soustype était moins intensif que le soustype **LA** avec un équipement en main d'oeuvre généralement compris entre 7 et 11 PAT, pour 100 ha SAU, un équipement en matériel de traction de 35 à 75 CV pour 100 ha de terre cultivée et un équipement en cheptel vif de 4 à 10 unités de gros bovins pour 100 ha de SAU.

C'était une agriculture un peu moins polyculturale que le soustype **LA** mais plus polyculturale que tous les autres types (coefficient de spécialisation de 0.15 à 0,30, seule la wilaya de Jijel atteignait 0,39). Les cultures permanentes occupaient de 10 à 30% de la SAU. Dans la partie occidentale, c'était la vigne qui dominait (jusqu'à 40% de la production commercialisée) et dans les wilayate de Mascara, El Asnam et Skikda, les agrumes (40 à 45% de la production commercialisée). Une production secondaire mais non negligeable, les olives, constituait 5 à 10 % de la production commercialisée. La part des céréales était très différente: elle variait de 15% dans la wilaya de Mascara jusqu'à 63% dans la wilaya de Jijel. Dans certaines wilayate, les pommes de terre se trouvaient parmi les productions importantes.

Le rôle des productions animales était assez restreint: 7 à 16% de la production globale et de la production commercialisée; dans la plupart des wilayate, moins de 10%; dans la wilaya de Bouïra seulement respectivement 22 et 26%. L'élevage des bovins (surtout pour le lait) constituait la branche principale et l'élevage des ovins (surtout pour la viande), la branche supplémentaire.

Par rapport au soustype **LA**, la productivité de la terre était plus basse: la production globale et commercialisée à l'hectare de SAU variait de 4 à 6 unités. La productivité du travail était, au contraire, un peu plus élevée: généralement de 55 à 90 unités de production globale et commercialisée par travailleur. Le degré de commercialisation était aussi plus élevé: généralement de 93 à 97%.

TYPE C

Le soustype **CC** composé des wilayate de Tiaret, Guelma et Constantine constitue le noyau de ce type. Ces wilayate occupent les Hautes Plaines situées au sud de l'Atlas Tellien et aussi en partie ses versants meridionaux. Comme elles sont séparées de la Méditerranée par la chaîne de l'Atlas Tellien, le climat y est continental et les précipitations atmosphériques sont, en moyenne, plus basses que sur le littoral. La densité de population est différente (respectivement 28, 68 et 77 pers./km^2) mais plus basse que sur le littoral. Au même type appartient la wilaya de Biskra qui constitue à elle toute seule le soustype **CB**. C'est une wilaya saharienne proche des wilayate limitrophes de Laghouat et Ouargla, appartenant au type **D**, quant aux conditions physiques et démographiques.

Du point de vue de la superficie, les exploitations du soustype **CC** étaient plus grandes que celles des types **D** et **L**: respectivement 2700 ha, 1200 ha et 1500 ha de SAU (environ) par exploitation, mais moyennes en ce qui concerne la main d'oeuvre: de 40 à 60 travailleurs par exploitation.

L'agriculture y était moins intensive que celles des types **D** et **L**. L'équipement en main d'oeuvre était de 2 à 4,5 PAT pour 100 ha de SAU; l'équipement en matériel de traction, de 15 à 40 CV pour 100 ha de terre cultivée; l'équipement en cheptel vif, de ca 4 unités de gros bovins pour 100 ha de SAU. La superficie irriguée constituait seulement de 0 à 4% de la terre cultivée et le coefficient de l'intensité de l'utilisation des terres labourables était de 60 à 70.

C'était une agriculture assez spécialisée (coefficients de spécialisation 0,81, 0,47 et 0,56) dans la culture des céréales qui constituaient de 70 à 95% de la production totale (globale et commercialisée) et 80 à 100% des productions végétales. Les cultures permanentes, qui couvraient de 0,2 à 5,4% de SAU, n'y jouaient pas de rôle significatif. Les productions animales, dont la part dans la production était variée: 2, 9 et 14%, n'étaient pas non plus une branche importante. On y élevait les ovins (surtout pour la viande) et les bovins (surtout pour le lait).

La productivité de la terre y était plus basse que dans les types **D** et **L** mais plus élevée que dans le type **H**: la production globale et commercialisée à l'hectare de SAU était de 4 à 8 unités. Mais la productivité du travail y était la plus élevée: 390 unités par travailleur dans la wilaya de Tiaret et ca 120 unités dans deux autres. Le degré de commercialisation était de 97 à 100%.

Le soustype **CB** était different à certains égards du soustype **CC**. Son milieu était le même que celui du type **D**. Mais il présentait les deux formes de l'agriculture saharienne: intensive et extensive. Cela l'éloignait du type **D** et le rapprochait du type **C**. Outre la culture des dattiers, qui occupaient seulement 14% de la SAU, mais donnaient 96,5% de la production, on y rencontrait, sur une petite échelle, la culture extensive des céréales ainsi que les pacages et des jachères étendus, presque inutilisés à cause du manque de cheptel vif: 1,7 unité de gros bovins pour 100 ha de SAU. Les productions animales constituaient d'ailleurs seulement 0,2% de la production totale.

Le soustype **CB** différait aussi du soustype **CC** par un meilleur équipement en main d'oeuvre (81 travailleurs par exploitation, 7 PAT pour 100 ha de SAU), par la part plus élevée des terres irriguées (21%) mais, par contre, par l'intensité beaucoup plus basse de l'utilisation de terres labourables (5). La productivité de la terre cultivée y était plus élevée (44 unités), bien que la production à l'hectare de SAU totale ne fût pas différente de celle du soustype **CC**.

TYPE H

Les wilayate appartenant au type **H** occupent les Hautes Plaines entre l'Atlas Tellien et l'Atlas Saharien. Seule la wilaya de Médéa est située en grande partie sur le versant méridional de l'Atlas Tellien.

Les exploitations autogérées y étaient grandes du point de vue de la superficie (1 à 2 mille ha SAU) mais petites du point de vue de la main d'oeuvre (25 à 60 travailleurs).

Le type **H** représentait une agriculture moins intensive que les types **D** et **L**. L'équipement en main d'oeuvre était de 1 à 4 PAT pour 100 ha de SAU; l'équipement en matériel de traction, de 20 à 30 CV pour 100 ha de terre cultivée; l'équipement en cheptel vif, de 3 à 7 unités de gros bovins pour 100 ha de SAU. La part de la surface irriguée dans la terre cultivée ne dépassait 2%. Le coefficient de l'intensité de l'utilisation de la terre labourable se situait entre 60 et 70.

Cette agriculture était moins spécialisée (coefficient de 0,20 à 0,45) que les types **D** et **C** mais plus que le type **L**. La culture des céréales dominait avec 60 à 70% de la production totale et 80 à 100% des productions végétales. Les cultures permanentes couvraient seulement de 0,4 à 4,1% de la SAU, sauf pour la wilaya de Médéa où elles atteignaient 9%, grâce à la viticulture. Ce type se caractérisait par le rôle plus important des productions animales: de 15 à 35% de la production totale. L'élevage des ovins (pour la laine et pour la viande) constituait la branche principale des productions animales et l'élevage laitier des bovins, la branche supplémentaire.

La productivité de la terre y était la plus basse: la production à l'hectare de SAU était de 1 à 3 unités et à l'hectare de terre cultivée de 3 à 4,5 unités. La productivité du travail était assez différenciée et variait de 40 à 110 unités par travailleurs. Le degré de commercialisation était de 91 à 98%.

Les wilayate de Djelfa et Batna se distinguaient des autres appartenant à ce type par l'importance de l'élevage des ovins. C'étaient les seules en Algérie orientées vers l'élevage. La part des productions animales dans la production globale et commercialisée était respectivement de 77% et 79% dans la wilaya de Batna et de 61% et 69% dans la wilaya de Djelfa.

Elles ne se distinguaient des autres wilayate de ce type ni par la taille des exploitations ni par l'intensivité ni même par la culture dominante – les céréales. Les différences concernaient les critères de production mais dans deux sens opposés. L'agriculture de la wilaya. de Batna était plus productive que celles des autres wilayate de ce type: production à l'hectare de SAU proche de 4 unités, production à l'hectare de terre cultivée proche de 10 unités, et de 210 à 220 unités par travailleur. Pour ce dernier indicateur, elle se trouvait à la seconde place en Algérie après la wilaya de Tiaret. La valeur de cet indicateur était 2 à 5 fois plus élevée que dans les autres wilayate algériennes.

Par contre l'agriculture de la wilaya de Djelfa était moins productive: la production à l'hectare de SAU y était de 0,4 unité; à l'hectare de la terre cultivée de 1,2 unité et de 30 unités par travailleur. Le degré de commercialisation y était aussi un peu plus bas: 88%.

COMPARAISON AUX TYPES MONDIAUX DE L'AGRICULTURE

Les types de l'agriculture autogérée algérienne, distingués et décrits ci-dessus, ont été comparés aux types mondiaux de l'agriculture définis par J. Kostrowicki. A l'aide de la formule mentionnée ci-dessus, on a calculé les distances taxonomiques des unités étudiées (wilayate) aux étalons des types mondiaux. Les distances aux types les plus proches sont contenues dans les Tableaux 7–10.

TABLEAU 7. Distances taxonomiques des wilayate du type **D** aux étalons des types mondiaux

Nº.	Wilaya	T	M	S	*Sh*	*Shv*	*Shf*	*Shj*	*Shh*
26	Laghouat	42	**31**	**28**	**19**	18	16	18	23
27	Ouargla	39	**30**	**25**	**18**	15	17	17	22

TABLEAU 8. Distances taxonomiques des wilayate du type **L** aux étalons des types mondiaux

Nº.	Wilaya	M	T	S	*Sc*	*Sm*	*Se*	*Scc*	*Smc*	*Smj*	*Shj*	*Sem*	*Sec*
1	Alger	34	35	**19**	27	25	**19**	24	18	20	13	21	15
2	Blida	36	35	**19**	23	27	**17**	20	20	20	13	21	13
6	Tizi Ouzou	34	**33**	**13**	25	**21**	**15**	22	14	18	15	17	13
14	Béjaïa	34	35	**17**	23	25	**17**	20	18	16	13	19	13
17	Annaba	**32**	**33**	**15**	25	**21**	**13**	22	14	14	17	15	**11**
9	Tlemcen	37	38	**16**	**16**	**20**	**14**	13	17	15	14	18	12
8	Sidi Bel Abbés	38	41	**17**	**15**	23	**15**	12	20	16	13	19	13
7	Oran	40	39	**21**	**19**	25	**15**	18	22	16	17	21	13
12	Mostaganem	39	38	**18**	**18**	**22**	**14**	15	19	15	14	20	12
13	Mascara	39	42	**20**	**18**	24	**18**	17	21	13	14	20	14
3	El Asnam	**32**	39	**13**	**17**	**19**	**19**	14	14	14	**11**	17	15
5	Bouïra	35	38	**16**	**18**	**18**	**14**	17	15	**11**	16	16	14
15	Jijel	36	41	**21**	**17**	23	**17**	16	22	14	17	17	15
16	Skikda	34	39	**17**	**17**	**21**	**15**	14	18	14	13	17	13

TABLEAU 9. Distances taxonomiques des wilayate du type **H** aux étalons des types mondiaux

N°.	Wilaya	M	E	S	*Sc*	*Sm*	*Se*	*Scc*	*Sme*	*Smc*	*Smj*	*Shj*	*Sec*
24	Tébéssa	34	36	**19**	**17**	23	**15**	18	22	22	14	21	**15**
23	Oum El Bouaghi	37	35	**20**	**16**	24	**16**	17	21	21	15	22	**16**
20	Sétif	35	37	**20**	**14**	**22**	**20**	15	19	23	13	20	**20**
21	M'Sila	39	39	**26**	**20**	28	**22**	21	23	27	17	22	**18**
4	Médéa	39	37	**20**	**16**	**22**	**16**	17	21	23	11	20	**14**
10	Saïda	37	37	**18**	**16**	**22**	**16**	17	21	19	13	20	**16**
22	Batna	35	39	**26**	**20**	**20**	24	19	**11**	27	17	26	24
25	Djelfa	42	36	**29**	25	25	25	26	16	32	18	31	25

TABLEAU 10. Distances taxonomiques des wilayate du type **C** aux étalons des types mondiaux

N°.	Wilaya	A	M	S	*Sc*	*Sm*	*Se*	*Scc*	*Sme*	*Smj*	*Shj*	*Sem*	*Sec*
18	Guelma	42	**33**	**16**	**12**	**20**	**16**	**9**	19	13	12	16	14
19	Constantine	43	35	**20**	**12**	**22**	**20**	**11**	19	13	16	18	18
11	Tiaret	37	36	**21**	**11**	**21**	**21**	**8**	16	16	17	19	19
28	Biskra	36	39	**24**	**22**	26	24	19	25	19	18	22	20

L'affectation au type mondial d'ordre I ne fait aucun doute. C'est le type *S*[13] (agriculture socialisée) qui, de tous les types, est le plus proche de toutes les wilayate. C'est le type algérien **L** qui est le plus proche du type *S* et le type **D** en est le plus éloigné. Mais en aucun cas la distance à l'étalon de ce type ne dépasse 33.

Quant aux types d'ordre II, en obéissant à la règle de la distance maximale 22, on peut affecter sans aucun doute le type **D** au type mondial *Sh*. Les wilayate du type algérien **C** sont les plus proches du type *Sc* et les wilayate du soustype **LO** du type *Se*. C'est donc dans ces types qu'il faut les classer. Le type **H** ainsi que le soustype **LO** pourraient être considérés comme intermédiaires entre *Sc* et *Se*, bien qu'ils ressemblent un peu (surtout le soustype **LO**) au type *Sm*[14]. Mais, tout compte fait, il faut affecter le type **H** au type *Sc* duquel il est le plus proche et le soustype **LO**, au contraire, au type *Se*. La wilaya de Djelfa est la seule qui ne peut être incorporée à aucun des types mondiaux d'ordre II. Mais elle serait un fondement

[13] Agriculture socialisée (collective ou étatique) aux exploitations de grande taille, à l'intensivité et la productivité différenciées, hautement commercialisée. Voir J. Kostrowicki: A hierarchy..., op. cit.

[14] Type *Sc*: Agriculture socialisée, extensive basée sur la céréaliculture; distinguée en Union Soviétique. Type *Sh*: Agriculture socialisée intensive orientée vers les cultures alimentaires horticoles; distinguée dans plusieurs pays socialistes européens. Type *Se*: Agriculture socialisée initiale; distinguée en Bulgarie, Roumanie et Union Soviétique. Type *Sm*: Agriculture socialisée extensive mixte; distinguée dans plusieurs pays socialistes européens. En ce qui concerne les détails, voir J. Kostrowicki: A hierarchy..., op. cit.

douteux à la distinction d'un nouveau type mondial, d'autant qu'elle est assez proche des types *Sc*, *Sm* et *Se*.

Par contre en ce qui concerne les types d'ordre III, seulement 8 des 28 wilayate pourraient être affectées à un type déjà décrit. Et la distance de 6 de ces 8 wilayate au type mondial n'est que de 11, donc borne. Ainsi les cas étudiés peuvent constituer le fondement d'un élargissement de la liste des types mondiaux. Le soustype **CC** seul peut être indiscutablement incorporé au type *Scc*[15].

Le type **H** surtout peut être traité comme un type mondial nouveau (p.ex. avec le symbole *Sca*). Il se distingue de types déjà décrits et sa superficie – environ 457 000 ha – n'est pas négligeable. Le type **D** et le soustype **CB** sont aussi suffisamment distincts pour devenir des noyaux de types nouveaux (p.ex. *Sho* et *Sco*). Mais c'est plus discutable à cause de leurs superficies restreintes (Tableau 6).

Le cas le plus compliqué est représenté par le type **L**. D'une part seulement 3 des 14 wilayate appartenant à ce type peuvent être affectées aux types déjà

TABLEAU 11. Proposition d'affectation des wilayate aux types mondiaux

No.	Wilaya	Type	Distance de l'étalon
1.	Alger	*Shj*?	13
2.	Blida	*Shj/Sec*?	13
3.	El Asnam	*Shj*	11
4.	Médéa	*Sca*	5
5.	Bouïra	*Sca*	9
6.	Tizi Ouzou	*Sec*?	13
7.	Oran	*Sec*?	13
8.	Sidi Bel Abbés	*Sca/Scc*?	12
9.	Tlemcen	*Sec*?	12
10.	Saïda	*Sca*	3
11.	Tiaret	*Scc*	8
12.	Mostaganem	*Sec*?	12
13.	Mascara	*Sca*	11
14.	Béjaïa	*Shj/Sec*?	13
15.	Jijel	*Sca*	8
16.	Skikda	*Sca*?	12
17.	Annaba	*Sec*	11
18.	Guelma	*Scc/Sca*	9
19.	Constantine	*Sca*	7
20.	Sétif	*Sca*	3
21.	M'Sila	*Sca*	7
22.	Batna	*Sca*	11
23.	Oum El Bouaghi	*Sca*	1
24.	Tébéssa	*Sca*	5
25.	Djelfa	*Sca*	10
26.	Laghouat	*Sho*	4
27.	Ouargla	*Sho*	1
28.	Biskra	*Sco*	0

[15] Type *Scc*: Agriculture socialiste extensive basée sur la céréaliculture; distinguée au sud-est de la partie européenne de l'Union Sovietique. Voir J. Kostrowicki: A hierarchy... op. cit.

connus et 2 autres encore – au type nouveau *Sca*. Il en reste donc 9. Mais d'autre part les distances taxonomiques de ces 9 wilayate aux étalons des types mondiaux les plus proches d'elles sont 12 et 13 – elles ne sont pas donc très éloignées des types déjà décrits – et la distinction d'un nouveau type serait dans ce cas discutable (ne pas multiplier les êtres plus qu'il ne faut!). Cette question ne peut être resolue sans un réexamen des étalons des types concernés [16] et de leurs fondements.

RÉSUMÉ

I. La méthode de la Commission de Typologie Agricole de l'UGI peut être appliquée au secteur autogéré de l'agriculture algérienne. Les données existantes le permettent. On peut confirmer encore une fois que cette méthode est applicable aux pays du Tiers Monde.

II. L'agriculture autogérée algérienne se divise en quatre types principaux:

1) Agriculture saharienne intensive basée sur la culture des dattiers.

2) Agriculture méditerranéenne "polyculturale" dominée par la culture des fruits et des légumes.

3) Agriculture des hautes plaines basée sur la céréaliculture.

4) Agriculture extensive des hautes plaines basée sur la céréaliculture et l'élevage des ovins.

III. L'agriculture étudiée peut être classée dans le cadre du système mondial des types d'agriculture d'ordre I et II déjà décrits. En ce qui concerne les types mondiaux d'ordre III. on peut proposer l'élargissement de leur liste par trois types nouveaux:

– *Sca*: Agriculture socialisée extensive basée sur la céréaliculture et l'élevage. Code: – 1115353 – 1133131 – 1123513 – 133221.
– *Sho*: Agriculture socialisée désertique intensive basée sur la culture des fruits (dattes) dans les oasis. Code: 1115333 – 3153542 – 4433544 – 515111.
– *Sco*: Agriculture socialisée désertique combinant la culture intensive des fruits dans les oasis avec la culture extensive des céréales. Code: – 1115453 – 2133211 – 2333525 – 251111.

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[16] Surtout types *Shj* et *Sec*. Type *Shj*: Agriculture socialisée spécialisée dans la culture des fruits et des legumes; distinguée en Yougoslavie. Type *Sec*: Agriculture socialisée initiale mixte à productions végétales dominantes; distinguée en Roumanie et en Union Soviétique. Pour les détails voir: J. Kostrowicki: A hierarchy.... op. cit.

AGRICULTURAL TYPOLOGY OF BULGARIA

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The study presents an attempt at the agricultural typology of Bulgaria, prepared in accordance with the latest version of world agricultural typology method (Kostrowicki 1980).

Bases and methodological premises of world agricultural typology were prepared by the Commission on Agricultural Typology of the IGU a few years ago (Kostrowicki 1973, 1977) and have been used in many typological studies concerned with agriculture in numerous countries and regions.

The present study on Bulgarian agriculture is based on statistical data referring to the year 1976, arranged according to 28 districts, called *okryzii* (see Fig. 1). This material has also been used as a basis of the map of Bulgaria's types of

Fig. 1. Administrative division

agriculture, which is a part of types of agriculture map of Europe prepared under the supervision of Professor Jerzy Kostrowicki by the Department of the Geography of Agriculture and Rural Areas of the Institute of Geography and Spatial Organization. Polish Academy of Sciences (Kostrowicki 1982).

Bulgarian agriculture is a large-scale, socialized agriculture. The adoption of this organizational form has brought about far-going changes in land-use as well as in the organization of production and management; it has also made necessary to introduce a large-scale mechanization and machine work in agriculture, and to increase inputs on agricultural production.

Results obtained by Bulgaria are an evidence that the adopted conception of the organization of agriculture is correct; this branch of economy has become a valuable partner of industry and an important source of exports. In 1977 the raw materials of vegetable and animal origin, together with processed products of agricultural origin accounted for 29.3% of the country's total export.

Transformations in Bulgarian agriculture were initiated by the agricultural reform of 1946, which limited the area of the individual holding to 20 ha, and in part of Southern Dobrudja to 30 ha. Land obtained thanks to the reform was subdivided among small farmers and landless people. The reform affected somewhat only a part of the country (north-eastern), as in the remaining area there were no larger farms. Therefore, some further moves and decisions which could bring about important changes in agriculture were made.

The subsequent step was socialization of agriculture. It seems worth while emphasizing that the process of socialization, which was fully successful in Bulgaria, has its roots in the period of the capitalist economy, when some attempts were already made to organize collective farms modelled partly on Soviet kolkhozes and partly on Italian communes. Many collective farms were then formed, mainly in the region of Plovdiv, Vratsa and Burgas; 33 of them survived unitl September 1944. Those were either independent co-operatives, or production branches of rural consumers' co-operatives. A majority of them practised a non-specialized agriculture. Their efforts to raise the technical standards, rationalize production, increase yields, and improve livestock production, as well as to better labour conditions, to get higher investment and develop social facilities were quite successful (Grigoroff 1956, Strużek 1963).

As a result of socialization of agriculture the two types of farms have developed: collective (TKZS) and state (DZS). The process of socialization proceeded so rapidly that by 1957 already 91% of holdings had been socialized. It was totally completed in 1959, though the rate of its implementation was uneven, having been very rapid in the regions specializing in grain crops and slow in the mountainous areas.

Further changes were initiated as early as in 1958. Economically weak holdings were then amalgamated to form larger and more efficient farms. For example, out of 3202 collective farms in 1957, in 1965 there remained 920, and 725 in 1971. The number of state farms increased only slightly (104 in 1965 and 149 in 1971). Those changes brought about a substantial increase in the average areas of cultivated land per farm.

The process of transformations was continued. In the 1970s new forms of the organization of agricultural production were introduced not only in Bulgaria, but also in the remaining countries of the Socialist Camp. However, in Bulgaria the model of further development through concentration and specialization in agriculture was slightly different. Following the amalgamation of collective (TKZS) with state (DZS) farms, or of collective farms only, agro-industrial complexes (APK) were organized, in which the processing industry of agricultural goods became the leading factor in the integration process, as well as other economic organizations, closely connected with agriculture, were also included (Otoliński 1976).

The principal aims underlying the organization of the agro-industrial complexes are: to secure better production effects and to adapt methods as well as the scale of agricultural production to the already achieved level of concentration and modernization in processing industries by speeding up complex mechanization and technical modernization in agriculture, and to check up population outflows from rural to urban areas by improving working conditions and raising living standards in the former. An evidence of the organizational changes is the changing number of complexes. In 1971 there were 170 complexes, whereas in 1976 their number went down to 143. However, in 1978 the number of complexes reached again 170.

In 1976 some changes affected also the system of the management of the country's economy. Under the Ministry of Agriculture and Food Industry, a National Agro-Industrial Complex was called into being to control the manufacture of production means, agricultural production, purchase, processing, storage, and selling, as well as scientific and technical services associated with the activities listed above. Decisions became then more and more centralized and rights of individual components of the complex were curtailed.

In the spring of 1979, however, the Ministry of Agriculture and Food Industry was liquidated and a National Agro-Industrial Union was established. The new Union was entrusted with all the rights as regards the steering of food economy, and it is quite likely that this change will affect the activity of the APK and the whole system of management. Stolinska-Janic (1980) believes that the fact that the system of running the National Union as well as the internal system of management of the APK are based on self-government and election of all-rank organs is an important factor since similarity between the two systems has opened up new perspectives for the strengthening and consolidation of all elements and features of democracy, typical of the co-operative movement, which have been inherited by the APK from collective farms.

In 1976, that is the year analysed by the author in detail, 90.8% of agricultural land were held by the socialized sector; plots owned by members of collective farms and persons employed outside agriculture accounted for the remaining percentage.

Land under agricultural use covers 55.9% of Bulgaria's area. Out of agricultural land (6.2 million ha) cultivated land occupies 4.7 million ha, of which arable land amounts to 3.9 million ha, mown meadows and cultivated pastures to 429 thousand ha, and perennial crops to 371 thousand ha. Non-cultivated pastures, lying predominantly in the mountains (almost 1.5 million ha), take the remaining area of agricultural land.

Since Bulgaria is predominantly a mountainous country the area of cultivated land is limited and therefore very intensively utilized. For example, thanks to heavy fertilization and irrigation two or three yields per year are a common occurrence. Spatial differences in the relief and quality of soils largely affect the land-use orientations. For example, in the southern, mountainous part the proportion of perennial grassland (pastures) was 76.5% (Smolyan) and 67.5% in Blagoevgrad, whereas in the northern part it was merely 8.1% (Ruse), or 9.8% in the district of Tolbukhin. This high percentage of low-productive perennial grassland has caused that already for a long time the sheep breeding has been favoured there. Though in Bulgaria, as a whole, cattle and pigs breeding is on the increase thanks to fodders from cultivated land, sheep breeding plays still an important role in livestock breeding. The average number of livestock per 100 ha of agricultural land is, however, not high (59.1 big conventional units).

Work is highly mechanized. Basic field work, like ploughing, harrowing, sowing, and harvesting cereals and oleaginous crops, is almost totally mechanized. Harvesting of vegetables and fruit is, however, little mechanized. In 1974 in animal production milking was mechanized in 79%, sheep shearing in 68% and removal of animal waste in 56% (Otolinski 1976).

The use of chemical fertilizers varies from region to region and oscillated between 76.4 kg NPK per ha of agricultural land in the district of Gabrovo and 187.6 kg in the district of Plovdiv.

The irrigated area increases also from year to year. In 1976 it amounted to 1147 thousand ha.

High inputs spent on fertilization, irrigation and mechanization of agricultural production bring about gratifying productive results. For example, in 1976 the average yield of wheat was 39.7 q/ha (in 11 districts it has even exceeded 40 q/ha), of barley – 34 q/ha, sugar beet – 332 q/ha, and of fodder beet – 594 q/ha. The increasing vegetable production is predominantly an effect of both a larger area under crops, as well as obtained yields (e.g. of barley, maize, tobacco). However, sometimes, e.g. as regards wheat, the growth of production was caused by much higher yields since the area under this cereal steadily diminishes.

A characteristic feature of Bulgarian agriculture is the predominance – though diminishing – of crop production over animal production. In 1977 the former accounted for 54.6% of gross production, when in 1970 its share had been 64.7%. Cereals and fodder crops prevailed in agricultural gross production, whereas vegetables and fruit in commercial production, as well as industrial plants played also an important role together with cereals.

In the 1970s the proportion of animal production in gross production increased because of both a growing number of livestock and higher productivity per head.

Transformations occurring in Bulgaria's agriculture have brought about constant changes to the rural areas. One of the most important changes is a diminishing labour force. This is a continuous process, caused by the outflow of population, mainly the younger generation, to work in industry and towns. The spatial distribution of this process is uneven; it is often influenced by such factors as the proximity of a town or a factory, or even the production profile of the farms. Where farms are highly mechanized and the production of cereals dominates, bigger numbers of males are willing to remain and work as mechanics or skilled workers tending machines (Borissov 1974). In the farms where labour-consuming, little-mechanized work prevails, the situation is quite different.

The age structure of the rural communities undergoes undesirable changes, particularly among people employed in agriculture. Their number, in the over 50-year group has substantially been increasing, while that of younger people diminishing. The outflow of younger people is often caused by a great disproportion between wages in agriculture and other branches of economy. This is particularly true of seasonal labourers.

The development of the agro-industrial complexes seems to be a promise to check up the outflows of population from agriculture since there are better prospects for higher wages owing to the amalgamation of agricultural and industrial enterprises. This might become an incentive to keep young people in the rural areas.

The typological approach in the analysis of the spatial structure of agriculture has made it possible to present it in a synthetic picture. The final effect of this procedure is the identification of agricultural types singled out on the basis of the combination of characteristics representing all essential aspects of agriculture. Bulgaria's agricultural typology is a result of the analysis of 27 variables, successively representing the 7 social and ownership, 7 operational, 7 productive, and 6 structural characteristics (Kostrowicki 1980, 1982).

Subsequently, the indices representing those characteristics have been normalized on the basis of the five-class world divergences, which include the following groups: 1) very low, 2) low, 3) medium, 4) high, and 5) very high. Agricultural types and their place within the model of world agricultural types have been identified by means of the deviation method (Kostrowicki 1980). A computer has therefore been used to compare the codes for Bulgaria's separate administrative units with the model codes of world types of agriculture.

The comparison reveals that Bulgarian agriculture is similar to the following models of the third-rank types of world agriculture:

Sem 1115443 – 3233132 – 2333321 – 133331
Smm 1115555 – 2144143 – 3434432 – 132341
Smc 1115555 – 3233242 – 3433432 – 223221
Smu 1115555 – 3144243 – 3344534 – 114222
Smi 1115555 – 2154443 – 4455543 – 122222

The method of successive quotients (four successive quotients) has been used to determine the degree of similarity between the units under study and the models (Tyszkiewicz 1977). Various combinations of the third-rank types, which have been obtained, are an evidence that agriculture is complex in the separate districts.

In Bulgaria the most frequent agricultural types are: *Smc* and *Smm*, which dominate in some areas, while in others they enter into combination with one another, or with some other types.

The *Smc* type, representing mixed agriculture with crop production prevalent, dominates in the western part of Thracian Valley (districts of Pazardzhik and Plovdiv) and in the district of Sliven (Fig. 2, Table 1). Agriculture in those parts is characterized by high inputs on mechanization and chemical fertilization, as well as on irrigation. The highest percentage of irrigated land is found in the districts of Plovdiv and Pazardzhik (over a half of cultivated land). Arable land is there utilized intensively and yields are high. Irrigation is necessary there because of insufficient soil humidity; in some places precipitation does not exceed 500 mm per annum (Maruszczak 1971).

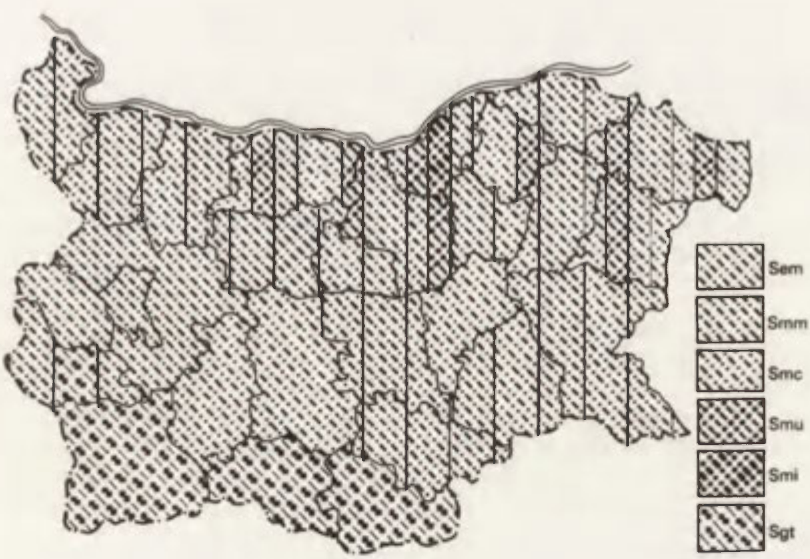

Fig. 2. Agricultural types in Bulgaria

TABLE 1. Agricultural types in Bulgaria

No.	Districts	Agricultural type	Typological characteristics																										
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1.	Blagoevgrad	Sgt_4	1	1	1	5	5	5	5	3	4	4	4	4	3	3	2	3	2	2	4	2	2	1	4	1	2	3	2
2.	Burgas	Smm_2Smc_2	1	1	1	5	5	5	5	2	2	4	4	2	4	3	3	3	3	3	4	3	1	1	2	2	2	2	1
3.	Gabrovo	Smm_2Smc_2	1	1	1	5	5	5	5	2	3	4	3	2	4	3	3	3	4	3	3	3	2	1	3	3	2	3	1
4.	Khaskovo	Smm_2Smc_2	1	1	1	5	5	5	5	3	3	4	4	3	4	3	3	3	3	3	4	3	1	1	2	1	2	3	1
5.	Kurdzhali	Sgt_4	1	1	1	5	5	5	5	4	4	4	4	2	4	3	2	2	1	1	4	2	3	1	3	1	2	2	3
6.	Kyustendil	Smm_2Sgt_2	1	1	1	5	5	5	5	2	2	4	4	3	4	3	2	3	2	3	4	2	2	1	3	1	3	3	1
7.	Lovech	Sem_2Smm_2	1	1	1	5	5	5	5	2	3	3	4	2	4	3	2	3	3	3	3	2	1	1	3	1	3	3	1
8.	Mikhaylovgrad	Smm_2Smc_2	1	1	1	5	5	5	5	2	2	4	4	2	4	3	3	3	3	3	4	3	2	1	2	2	2	3	1
9.	Pazardzhik	Smc_4	1	1	1	5	5	5	5	3	2	4	4	4	4	3	3	3	3	3	4	3	1	2	2	2	2	3	1
10.	Pernik	Smm_4	1	1	1	5	5	5	5	2	1	3	4	2	3	3	2	3	3	3	4	2	2	1	3	2	3	4	1
11.	Pleven	$Smm_1Smc_2Smu_1$	1	1	1	5	5	5	5	2	2	4	4	3	4	3	3	3	4	3	4	3	2	1	1	2	2	2	1
12.	Plovdiv	Smc_4	1	1	1	5	5	5	5	3	3	4	4	4	4	3	3	4	3	3	4	3	1	2	2	2	2	2	1
13.	Razgrad	$Smm_1Smc_2Smu_1$	1	1	1	5	5	5	5	3	2	4	4	2	4	3	3	3	3	3	4	3	1	1	1	2	2	3	1
14.	Ruse	$Smm_1Smc_1Smu_1Smi_1$	1	1	1	5	5	5	5	3	2	4	4	2	4	3	4	4	4	4	4	4	1	1	1	2	2	2	1
15.	Shumen	Smm_2Smc_2	1	1	1	5	5	5	5	3	2	4	4	2	4	3	3	3	3	3	4	3	1	1	1	2	2	3	1
16.	Silistra	Smm_2Smc_2	1	1	1	5	5	5	5	3	2	4	4	1	4	3	3	4	3	3	3	3	1	1	1	2	2	2	1
17.	Sliven	Smc_4	1	1	1	5	5	5	5	2	2	4	4	3	4	3	3	3	3	3	4	3	1	2	2	2	2	2	1
18.	Smolyan	Sgt_4	1	1	1	5	5	5	5	3	4	4	4	2	3	3	2	3	1	2	4	2	2	1	4	1	2	3	1
19.	Sofiya-city	Smm_4	1	1	1	5	5	5	5	3	2	4	4	3	4	4	3	3	4	3	3	3	3	1	2	1	3	4	1
20.	Sofiya	Smm_4	1	1	1	5	5	5	5	2	2	3	3	2	4	3	2	3	3	3	4	2	2	1	3	1	3	4	1
21.	Stara Zagora	Smm_2Smc_2	1	1	1	5	5	5	5	2	2	4	4	3	4	3	3	3	4	3	4	3	2	1	2	2	2	3	1
22.	Tolbukhin	$Smm_2Smc_1Smu_1$	1	1	1	5	5	5	5	2	2	4	4	1	4	3	3	4	4	4	4	3	2	1	1	2	2	2	1
23.	Tŭrgovishte	Smm_2Smc_2	1	1	1	5	5	5	5	3	2	4	4	2	4	3	3	3	3	3	4	3	1	1	2	2	2	3	1
24.	Varna	$Smm_1Smc_2Smu_1$	1	1	1	5	5	5	5	2	2	4	4	2	4	3	3	3	3	3	4	3	2	1	1	2	2	2	1
25.	Veliko Tŭrnovo	$Smm_2Smc_1Smu_1$	1	1	1	5	5	5	5	2	2	4	4	3	4	3	3	3	4	3	4	3	1	1	1	2	2	3	1
26.	Vidin	Smm_2Smc_2	1	1	1	5	5	5	5	2	2	4	4	3	4	3	3	3	3	3	4	3	2	1	2	2	2	3	1
27.	Vratsa	Smm_2Smc_2	1	1	1	5	5	5	5	2	2	4	4	3	4	3	3	3	3	3	4	3	1	1	1	2	2	3	1
28.	Yambol	Smm_2Smc_2	1	1	1	5	5	5	5	2	2	4	4	2	4	3	3	3	3	3	4	3	1	1	2	2	2	3	1

Animal production is a supplementary factor there. Cattle dominates in livestock breeding, the proportion of sheep is high, and the percentage of pigs rather low. Livestock breeding is based on natural fodders (the share of perennial grassland in agricultural land is 27% on average), as well as on fodders cultivated on arable land or purchased.

Land productivity, labour productivity and the level of commercialization are at the medium world level. The volume of commercial production per person employed in agriculture is also medium. The degree of commercialization is, however, high.

Commercial production from the areas classified as the *Smc* type plays an important role not only on the home market, but also in exports (vegetables, fruit, industrial crops).

The *Smm* type occurs in the districts of Pernik, Sofiya and Sofiya-city lying in the central-western part of Bulgaria (see Fig. 2 and Table 1).

In that type animal production plays a much more important role than elsewhere in Bulgaria. Livestock breeding, mainly of dairy cattle and sheep, is based mostly on natural fodders. The proportion of perennial grassland is medium on the world scale and oscillates between 29.2% (Sofiya-city) and 49.7% (Sofiya-district). Poultry breeding, mainly of broilers, plays also an important part.

The proximity of such a big agglomeration as Sofiya causes that farms are highly specialized, oriented mainly towards the production of milk and vegetables for the city market. Cereals and fodders are cultivated in the areas situated farther from Sofiya, whereas rye, oats, potatoes and flax on the cooler and more humid areas, lying higher up (e.g. Samokov Valley).

The number of persons employed in agriculture is the lowest in the districts of Sofiya and Pernik – under 10 persons per 100 ha of agricultural land; the only exception is agricultural land within the administrative boundaries of Sofiya. This fact is connected with a high outflow of population from the rural areas to work in extractive industries (Pernik), or in industry, services, and administration (Sofiya-city).

Agriculture in this area is medium productive; labour productivity and commercial production per person are also medium, whereas the degree of commercialization is generally high.

However, the most common occurrence in Bulgaria is the combination of these two types *Smm* and *Smc*, closely resembling both the *Smm* type, representing mixed agriculture, and the *Smc* type, representing mixed agriculture with crop production prevalent.

Such a combination appears in 11 districts (see Fig. 2 and Table 1) in the north-western part of Bulgaria (Vidin, Mikhaylovgrad, Vratsa), in the central-western part (Tŭrgovishte and Shumen), in the north-eastern part (Silistra) and also in central Bulgaria (Gabrovo, Stara Zagora), as well as in the south-eastern part (Khaskovo, Yambol, Burgas). Labour inputs on agriculture are mostly low there, from 10.1 persons per 100 ha of agricultural land (Gabrovo) to 14.5 persons (Burgas), and only sporadically medium, from 18.5 to 20.0 persons.

Inputs of mechanical power per hectare of cultivated land are high, similarly as in the whole country, and oscillate between 36.0 HP in the district of Gabrovo and 56.3 HP in the district of Khaskovo. Mineral fertilizers are much in use: from 114 kg NPK in Vidin to 173 kg NPK in Khaskovo. Since field work is almost totally mechanized, draught animals are hardly used (from 3.9 to 8.0 draught units per 100 ha of cultivated land), with the only exception of the districts of Khaskovo and Gabrovo where that index is higher.

Crop production prevails, as evidenced by a relatively low percentage of animal production in gross production (from 27% in the district of Burgas to 34%

in the district of Khaskovo). Since the commercialization of products of animal origin is higher, the proportion of animal production in commercial production is also higher (from 36% in Burgas to 57% in Gabrovo).

Agricultural land-use orientations are largely influenced by natural conditions (relief and soils in particular). For example, in the submountainous areas the share of perennial grassland in the area of agricultural land is much higher (e.g. 46.1% in the district of Gabrovo, or 34.0% in that of Khaskovo). Possibilities for livestock breeding (mainly sheep and also cattle), based on natural fodders, are therefore much greater.

Favourable natural conditions and high agricultural standards account for a highly intensive utilization of arable land: from 83% in Gabrovo to 97% in Silistra.

Perennial crops play a relatively minor role, and their share in agricultural land oscillates between 3.5% in the district of Yambol and 9.3% in that of Stara Zagora. Orchards and vineyards prevail; they are mainly situated in the submountainous areas with a better sun exposition (Gabrovo 7.5%, Shumen 8.2%, Burgas 8.0%, Stara Zagora 9.3%).

Production results, land productivity and the level of commercialization are medium, similarly as labour productivity, which oscillates between 130.9 grain conventional units in the district of Khaskovo and 256.6 grain conventional units in the district of Gabrovo. The degree of commercialization is, however, high.

The combination of the same two types: *Smm*, *Smc* with *Smu* occurs quite frequently and can be found in five districts (see Fig. 2 and Table 1), lying mainly in the central part of the coastal lowland (Pleven, Veliko Turnovo, Razgrad) and in the north-eastern (Tolbukhin) as well as the central-eastern part (Varna). An even richer combination occurs in the district of Ruse: four agricultural types (*Smm*, *Smc*, *Smu*, *Smi*) are found there.

Field orientations are prevalent and contrary to the combination of *Smm–Smc* types, described above, the share of perennial grassland is much higher and of food crops as well as industrial crops (mainly sunflower and sugar beet) higher.

The combination of *Sem* i.e. of the incipient socialized agriculture and *Smm* types occurs only once (the district of Lovech).

A comparison of the agricultural codes for the districts situated in the southern and south-western part of Bulgaria with the models of world agricultural types reveals that the former do not resemble any type of the third or even second order described before. On the other hand, similar deviations from the model codes were discovered earlier in a detailed analysis of selected Bulgarian farms (Gałczyńska 1982).

This new agricultural type of the second order has been identified in the southern and south-western parts of Bulgaria, the districts of Kurdzhali, Smolyan, Blagoevgrad, and as a combination with *Smm* also in the district of Kyustendil. It has also been discovered in the Armenian SSR and is described as *Sg* type (Kostrowicki 1982) of the 2nd order and *Sgt* of the 3rd order.

The type can be characterized as follows: socialized, large-scale agriculture, based on the intensive cultivation of industrial crops (mainly tobacco) in mountain valleys, and the extensive sheep and cattle grazing on large tracts of natural pastures in mountains. Its code reads:

1115555 – 4444342 – 2312423 – 141233

The type is marked by high inputs of labour and animal power, a high degree of mechanization and chemical fertilization, and partial irrigation. The productivity of agricultural land as a whole is low, that of cultivated land medium or high. The level of commercialization is also low, or very low, due to very high employment in agriculture. These territories, Kurdzhali and Smolyan in particular, are largely inhabited by a population of Turkish origin, characterized by a high natural increase. These people are mainly employed in the labour-consuming tobacco cultivation, which involves high labour inputs. It is precisely the cultivation of tobacco and livestock breeding, which make the degree of commercialization so high there. The degree of specialization is medium but higher than elsewhere in Bulgaria.

The fact that Bulgarian agriculture could be included in three types of the 2nd order and six types of the 3rd order of world agriculture (including the newly-created type), starting from incipient socialized agriculture through various types of more or less intensive mixed agriculture with crop or animal production prevalent to the newly discovered type, bears out the assumption that Bulgarian agriculture is spatially greatly differentiated.

Moreover, the existence of a number of transitional forms between those types may be also taken as an evidence of the dynamic development of agriculture, i.e. that the agricultural types which dominate in separate areas undergo a transformation and create transitory forms which in future will become homogeneous types characteristic of an already higher level of development. Whether this assumption is correct or not it could be verified when the next typology of Bulgarian agriculture is carried out after a longer time.

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SPATIAL DIFFERENTIATION OF AGRICULTURAL PRODUCTION IN POLAND

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This subject has already been dealt with quite extensively in literature concerned with methodological as well as cognitive aspects. Among earlier but still up to date studies are those by Dąbrowski (1977), Kulikowski (1977) and Szyrmer (1980). Of the latest publications which are not listed in the above two studies one should mention a collective work supervised and edited by Kostrowicki (1978) and another study by Kulikowski (1980), since they are also closely connected with the subject.

The analysis of the spatial differentiation and dynamics of land and labour productivities as well as of the degree and level of commercialization in agriculture is based on data compiled by the Department of Agriculture and Food Economy of the Central Statistical Office and published in the series *Rolnicza produkcja*... 1979 and 1981. The categories of agricultural production (i.e. gross, final and commercial) are given in fixed prices of 1976/1977 for voivodships with a subdivision into agriculture total, socialized agriculture and non-socialized agriculture, in 1976, 1977, 1978 and 1979.

Agricultural production increases less rapidly than that in the other branches of national economy. Agricultural gross production, irrespective of oscillations in separate years, in comparison with the average from 1950–1952, increased only two times whereas in the same period the gross production in industry increased four times and in building industry ten times, etc. For that reason, though there was an increase of agricultural production in absolute figure, its share in the creation of the country's national income went down from 58% in 1947 to 33.8% in 1960, 21.3% in 1970, and 11.8% in 1979.

The share of agriculture in Poland's national income is spatially very uneven: it is the highest in the voivodships of the east and north-east of the country (Łomża 55.5%, Biała Podlaska and Zamość 49.7% each), as well as of Southern part of Greater Poland (Leszno 45.9%) to the lowest in the highly urbanized voivodships (Katowice 3.2%, Warsaw 3.0%, Łódź 2.3%)[1].

The value of agricultural gross production in million zlotys (in 1976/1977 fixed prices) went up from 620,000 in 1976 to 629,000 in 1977 and 661,000 in 1978; subsequently, it went down to 646,000 in 1979 and 581,000 in 1980[2].

[1] For more detail cf. Kulikowski 1980, pp. 9–10 and Figs 1 A and B.

[2] Data pertaining to the volume of the various categories of production on the national scale for 1980 are estimated by the Dept. of Agriculture and Food Economy of the Central Statistical Office.

The changes are quite similar in both individual and socialized agriculture; a relative decrease in 1978–1980 gross production is, however, higher in socialized agriculture (13.1%) than in individual agriculture (11.8%).

LAND PRODUCTIVITY

Changes in the value of agricultural gross production were also accompanied by changes in its volume per area of agricultural land, that is land productivity. The country's average productivity increased unevenly: immediately after the war and in 1970–1973 the increase was quite rapid, in 1950–1955 it was minimal, and in 1962 and 1969 it went down quite sharply. In last decade the increase from 27.7 thous. zlotys in 1970 to 33.9 in 1974 was followed by a decrease to 32.9 in 1976; in 1978 it reached its peak (34.7) and went down to 34.0 in 1979 and 30.6 in 1980. The level of land productivity was higher in individual agriculture (32.8 thous. zlotys/ha of agricultural land in 1976, 35.2 in 1978 and 31.4 in 1980), lower in socialized agriculture (respectively 32.3, 34.0 and 28.1 thous. zlotys), and very low in the holdings farmed by agricultural circles (14.6 thous. zlotys in 1980).

In 1976–1979 the land productivity expressed as agricultural gross production (in fixed prices) in zlotys/ha of agricultural land increased in individual agriculture by 2.3 thous. and decreased in socialized agriculture by 0.6 thous. The spatial picture of these changes is presented in Figs. 2 A and B.

In non-socialized agriculture the highest increase was noted in the western voivodships (Legnica + 9.0 thous, Zielona Góra + 7.2 thous., Szczecin + 6.4 thous.); it was quite substantial (3–5 thous.) in the remaining parts of Pomerania and Greater Poland, the urbanized areas of Upper Silesia and in the municipal voivodships (Warsaw, Łódź, Cracow), as well as the Lublin Plateau and the vast Subcarpathian areas.

A small increase (up to 1 thous.) was noted in the north-eastern voivodships; in Łomża and Siedlce there were even cases of decrease.

In socialized agriculture the land productivity decreased in as many as 34 voivodships, situated mainly in Poland's eastern part, as well as in Cuiavia, Pomerania and the south-west. In the remaining voivodships, lying in the country's western part, some slight increases or a kind of stagnation were noted.

As a result of these changes the divergence between individual agriculture, where the value of this characteristics was higher, and socialized agriculture widened (0.5 thous. in 1976 and 3.3 thous. in 1980).

Spatial differences in the volume of gross production per ha of agricultural land in non-socialized and socialized agriculture in 1979 are presented in Figs. 1 A and B.

In non-socialized agriculture the highest values of this index (over 45 thous.) occurred in the voivodships in which agricultural standards were high (Leszno, Poznań, Legnica and Wroclaw) and in greatly urbanized voivodships (Warsaw, Katowice, Cracow and Łódź), where because of the close proximity of large and absorptive markets, the main orientation of most farms was market-gardening[3], requiring high inputs.

In Cuiavia, along the Lower Vistula, in Western Pomerania, along the Central Odra, in Opolian Silesia, Subcarpathia and in Lublin Plateau the land productivity was high (35–45 thous.). Land productivity, higher than the country's average, in individual holdings in Subcarpathia and the Lublin Plateau was mainly due

[3] Production of market-gardening (vegetables, fruit and flowers) in the Warsaw voivodship in 1977 amounted to ca 30% of the total agricultural gross production.

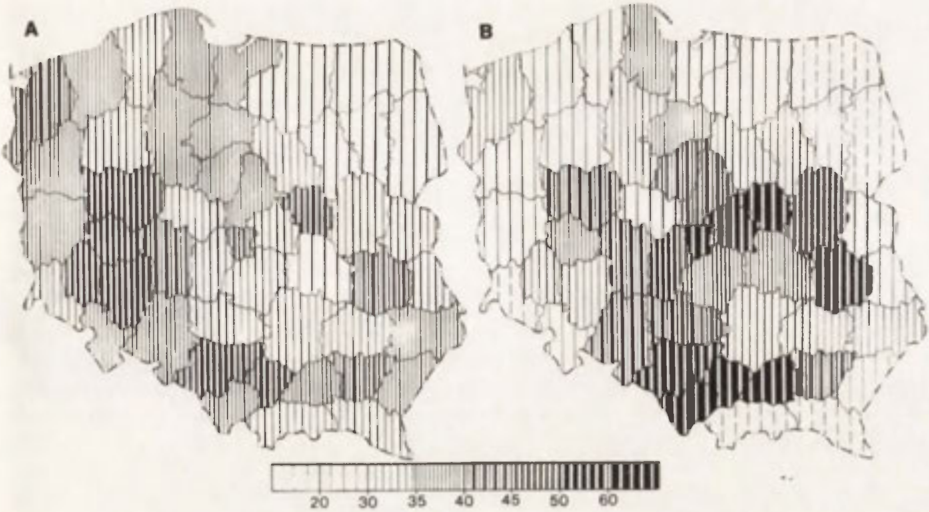

Fig. 1. Agricultural gross production in thous. zlotys per ha of agricultural land in 1979
A non-socialized agriculture. B Socialized agriculture

to good soils and high labour inputs (cf. Stola 1978, Fig. 24, p. 52 and Fig. 38, p. 71).

Land productivity was the lowest in the country's north-eastern part, particularly in the voivodships of Suwałki, Białystok, Łomża and Ostrołęka (26-27 thous.). For quite many years these areas have been characterized by the lowest values of this characteristics (cf. Kulikowski, Szyrmer 1978, Fig. 254, p. 365; Fig. 255, p. 366; Fig. 256, p. 370).

Divergences and spatial differences in land productivity calculated in the same

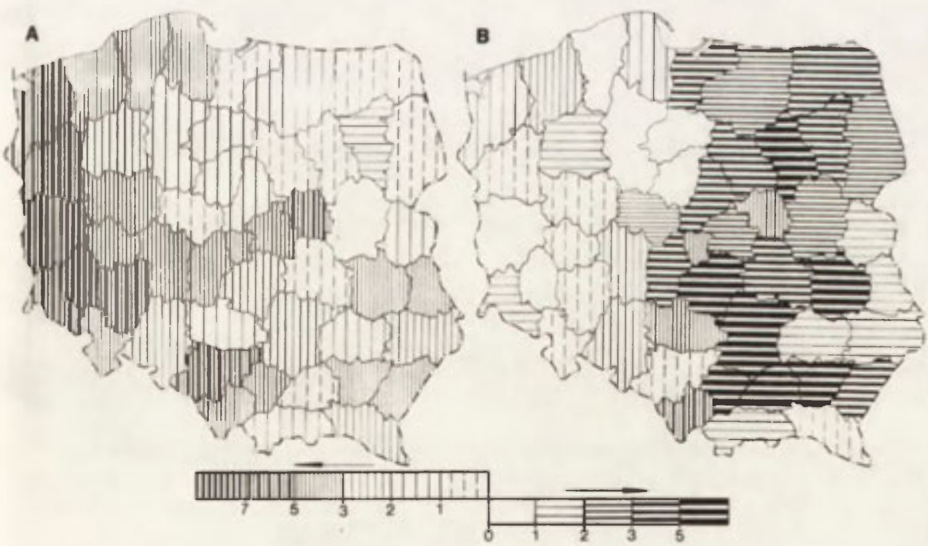

Fig. 2. Changes in agricultural gross production in thous. zlotys per ha of agricultural land in 1976-1979
A Non-socialized agriculture B Socialized agriculture

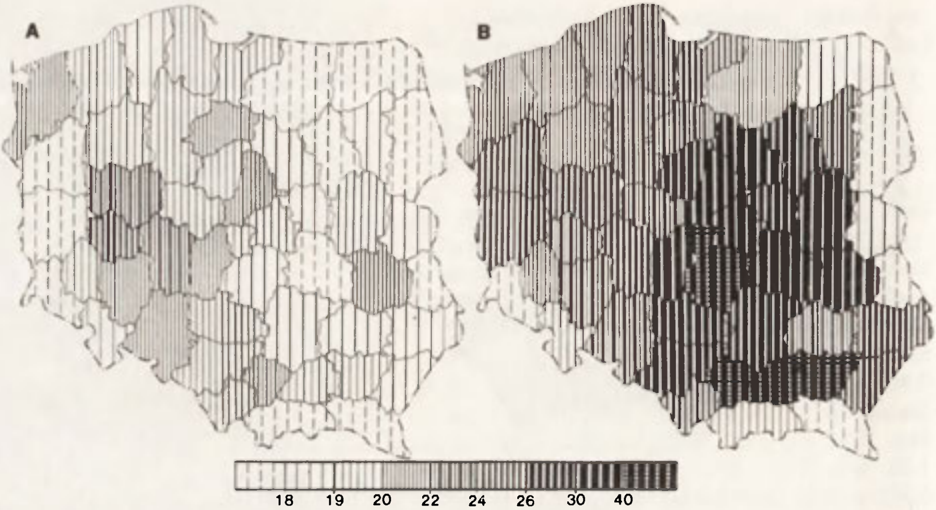

Fig. 3. Material costs of agricultural production in thous. zlotys per ha of agricultural land in 1976

A – Non-socialized agriculture. B – State farms

way (Fig. 1 B) are much wider in socialized agriculture than in individual agriculture.

This characteristic in 1979 was the highest in the Subcarpathian voivodships (Bielsko-Biala 81.4, Cracow 67.2, Tarnów 62.1 thous. zlotys) and also in some voivodships of central Poland, where, however, socialized farms have occupied small areas. In the areas where they were more numerous, land productivity was high in parts of Greater Poland and Opolian Silesia and very low in the voivodships of Jelenia Góra (18.0), Suwałki (18.7) and Olsztyn (24.9).

In the post-war period the agricultural net production has increased much less dynamically. In comparison with 1950 it was the highest in 1968 (149.6%) and

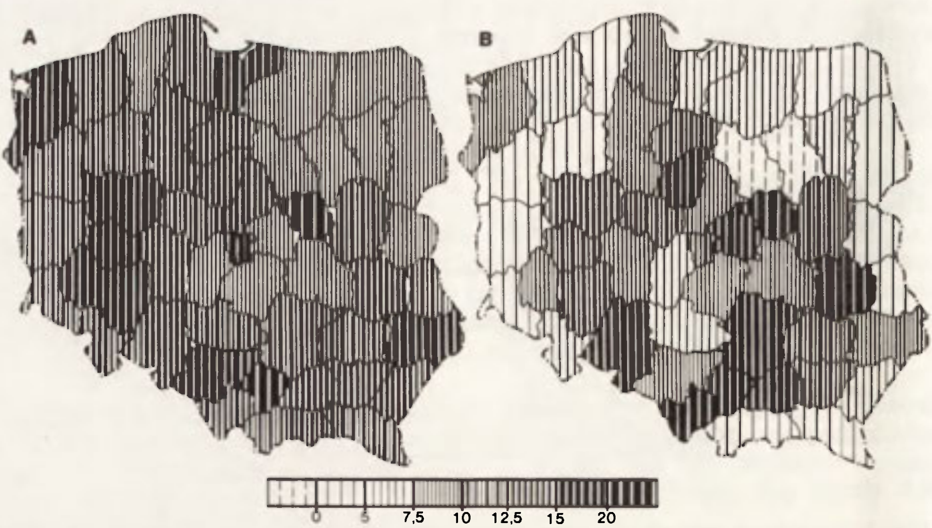

Fig. 4. Agricultural net production in thous. zlotys per ha of agricultural land in 1976

A – Non-socialized agriculture. B – State Farms subsequently in 1972 (140.7%) and 1973 (143.5%); in 1975 and 1976, however, it went down to circa 120%.

Since material costs of agricultural production in socialized farms are much higher than analogial costs in peasant holdings (see Figs 3 A and B), the average net production expressed in current prices (in zlotys/ha of agricultural land) was in 1976 much higher in the latter (12.1 thous.) than in the former (6.9 thous. in state and 0.8 thous. in collective farms). Poland's net production (almost 90%) was therefore mainly supplied by individual agriculture even if agricultural land cultivated by private farms was much smaller (77.7% of Poland's agricultural land).

The spatial differentiation of this characteristics was sharper in socialized agriculture than in individual agriculture (see Figs 4 A and B). The highest values of agricultural net production per ha of agricultural land were noted in the state farms of the Bielsko-Biała (34.6 thous.) and Lublin (29.9 thous.) voivodships, where, however, these farms have occupied small areas. In the areas where they were larger, the index was much lower. In Greater Poland and the Silesian Lowland it oscillated between 10 thous and 15 thous. It was much lower than the country's average in the northern and western voivodships (Gdańsk 1.5 thous., Zielona Góra 2.3 thous.). The lowest (negative) index was in the voivodships of Ciechanów and Ostrołęka.

Territorial differences in individual agriculture were less sharp. The highest values of net production per ha of agricultural land (circa 22 thous.) were noted in 1976 in individual farms situated in the suburban zones of Warsaw and Cracow. The index was quite high (15–20 thous.) in Greater Poland, the Silesian Lowland, Western Pomerania, the Delta of the Vistula River, the eastern part of the Lublin Plateau and the voivodship of Cracow. An index higher than the country's average was found also in Subcarpathia, Cuiavia, and the remaining part of the Lublin Plateau. It was low (under 10 thous.) in north-eastern Poland and some central voivodships.

The comparison of the cartographical picture of differences in land productivity as regards individual agriculture (calculated on the basis of gross and net productions) with the distribution of material inputs on the one hand (see Figs 3 A and B) and the distribution of labour inputs on agriculture on the other hand (cf. Stola 1978, Fig. 24, p. 52; Fig. 38, p. 71; Fig. 42, p. 77), corroborates the conclusion that the relatively high level of land productivity in south-eastern Poland, the Subcarpathian belt in particular, was largely achieved owing to high inputs of human labour and animal power. On the other hand, in the western part the high land productivity was mainly due to higher agricultural standards and therefore higher capital and lower labour inputs.

LABOUR PRODUCTIVITY

The usual definition of labour productivity is that it is the volume of agricultural production per unit of labour. In this study labour productivity in socialized and non-socialized agriculture is measured by agricultural gross production in zlotys per person employed in agriculture[4].

An analysis of labour productivity in individual agriculture, carried out by the present author earlier (cf. Kulikowski 1977, pp. 195–208, and Kulikowski and

[4] Data pertaining to agricultural employment in 1978 are taken from the Central Statistical Office's publications: *Ludność, Gospodarstwa Domowe i Warunki Mieszkaniowe*, NSP, GUS, 1980, Table 3, pp. 35–38, and statistical yearbooks of the voivodships. Data for 1976 have been calculated on the basis of the falling employment trend in 1970–1978.

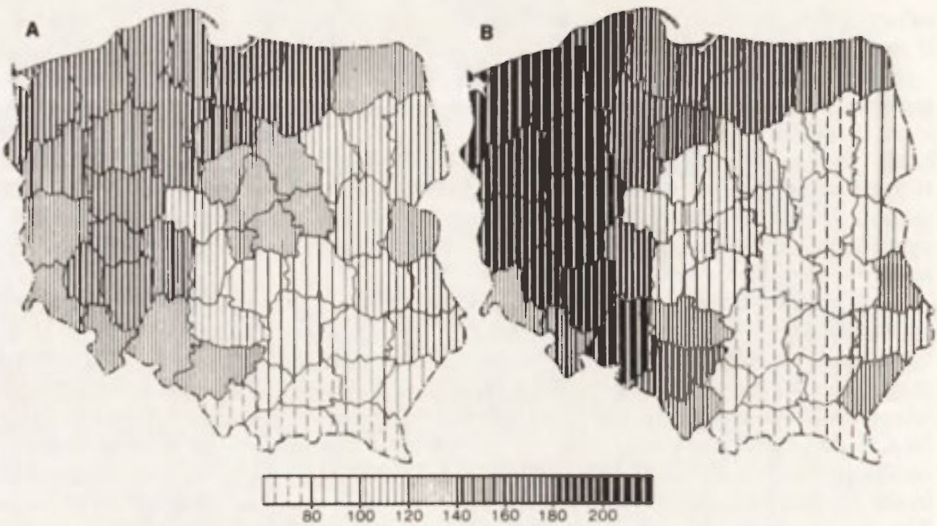

Fig. 5. Agricultural gross production in thous. zlotys per person employed in agriculture in 1979

A – Non-socialized agriculture B – Socialized agriculture

Szyrmer 1978, pp. 371–380) shows that in 1960–1970 the spatial differences of this characteristics were big and, though labour productivity considerably increased, the character of its spatial distribution was not substantially changed. In 1970 – and even nowadays (see Fig. 5 A) – the index quite clearly reflects the partition boundaries of Polish territories before the First World War.

In 1979 labour productivity was higher in socialized (153.9 thous.) than in non-socialized (114.9 thous.) agriculture. There are several reasons to explain this

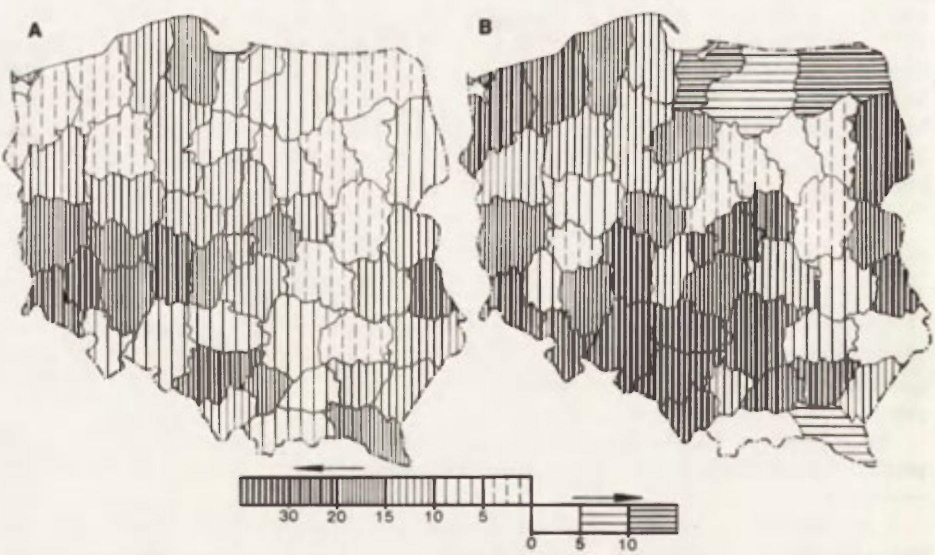

Fig. 6. Changes in agricultural gross production in thous. zlotys per person employed in agriculture in 1976–1979

fact. Socialized agriculture is much better equipped in machinery and technical appliances than individual agriculture[5]. Though the number of employed per unit of agricultural land is much lower, and differences in the size of holdings are big, material costs of agricultural production are much higher in social farms (see Figs 3 A and B).

In 1976–1979 the labour productivity increased at the same rate (by ca 12 thous.) both in individual and social agriculture. However, the value of machinery and technical appliances went up then by only 29.6% in individual farms, almost two times in state farms, and two-and-a-half times in collective farms. Thus, increased land productivity in socialized agriculture resulted largely from increased costs of agricultural production, whereas in individual farms it was predominantly due to increased labour efficiency.

In individual farms labour productivity went up from 103.2 thous. in 1976 to 114.9 thous. in 1979. The highest increase in labour productivity between those two years was noted in the Legnica voivodship (+31.6 thous.); quite high (20–30 thous.) occurred also in Katowice, Kalisz and Jelenia Góra voivodships. The lowest increase was found in Central and Western Pomerania and north-western Poland; in the Łomża voivodship there was even a slight decrease (see also Fig. 6 A).

In socialized agriculture the highest increase in labour productivity (over 30 thous. zlotys) was noted then in Upper Silesia and Opolian Silesia, as well as in the Kalisz, Tarnobrzeg and Chelm voivodships. A substantial increase occurred also in Pomerania, the Sudetes and some voivodships in central Poland. A decline in labour productivity characterized socialized farms in the Mazurian Lakeland and the Vistula Delta, as well as in the Carpathians and the eastern part of the Lublin Plateau.

Irrespective of those changes the spatial picture of labour productivity in non-socialized agriculture in 1979 was very much the same as in 1960, 1965 and 1970 (cf. Kulikowski and Szyrmer 1978, Fig. 257, p. 373; Fig. 258, p. 374; Fig. 259, p. 375).

In 1979 the highest labour productivity in individual agriculture was achieved in the voivodships of Greater Poland (Poznań 176.7 thous., Leszno 165.4 thous.) and the Silesian Lowland (Legnica 172.8 thous., Wroclaw 168.5 thous.). It was quite high (160–165 thous.) in Pomerania and the Bydgoszcz, Elbląg and Olsztyn voivodships, but low in the Lesser Poland Upland and Subcarpathia (80–100 thous.) and the lowest in the Carpathian voivodships (Nowy Sącz 63.3 thous., Krosno 70.7 thous.).

The spatial picture of labour productivity in socialized agriculture (including state and collective farms as well as agricultural circles) is sharply differentiated. A very high labour productivity was noted in 1979 in the voivodships where the percentage of agricultural land of the state farms was high (in thous. zlotys: Opole 255.5, Poznań 244.1, Leszno 219.3, Szczecin 216.8, Piła 212.4). It was very low in central and south-eastern Poland (Nowy Sącz 34.6, Tarnobrzeg 48.6, Lublin 54.6), where state and collective farms were scarce and agricultural circles, as might be expected, were characterized by a very low labour productivity. It seems, therefore, worth while complementing this picture with a map of the spatial differentiation of labour productivity in state farms (cf. Kulikowski 1980 Fig. 6B), for which the presented index was calculated on the basis of agricultural gross production (in current prices) in 1976 per person employed in state farms.

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[5] The value of machinery and technical appliances per 100 ha of agricultural land amounted in 1979 to 1264.7 thous. zlotys in state farms, 1359.2 in collective farms and merely 470.0 in individual holdings.

CAPITAL PRODUCTIVITY

Capital productivity in the present study is understood as the volume of agricultural production, expressed as the value of agricultural gross production in zlotys (current prices) per unit (100 zlotys) of material inputs on agricultural production. This index is only a symptom of capital productivity since the spatially differentiated value of capital equipment is not taken into account in material costs of agricultural production.

In 1976 the productivity of material costs of agricultural production (see Fig. 7 A) was the highest in non-socialized farms (164 zlotys/100 zlotys of material inputs), lower in state farms (130) and the lowest in collective farms (101).

The highest productivity of material costs (over 200) was noted in individual agriculture in the greatly urbanized voivodships (Warsaw, Cracow, Katowice), in which suburban agriculture, predominantly specialized in market-gardening, is moreover well developed (cf. Kostrowicki, Kulikowski, Szyrmer 1978, Fig. 158; p. 240; Fig. 162, p. 244; Fig. 166, p. 248). A high capital productivity (180–200) was found in the areas rich in good soils in the Silesian Lowland, the western part of the Lublin Plateau and in Western Pomerania.

In individual agriculture the value of this characteristics was low (148–160 zlotys) in the Mazurian Lakeland, the central part of the Pomeranian Lakeland and the Mazovia-Podlasie Lowlands (with the exception of the Warsaw and Płock voivodships). The lowest level was noted in the Piotrków (145) and Skierniewice (147) voivodships. In state farms, similarly as in the case of labour productivity, the volume of agricultural gross production per unit of material costs incurred on agricultural production was more sharply differentiated in the areas where there were no large state farms; the highest index was found in the Bielsko-Biała voivodship (228) and the lowest in the Ostrołęka and Ciechanów (under 90).

In Poland's northern and western territories the differences in the values of this index were not so big and oscillated between 106–116 zlotys in the voivodships of Słupsk, Piła, Gorzów and Jelenia Góra, and 140–160 in the eastern and central parts of the Silesian Lowland, in certain parts of Greater Poland and in the Szczecin voivodship.

Spatial differences and divergences between individual and state farms were much wider as regards the productivity of capital inputs calculated on the basis of the volume of net production (Figs 8 A and B). In 1976 this index amounting to 64 zlotys in individual agriculture was over two times higher than that in state farms.

In individual agriculture the net production per 100 zlotys of material costs was the highest in the specialized agriculture of the suburban zones of the following voivodships: Warsaw 122, Katowice 125, Cracow-city 203 zlotys. The index was high (80–100) in the territories with good soils of the Silesian Lowland, Western Pomerania and the eastern part of the Lublin Plateau. It was also high in the areas with favourable soil conditions of the country's south-eastern part as well as in the territory spread from the Bay of Gdańsk through the Eastern Pomerania, Cuiavia, Greater Poland to Lower Silesia.

The index was the lowest (40–60 zlotys), though it greatly exceeded the average level in state farms situated in the same area, in individual farms in the Mazurian Lakeland and the central part of the Pomeranian Lakeland and also in the Mazovia-Podlasie Lowland, as well as in some voivodships in central Poland.

In state farms, where as already mentioned the net production per unit of material inputs was much lower, spatial differences were also less sharp. Big differences in the productivity of capital inputs incurred on agricultural production were found in a few voivodships only, where state farms have occupied small areas.

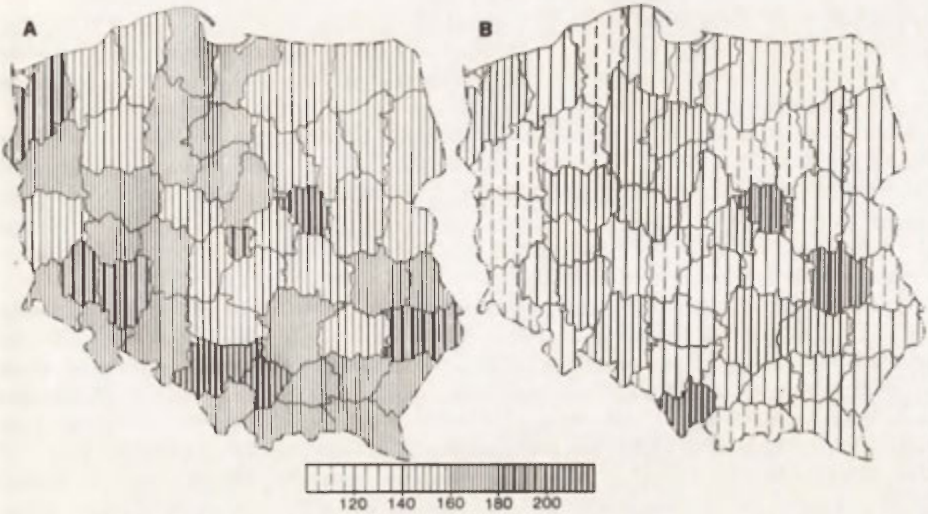

Fig. 7. Agricultural gross production in zlotys per 100 zlotys of material inputs on agricultural production in 1976

A – Non-socialized agriculture. B – State Farms

For example, in northern Mazovia (the Ciechanów and Ostrołęka voivodships) the material costs incurred on agricultural production exceeded the value of net production created there. For a change, it is worth while noting that in the Bielsko Biała voivodship this index (128 zlotys) was high. In the remaining voivodships where state farms were numerous this index oscillated between 6–9 in Gorzów and Zielona Góra and 50–60 in Poznań and Opole.

A spatial analysis of the productivity of capital inputs incurred on agricultural production, carried out on the basis of gross and net productions, indicates that

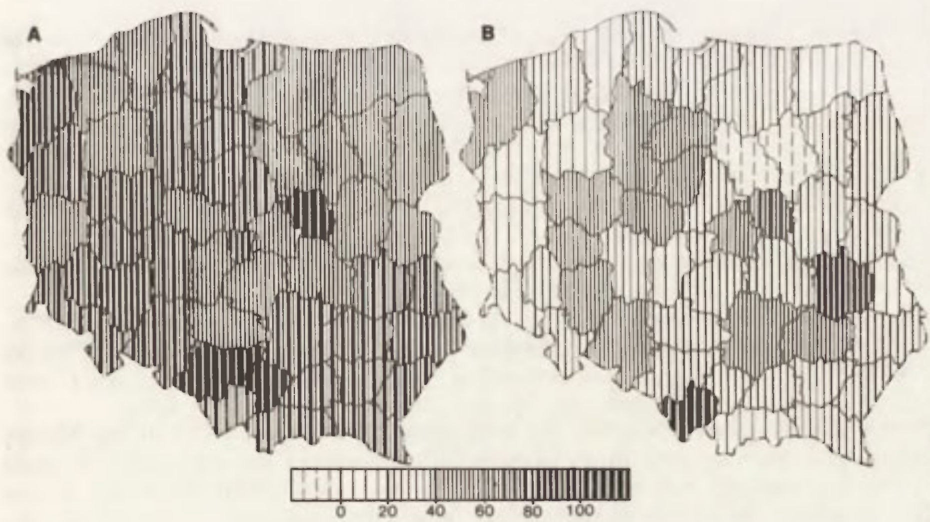

Fig. 8. Agricultural net production in zlotys per 100 zlotys of material inputs on agricultural production in 1976

A – Non-socialized agriculture. B – State Farms differences in individual holdings were bigger than in state farms. Moreover, the productivity of capital inputs in individual farms was much higher than in state farms. The differences are even bigger in the territories where the proportion of state farms is high.

Even now, in the country's present difficult economic situation, the fact that production in the state sector of agriculture absorbs so much capital, does not justify any discrimination of state farms; it is sufficient to mention here at least one fact that in Poland there are areas where agricultural labour is scarce (e.g. the northern voivodships and the Sudetes) and to preserve high labour productivity is still a grave problem, which worries particularly state farms. However, the urgent need to increase agricultural production as rapidly as possible at the time when Poland has been making all efforts to break out of the current economic crisis calls for such a distribution of means of production as to guarantee optimal results. In other words: if we want to get more and spend less, we should allot more means of production than it has been done so far to individual farmers. The spatial differentiation of the productivity of capital inputs in individual agriculture implies that the effectiveness of capital inputs in individual agriculture was the highest in greatly urbanized areas, where agricultural production was oriented towards meeting the needs of absorptive markets as well as where agricultural standards were high and the farms larger (Greater Poland, the Silesian Lowland, Western Pomerania, Cuiavia and the area along the Lower Vistula), and also in the higher parts lying in south-eastern Poland, rich in good soils.

Though protective policies as regards well-run farms, irrespective of the natural conditions in which the farmers work, must be a fixed factor, the proposed increased capital means alloted to areas with favourable soil and climatic conditions, should be treated as a temporary suggestion to be realized until Poland has broken out of the crisis.

THE DEGREE OF COMMERCIALIZATION

The most frequent definition of the degree of commercialization is that it is the percentage of agricultural commercial production in gross production.

In individual agriculture the degree of commercialization went up from 37.1% in 1950 to 41.8% in 1960, 45.3% in 1970, 49.8% in 1974 and in last years it increased: from 47.4% in 1976 and 1977 to 48.5% in 1978, 50.2% in 1979 and 51.9% in 1980 (see Fig. 9 A).

In socialized agriculture the degree of commercialization was in general much higher and went up from 65.4% in 1976 to circa 70% in 1978–1980.

Thus, in last few years the index increased in both agricultural sectors and was slightly higher in socialized agriculture.

In individual agriculture the degree of commercialization went up in 46 voivodships. A slight decrease was noted in Jelenia Góra, Sieradz and Koszalin (see Fig. 10 A). The highest rate of increase was found in individual farms in Upper and Cieszyn Silesia, as well as in the Tarnów and Łomża voivodships (6–8%).

In socialized agriculture the index went up quite substantially in the Olsztyn (+ 11.5%), Gdańsk (+ 9.5%) and some other voivodships, where, however, socialized agriculture did not play any greater role. In the country's northern and western parts, where socialized agriculture was of greater importance, agricultural commercialization went up by 2–4%, whereas in the Sudetes voivodships some decreases were noted (Jelenia Góra – 5.8%, Wałbrzych – 4.3%).

In 1979 the highest degree of commercialization was noted in non-socialized

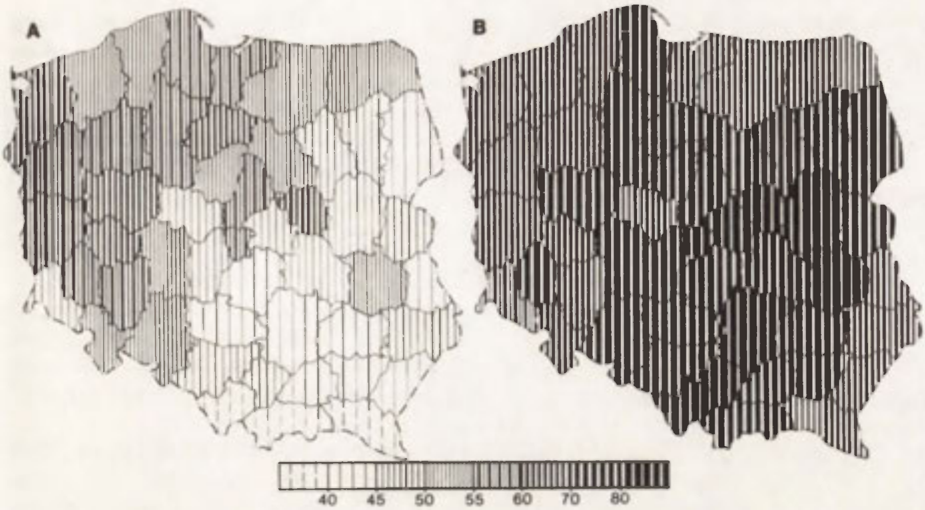

Fig. 9. The percentage of commercial production in agricultural gross production in 1979
A – Non-socialized agriculture. B – Socialized agriculture

agriculture in the Warsaw voivodship (over 60%), part of Greater Poland (Poznań and Leszno) and in the Szczecin and Toruń voivodships. The degree of commercialization was also high in individual farms along the Lower Vistula, in the central part of the Silesian Lowland, and in the area along the middle course of the River Odra.

In eastern and south-eastern Poland the values of this index were low, the lowest (circa 36%) in the highly populated Krosno, Nowy Sącz and Bielsko-Biała voivodships.

In socialized agriculture the highest degree of commercialization (over 80%) was

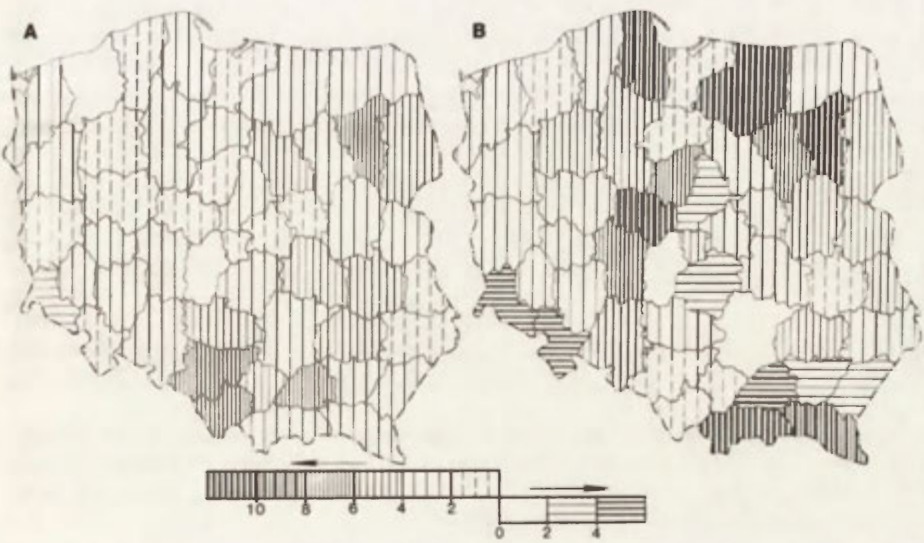

Fig. 10. Changes in the degree of agricultural commercialization in 1976–1979
A – Non-socialized agriculture. B – Socialized agriculture

found in the group of voivodships lying in central and southern Poland, where however socialized farms were few. In the western and northern voivodships this index amounted from 60% to 70%, with the exception of Jelenia Góra, where it was lower (57.4%).

As a result, socialized agriculture with its higher degree of commercialization supplied 32.1% of the country's commercial production, though its share in Poland's gross production was much lower (23.4%).

THE LEVEL OF COMMERCIAL PRODUCTION

The above term denotes the volume of agricultural commercial production per unit of agricultural land. In the present study the measure of the level of agricultural commercialization is the value of commercial production in 1976/1977 fixed prices per ha of agricultural land.

In individual agriculture the index went up from 2.7 thous. zlotys in 1950 to 4.9 in 1960, 7.4 in 1970[6]. In last few years it increased from 15.5 thous. zlotys in 1976 to 17.6 in 1979; in 1980 it went down to 16.3 thous. zlotys. In socialized agriculture the level of commercialization was higher (21.1 thous. zlotys in 1976 and 23.8 in 1978); since the degree of agricultural commercialization was much higher. However, in 1979 it went down to 22 and in 1980 to 20 thous. zlotys.

The analysis of changes in the level of agricultural commercialization in 1976–1979, undertaken in this study, reveals that the increase was higher in individual agriculture (+ 2.1 thous.) than in socialized agriculture (+ 0.9 thous.), irrespective of the fact that inputs on agricultural production in state and collective farms increased much more rapidly than in non-socialized agriculture.

In individual agriculture the highest increase in the investigated period was noted in the voivodships of Legnica (+ 6.5 thous. zlotys/ha of agricultural land) and of Katowice (+ 5.4). Municipal voivodships, certain voivodships in Greater Poland and in the country's west, as well as Subcarpathia and the voivodship of Lublin were marked by a quite high (3–5 thous. zlotys) increase (see Fig. 12 A). A relatively lowest increase was noted in individual farms in the nort-eastern part of the country.

In socialized agriculture there were substantial decreases (given in thous. zlotys) in central Poland (voivodships of Piotrków 7.8, Płock 5.7, Sieradz 5.6), southern Poland (voivodships of Cracow 20.1, Tarnów 22.8, Rzeszów 18.0) and nort-eastern (voivodships of Ostrołęka 7.2, Suwałki 1.5). In the remaining areas where socialized agriculture holds a large part of agricultural land, the level of agricultural commercialization went up (1–2 thous. zlotys/ha of agricultural land) and only in the Sudetes and in the voivodship of Gdańsk some slight decreases were noted.

Irrespective of those changes, the general picture of the spatial differentiation of the level of agricultural commercialization in 1979 does not greatly differ in both non-socialized (Fig. 11 A) and socialized (Fig. 11 B) farms from the spatial differentiation of this characteristics in 1976 (cf. Kulikowski 1980, Figs 14 A and B).

In 1979 the highest level was found in non-socialized agriculture in the vicinity of Warsaw (the Warsaw-capital voivodship 30.4 thous. zlotys), in Greater Poland (Leszno 29.0, Poznań 27.6), in the Silesian Lowland (Legnica 28.3, Wrocław 26.9) and in Western Pomerania (Szczecin 27.9).

[6] Data after Kulikowski and Szyrmer 1978, pp. 401–409; this index has been calculated on the basis of the value of agricultural commercial production expressed in fixed prices as before 1970.

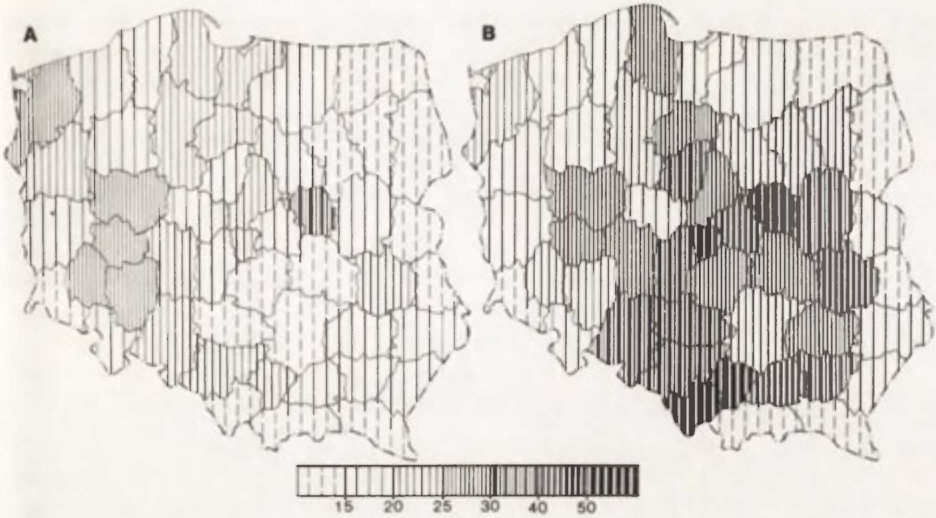

Fig. 11. Agricultural commercial production in thous. zlotys per ha of agricultural land in 1979

A – Non-socialized agriculture. B – Socialized agriculture

The level of commercialization (given in thous. zlotys) was low in individual agriculture in the country's eastern part (Białystok 11.8, Suwałki 13.1, Chełm 14.4) and the lowest in the Carpathian voivodships (Nowy Sącz 11.3, Krosno 11.6).
In socialized agriculture the highest index was noted that year in the Subcarpathian voivodships (Bialsko-Biała 67.2 thous. zlotys, Cracow 56.4, Tarnów 49.0) and in Central Poland (Łódź-city 55.5, Warsaw-capital 51.6, Skierniewice 42.3), where, however, the area of agricultural land held by socialized farms was small.
In the areas where socialized agriculture held large portions of agricultural land the level of commercialization was similar in both sectors of agriculture.

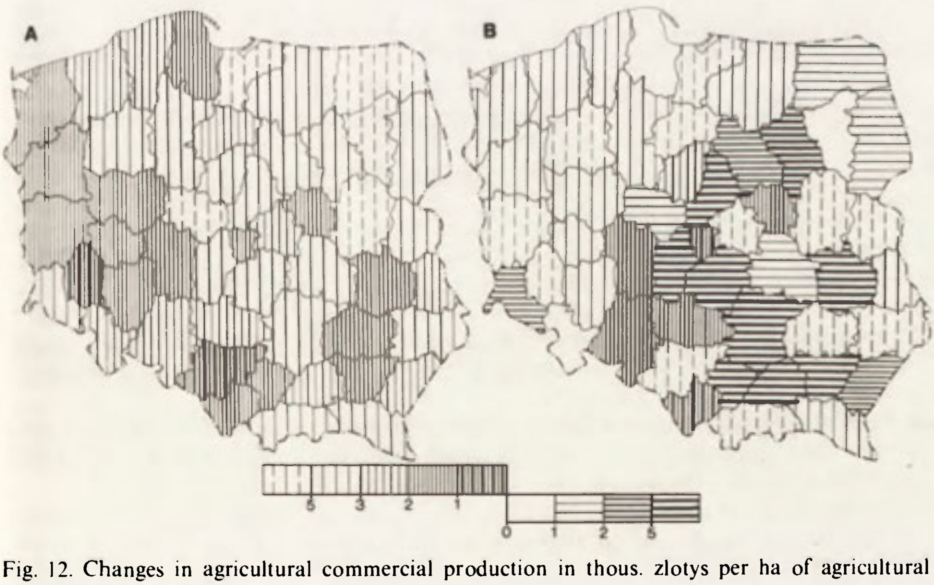

Fig. 12. Changes in agricultural commercial production in thous. zlotys per ha of agricultural land in 1976–1979

A – Non-socialized agriculture. B – Socialized agriculture with the exception of voivodships of Opole and Gdańsk, where it was much higher in socialized farming, and in the Sudetes (Jelenia Góra 10.3 thous. zlotys) as well as in the voivodships of Szczecin, where it was higher in individual agriculture.

The analysis of the spatial differentiation and dynamics of agricultural production characteristics in 1976–1979 is incomplete, since, for example, the analysis of agricultural orientations and specialization has not been made. Another important problem which has not been analysed though it exerts influence particularly on labour productivity, is the territorial differentiation of fixed assets allotted to agriculture. However, it was not possible to undertake this last analysis because of lack of respective source materials.

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INTRODUCING THE WORLD FOOD SYSTEM

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This article is an attempt to introduce the concept of the world food system[1]. Attention is here focused on the first stage in developing the concept. This stage covers the definition, origin and scope of the concept. The argument presented is based on three lines of reasoning:

1. The systems approach is an essential tool in the analysis of complex sets of relations.
2. In the contemporary world we have to deal with interdependencies of a global character which form a system at the world level.
3. Within this world system an area of interdependent relationships concerning international food supplies can usefully be recognized.

THE SYSTEMS APPROACH

For every research worker faced with a task of scientific description, explanation and prediction – it is essential to choose an appropriate methodology. We can recognize that for many aspects of world economic and social interrelationships there exists a complexity and yet a regularity for which a systems approach is the most effective method of analysis which we have at our disposal.

Systems approach strictly conceived as a methodological framework has been developed within the last 30 years, although the origin of holistic thought lies in the more ancient philosophies. The systems approach comes from a fundamental change in scientific thinking, and represents a departure from this continuum of scientific procedures which stretches back to physics of Galileo and Newton. The classical paradigm was to break down the phenomena observed into separate elements, to analyze them, and finally to synthetize them. As Laszlo points out, "complex sets of events could be understood by this science only when broken down to their elementary interactions" (Laszlo 1972, p. 11). The world was then understood and described in a mechanistic way, which for a long time gave satisfactory results within physics and engineering. Neopositivism tried to extend this analytical method to the whole of science, including biology and the social sciences.

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[1] The author wishes to thank Professor W. B. Morgan of King's College, London, for his critical comments and valuable help in translating this article. The article and its faults remain, of course, the author's responsibility.

At the beginning of the 20th century the mechanistic approach as a universal paradigm had been questioned even within physics. Science was already concerned with phenomena whose complexity had made a reduction to simple elements impossible.

The present systems approach, as opposed to the analytical approach, was developed mainly within the biological sciences, the theory of information and cybernetics. Since the pioneering work of von Bertalanffy (1951), systems methodology has spread into most scientific disciplines, and it can be said that systems theory has become a branch of scientific thinking in its own right. On the other hand, we also note that within the extensive literature on systems theory there is a great variety of interpretation, and new concepts and definitions are continually being developed.

What are the general principles of this approach as an interdisciplinary research method?

The point of departure is the assumption that the world around us should be understood as a system that is a hierarchical set of mutually interdependent elements[2]. These elements can be material objects, any organized phenomena and processes. The relationships involved may include the flows of matter, energy and information, and also logical relationships. The system is of hierarchical construction, i.e. the elements of a given system may be seen as subsystems. By contrast with the analytical approach, the main emphasis of the systems approach has moved from the analysis of individual elements to the study of systems as wholes together with their complexity and dynamics (de Rosnay 1975, pp. 109–110). Systems analysis is consciously searching for universal statements of structural principles and functional relations that will be applicable to many different kinds of systems. Knowledge of the basic principles of organization and functioning of systems enables orderly description, explanation and prediction of phenomena. The general description of the complex of interdependent parts is usually the first, "qualitative" stage in systems analysis. The next stage, regarded by some as the essence of the systems approach, is the phase of modelling and simulation.

The most spectacular application of the systems approach, and in some cases the most important, lies in global modelling. Unfortunately, lack of space in this paper makes it impossible to review the literature in this field. However, it may be seen that more than 10 years of global modelling have brought positive results both in methodology and general substance concerning the state of the world and its possible future (Meadows 1981). The results published so far in the Reports to the Club of Rome, and also in other global models have indicated new opportunities for reasearch and have also pointed to the limits of the global modelling technique. However, the basic assumption of global modelling that the world itself is a system, so far has not been questioned.

In global studies one should not rely on an intuitive approach to the basic assumption about the existence of a world system. Therefore it would seem useful to devote at least some attention to the origin of the world system and to the conditions governing its existence.

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[2] There are many definitions of a system. It seems, however, that it is not rigorous definitions of a system, but systems approach in general, emphasizing lack of disciplinary boundaries, that has been the source of dynamism and progress in scientific research (Gaines 1979, p. 1).

THE ORIGIN AND THE CONDITIONS OF THE WORLD SYSTEM

The world around us in both physical and social spheres can be analysed by systemic categories. The physical environment over a long period of evolution has formed into a global ecosystem. By contrast with the physical environment, global interrelationships in the social sphere have only a very short period of historical evolution. Although the continuous growth of contacts and interdependencies between the individual and society characterizes the development of human civilization from its very beginning, nevertheless it is only in the last 500 years that processes leading to the formation of a socioeconomic system on a global scale have emerged.

There is a general conviction that the first realization of the possible existence of a world network came as a result of the great geographic discoveries at the end of the 15th century. They were the necessary, though not sufficient condition for the formation of global links. It is worth noting that already as early as in the 14th and 15th centuries commercial contacts were extensive through Europe, Asia and Africa, that is 3 continents with approximately 98 per cent of the world population at that time. Then a long distance trade linked the main centres of civilization, consisting of Christian Europe, the Islamic world, the Indian subcontinent, China and Black Africa.

The dominant role was played by Islam, the influence of which stretched from the Iberian peninsula in the West to the 'Spice Islands' (Indonesia) in the East. Due to the central position of Islam in the world, Arab traders dominated practically the whole intercontinental trade. Other traders, notably European and Chinese, were restricted to the ends of the world of 3 continents. The dominating role of Islam at that time, as expressed in the high level of its culture, in its central geographical position and in its control over intercontinental trade, had not, however, yet initiated the process which would have led to the development of the world economy under the aegis of Islam.

Apart from political and religious factors, the reason for the lack of development in this direction is to be seen in the nature of the long-distance trade of that time. In spite of the extensive nature of geographical coverage the quantities of the goods exchanged were small. The low level of productive forces could not ensure a surplus that would provide the basis for an extensive and permanent international trade. Also, the poor quality of transport and of transport routes together with lack of security in travel discouraged contact between far-away places. A long-distance trade, which concentrated on luxury goods was in effect only a supplementation to the feudal system, the essence of which was the formation of self-sufficient structures based on land ownership. Long-distance trade did not result from the feudal system, nor did it interfere with the basic mechanisms of that system. In this sense, in the period prior to the great geographical discoveries there were neither the possibilities nor real need for permanent global links to be developed. The world at that time was a set of nearly independent local and regional systems.

The period of change was, to use the terminology of Braudel, "the long 16th century", that is the period 1450–1650. It was then in Europe that cumulative changes started which finally led to the formation of a world market, and subsequently of a world economy. As a result of the dynamic development of Europe, a new system of international trade and the division of labour, oriented to the needs of Europe, was beginning to be formed. International links gradually covered basic economic activities and whole geographical areas became mutually dependent, though usually on unequal terms. The period of mercantile capitalism, preceding the industrial revolution, ends the first stage of global integration; many local markets were now linked into a world market system. However, still in the late 18th century large areas, such as China, Japan, most of the Indian subcontinent and Black Africa remained outside the world market.

A new, qualitative stage in the formation of the world system began with the industrial revolution at the end of the 18th century. The industrial revolution required sources of supply and markets that extended far beyond national borders. These became the determinants of a trade based on mass production. However, the formation of international division of labour on a permanent basis was not possible without a major change in the development of transport. The introduction in the 19th century of railways and steam ships, made possible long-distance movements of bulk goods and mass intercontinential migration. Many countries lost their previous isolation. The processes described did not develop without disturbance and fluctuation. Also, the benefits of this process of world integration were far from uniformly distributed. Nevertheless, we may state that by the end of the 19th century the geographical expansion of the world economy has been completed. These international linkages, though they extended in different degrees to various countries, covered political, cultural and economic spheres, including within the last the exchange of goods, the flow of capital, the movement of labour. The development of individual countries has become more and more interdependent.

The 20th century has brought several events and processes which have modified the functioning of the world economy. These factors, among which the most important are the decolonization process and the emergence of the communist bloc, have, nevertheless, not led to the disintegration of the world economic system. It seems that the general trend towards interdependence is a constant tendency, resulting from the growth of the productive forces, changes in standard of living and the use of natural resources. Without extensive linkages on a global scale it would be impossible to maintain modern technological processes and world-wide living standards.

The analysis of the above tendencies and conditions indicates that the growth of global contacts and interrelationships has reached a level which can be described as a world macrosystem. The basis for such a macrosystem consists of global interlinkages covering the use of natural resources, and thus affecting the sphere of natural environment, as well as processes in the socio-economic sphere, together with the interactions between both these spheres.

THE WORLD FOOD SYSTEM

INTRODUCTION OF THE CONCEPT

The question of food has always been a central issue in human societies, affecting the survival of whole civilizations. Throughout the entire history of mankind the mode of food production and distribution have been continuously changing. In geographical terms, however, these changes were not dramatic. Until the formation of the world economy in the 19th century basic food supplies came, as a rule, from local and regional sources. Only the development of the capitalist mode of production has made possible the international division of labour to the extent that permanent international linkages were involved in the exchange of food supplies. Although still at present the crucial decisions with regard to food supplies are being made within national borders, the interdependence of nations is critical in determining national policy options.

It seems that with the formation of extensive and permanent international linkages in food supplies, it is possible and useful to introduce the concept of the world food system. This concept, drawing on the systems approach, may serve as an appropriate framework for an analysis of such a complex phenomenon as the network of food exchange.

The concept of the world food system can be introduced in two ways:

a) taking the world food system as a functional part of the whole world macrosystem,

b) starting from the concept of the food system itself and seeing within it a hierarchy of organization.

We will now take these two ways in turn for fuller discussion.

(a) The point of departure here is the world macrosystem or a set of elements and their relationships which bring about a system of global interdependence. The world system, as conceived here, does not include every kind of relationships existing in the world, but primarily consists of those relationships which have a distinctly international or intercontinental character. Even with such limitations, the world macrosystem, permeating physical environment, economic, social, political and cultural spheres, is so complex that any attempt to model it as a whole would be fraught with considerable difficulty. It is worth remembering that despite the application of modern computer techniques, all world models developed so far have been concerned only with particular problem areas of the world system, quite apart from those problem areas which were either considered less important or were too difficult to model.

It would seem, in our present state of knowledge, a sensible and practical procedure, at least for the purpose of analysis, to separate the world system into problem areas, such as food, raw materials, politics, etc., remembering at the same time that all of these are interdependent within the system as a whole. In this approach, therefore, one has to separate from the world macrosystem those elements and relationships that determine the essential global interdependence in food supply. This procedure is consistent with the Platonic principle that we must study the whole before we examine the parts.

The world food system is not an isolated, closed system, but is clearly a part of the world macrosystem. However, for practical purposes or especially for analysis of world food problems it is clear that the world food system is a more useful concept that the world macrosystem as a whole.

(b) The second approach to introduction of the concept of the world food system begins with the food system itself. The food system as a general concept has already been introduced in the 1970s, but without clear definition and lacking in rigour. The clearest interpretation effected so far can be found in the studies of the United Nations Research Institute for Social Development (UNRISD), which were published in the late 1970s. In the UNRISD publication *Food systems and society* (1978), which was mainly concerned with future research, the following definition appeared on page 13: "Food system can be visualized as an irregular and complex pattern of food circuits... with flows fluctuating according to seasonal changes and annual differences in food production and total food availability, as well as to changes in the levels and patterns of consumption".

If we interpreted the food system concept in semantic terms it would include the processes of food production, distribution and consumption. It seems, however, that the scope of this concept would be too broad, if only for the reason that the process of production is fully covered by the agricultural sciences and most aspects of the process of consumption by nutrition studies. Therefore, we should focus our attention on those aspects of the food system which appear in the above definition, namely 'food circuits' and 'flows'. These are obviously not the only relations within the food system, but they are of its essence.

If flows and circuits are essential features of food systems then it is extremely important, particularly for geographers, to study their spatial pattern. This spatial extent of food systems may be a good basis for their classification. Such a classification should include at least three levels:

1. Local

This system covers flows and relationships within local and regional markets, usually in terms of town and hinterland interrelationships.

2. National

This system assumes the existence of a national market or of a uniform system of food distribution at the national level. The basis of a national food system is a nationwide network, within which it is possible to have flows of food uninterrupted by either physical or administrative barriers.

3. World

The essential factor in the existence of the world food system is the international division of labour, which is a basis for systematic flows of food between nations and continents. The key mechanism in the regulation of the food flows is the world market together with various systems of concessional food distribution.

The three food systems described do not exclude the existence of systems of an intermediate character. An example of an intermediate system may be seen in India's food zones created in the 1960s, which effectively hindered the interregional movement of food. An example at the supranational level consists of the European Economic Community, where the Common Agricultural Policy separates that system from the world food system.

It is debatable whether these systems of an intermediate character, both subnational and supranational, should be included in a system of general classification, or whether they should be treated as exceptional. It is perhaps more important to determine the basic criteria for such classification. The basic criteria of the three scales of food systems are the distinctive levels of network and of organization. Using these criteria it is possible to distinguish a world food system, which is at the highest level in the food systems hierarchy.

THE CONCEPTUAL BOUNDS OF THE WORLD FOOD SYSTEM

The introduction of a general concept involves the question of the essence and the content of the concept. Establishing the scope of the concept, we determine simultaneously its conceptual limits, that is, in systems terminology, we separate the system from its environment. This is an essential step in analysis. In the real world there are always more or less important interdependencies among innumerable elements, and we must, in most cases, arbitrarily decide which elements and relations should be included into the system under study. Otherwise, we could merely state that everything is interdependent, which does not solve anything and may reflect only the helplessness of the research worker. System boundaries cannot and do not always need to be strictly defined. It seems that a long discussion on the concept of a region in geography may help us in this question.

Of what, then, does the world food system consist? What elements and relations are within this system, and what is its environment?

In the world food system the organizational level and the network of flows must have a global character. Therefore, there must exist physical, technical, economic and political opportunities for the movement of large quantities of food between countries and continents.

Such opportunities arose in the process of forming the world economy during the period from the 16th to the 19th centuries. During this process there developed both surplus and deficit areas in the production and consumption of various foodstuffs. The growing international division of labour within the world system as a whole, has led to the formation of the complex network of food flows at a global level. It seems that acceptance of the network of food flows as the basis of the world food system can hardly be questioned. Without food flows on a global scale there can be no question of the existence of the world food system.

There exist, however, other international linkages that influence the food situation of individual countries and of the world as a whole. These involve trade in agricultural inputs and technology, flows of information, capital and scientific knowledge, and, last but not least, interactions along the networks of power. All these networks certainly influence the flows of food. Should not they also be included in the world food system?

We might ask the same question with regard to internal factors in individual countries, in other words, national food systems. Is not the world food system as a whole simply the sum or, at least, the resultant of all these national food systems in the world?

Such questions can be multiplied. We can always find an additional element or relationship influencing the world system whenever we try to look for them. As our search for influencing factors proceeds, we will finally discover that most of the world society, economy and ecology influence, or are influenced, by the networks of food. This finding is not particularly revealing because we have already been able to identify the world macrosystem and within it the world food system. Therefore, we must make a decision about the choice of only those elements and relations which are essential to the system. Other elements and relations, though they may influence the world food system, should be regarded as environment.

The essence of the world food system is in the flows of food on international and intercontinental scale, in quantities large enough to form a relatively stable network. It is only such linkages that form a world system, and without them we can only think about a set of relatively independent national and local systems.

The world food system is focused mainly on flows of food, that is on an intermediate stage between production and consumption. Therefore other relations, even on international scale, such as trade in agricultural inputs, which in fact influence the processes of production and consumption of food in individual countries, should not be included in the world food system *sensu stricto*[3].

The world food system is neither the sum nor the resultant of the national food systems[4]. There are important factors, operating at the world scale and influencing international food flows, which nevertheless cannot be deduced from individual, national food systems. Some of these factors will be shown in the diagram below. The inclusion into the world food system of all the national systems would also mean an increase of the order of several times in the number of elements and relationships which would have to be considered, making it difficult to determine the boundaries of the world food system within the world macrosystem.

Consideration of an aggregate of national food systems can clearly be very useful (*Food for all*..., 1981), for example, in order to study the food supply

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[3] Likewise the banking system, however broadly conceived, should not include the ways people earn their money, however important it is for the system.

[4] A different approach is, in fact, represented by the Food and Agriculture Program of IIASA where the international flows of agricultural goods and foodstuffs are only the "channel through which national models interact" (Keyzer 1977).

in the world or to forecast the food flows on a global scale. A set of interlinked national food systems can be used as a distinct construct, which can even be described as the world food system in a broad sense. In this paper, however, the world food system is used in a strict sense, and should be restricted to those food networks that link national food systems at a global level.

This paper is devoted only to the introduction of the concept of the world food system, to the determination of its essence and boundaries. The identification and analysis of elements and relationships in the system have been treated in a tentative manner, without going into details or using statistical data. The basic concept of the world food system is presented, in a simplified way in the diagram (Fig. 1).

The diagram presents the world food system as a concept distinct from the set of national food systems and also from the world macrosystem. The elements of the world food system are food deficits and surpluses which are produced by national food systems. These surpluses and deficits are at the same time the inputs and outputs of the world food system. Between so defined elements there is a network of interlinkages, with flows of food from surplus to deficit areas. The volumes of inputs and outputs (elements of the system) and also the pattern of flows (relations between elements) undergo constant changes and modifications. The behaviour of the food system and its evolution are determined by the actual pattern of elements and relations within the system. Those elements and relations

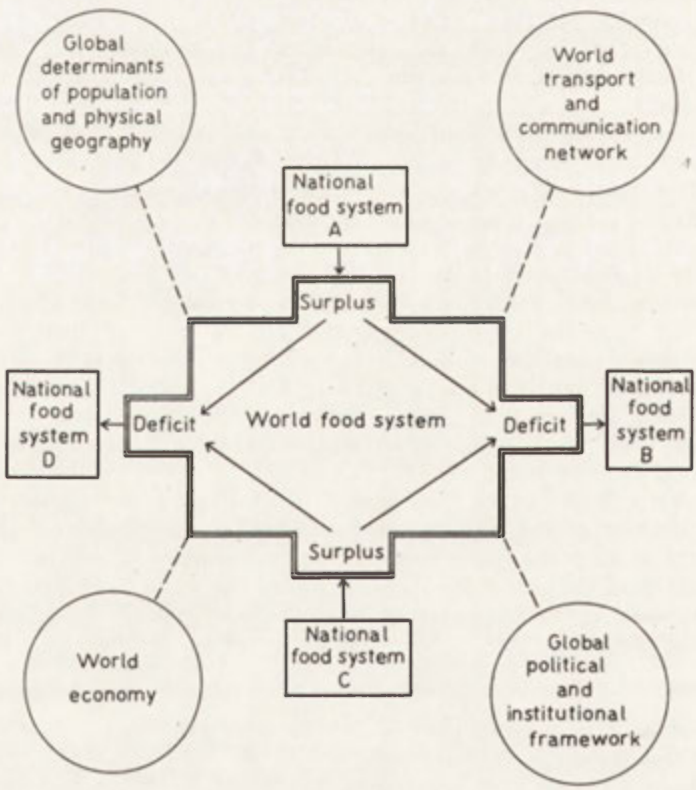

Fig. 1. The World Food System and its macro-environment

are, in turn, influenced by factors outside the system, that is national food systems and the world macrosystem as a whole.

In the diagram four national systems are exemplified: two deficit and two surplus systems. The real world is obviously much more complicated. First of all, the volumes of deficits and surpluses are not proportional to the size of a given national food system. There are many factors operating, which finally determine the level of self-sufficiency of a given national system. Even the distinction between deficit and surplus is not altogether clear. We may find, for instance, in a given country the food trade equilibrium, which puts thus such a country in a neutral, but not isolated position in the world food system.

Although the national food systems produce food surpluses or deficits (i.e. the elements of the world food system) they, nevertheless, do not determine exactly the pattern of international food flows (i.e. the relations in the system). There are always several areas in the world of surplus or deficit of each foodstuff and so a final pattern of flows is dependent on the behaviour of the world macrosystem as a whole. Thus, we have distinguished from the world macrosystem the four functional spheres (shown by circles in the diagram) which have most influence on the functioning of the world food system. These spheres cover groups of factors which cannot be directly deduced from the national systems.

In the group I there are the general factors of physical geography and population which act as determinants of the food flows on a world scale. These include, for example, the total area and geographical distribution of cultivable lands in the world, global proportions between population and food supply, the fluctuations and evolution of climates, pattern of distance between nations etc.

Group II includes the factors of world transport and communication. The process of formation of the world economy clearly indicates that transport development has always been an independent factor encouraging food flows. It is equally true of means of transport and of transport routes. For example, the mass inflow of cheap American grain to Europe at the end of the 19th century was generated primarily by the development of steam shipping in the Atlantic and by the extension of the railway network in the American continent. The development of new means of communication, such as telegraph and telephone, has made it possible to react quickly to local food shortages, even in distant countries.

Within group III we should consider the political situation, pattern of forces and institutional framework, which, independently of other factors, can favour or hinder international exchange and co-operation. Particularly affected are foodstuffs, commonly considered as strategic reserves. At present, there are many forms of international co-operation which facilitate the flows of food in the form of aid. On the other hand, the tense political situation and the lack of institutional forms of co-operation can lead to autarchy, self-sufficiency within national or even local systems.

Group IV includes factors of the world economy, particularly in international trade. Food flows do not take place in a closed system, they are a part of a wider trade network. Some countries are always surplus in food whereas others are in constant deficit. The balance for each country is being reached within the framework of the world trade and financial system. Therefore, any change in the international division of labour and in global trade and financial pattern influences also the world network of food flows.

Each of the presented groups of factors operating in the world macrosystem, independently of the others, influences the functioning of the world food system. These factors, combined with the set of national food systems, determine the volume and pattern of food flows on a world scale.

CONCLUDING REMARKS

This article has been limited to a presentation of the concept of the world food system. The stress has been put on conceptual boundaries, definition and, partly, external conditions of the system. Further work, which would require statistical data, should deal with: the structure of the system, analysis of the directions of flows, the mode of behaviour, the aims and functions of the system, its internal dynamics and alternatives.

If such an analysis results in identification and quantification of important internal and external linkages of the system, we may be able to proceed to a more formalized stage of modelling and simulation. This research procedure may serve as a means for presentation of an analysis of a given system. It plays thus an important heuristic role, making it possible to formulate statements on phenomena at a global scale, which so far have no theory of their own.

Systems analysis can also be treated purely instrumentally, as a tool providing a context for the inquiry. In such an approach, research would not be directed to the whole of the system, but to certain elements, relations, or problems, which can be better understood when analyzed within a given system. Following this line of reasoning, the knowledge of the world food system, of the ways it operates and changes, may be very helpful in the studies of specific problem areas, such as malnutrition, poverty, famines, food security or the perspectives of food supply in individual countries and the world as a whole.

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NEW PROCESSES IN THE WORLD ECONOMY AND THEIR INFLUENCE ON CONTEMPORARY SPATIAL ORGANIZATION

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INTRODUCTION

Geographers are currently facing a task of launching intensive, basic research into the factors and processes which cause the development of a new world organization of socio-economic space. This space and its evolution are increasingly influenced by the emergence and the rapid advancement of the world economy[1]. It should be considered a new and lasting element of the historical sequence of development in the second half of the 20th century, which will also be present in the early 21st century. It can be assumed that it will greatly affect the conditions of the life of people and societies.

The present article is an attempt at defining some of these factors and processes. They seem to exert a major influence on the current transformations in the organization of the global space.

THE EMERGENCE OF THE WORLD ECONOMY

The processes which have contributed to the development of the present system of the world economy are extremely complex. Moreover, it must be borne in mind that these processes were preceded by much earlier changes and transformations which accompanied the establishment of the foundations of the international division of labour and the world market. We mean, first of all, the consequences of the European colonial expansion and the progress of the economies of Europe and the USA[2]. In time, this division grew more diversified and deeper, both in the geographical and in the functional sense. Initially, the process involved only some spheres of economy in some countries or regions, whereas the others functioned on traditional principles, being of a local or regional scale. This led to the establishment of economies of a dual type, which comprised a modern and a traditional sector. Depending on the conditions of this process, which took place both in the developed and in the developing countries, the economies varied obviously in character

[1] I outlined these problems in the article titled *Niektóre współczesne procesy gospodarcze i tworzenie się nowej organizacji przestrzeni* (Some Contemporary Economic Processes and the Development of a New Spatial Organization), *Przegl. Geogr.*, 54, 2, 1982, pp. 283–289.

[2] Lubbe A., *Imperium Europejskie? Ekspansja Europy a powstanie gospodarki światowej* (A European Empire? The expansion of Europe and the development of World Economy), Warszawa 1982.

and structure. Strong links of dependence also evolved between these two groups of countries; in the developing countries they produced a specific economic structure, which was also reflected in the organization and structure of their socio-economic space. Development processes based on dependence characteristically prevailed till the end of World War II.

The gaining of independence by the majority of the colonial countries in the late 1950s and early 1960s marked a major breakthrough. The system of dependence which existed till that time began to change: formal and political dependence gradually disappeared, whereas functional dependence was consolidated and deepened. The later kind of dependence has been preserved till the present day. However, since the end of World War II we have also been witnessing growing socio-economic trends and processes which have been producting increased interdependence[3].

Trends towards socio-economic development based on interdependence have been growing not only in relations between the developed and the developing countries, but also in relations among the developed countries. The consolidation of interdependence seems to be one of the essential and most characteristic features of the contemporary world. Although this type of development co-occurs and mingles with the development based on dependence, it is the direction of evolution for the nearest future, despite the fact that certain temporary obstacles may or do unavoidably hinder its progress. This holds true for every single country and economy of the world.

In the sphere of the economy, the processes of interdependence result from the spread of technologically uniform production, which is accompanied by an increasing consolidation of the international division of labour and an internationalization of the labour market. The latter gives also rise to far-reaching structural transformations, also in the sphere of the location of production. The growth of interdependence is also promoted by the trend towards the development of international economic agreements and groupings of a regional character, both among the developed countries (e.g. the EEC) and between the developed and the developing countries (e.g. the association with the EEC of several countries of Africa, the Caribbean and the Pacific regions)[4]. Particularly important, however, is the foundation and activity of large supra-national corporations, which function in the world socio-economic space, frequently by-passing the existing formal political frontiers.

These trends, mentioned here just for the sake of illustration, lead to the intensification of economic development based on interdependence. Owing to them, there appear qualitatively new factors which influence the establishment and progress of new spatial production systems and production centres, the spatial relocation of production potentials within the burgeoning new international division of labour, and the establishment of a new structure and directions in the flow of goods and services.

The dynamic growth of the world economic system, and the resulting establishment of a new world spatial system of economic activities, entails the appearance of new functional and geographical divisions of these activities. The price revolution which followed the steep rise of oil prices in the 1970s greatly contributed to the appearance of new divisions. It is sometimes deemed one of the 'epochal changes'. The price shock has now been largely lessened, as it has brought about deep processes of structural transformations, both in the economies of individual countries

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[3] Rościszewski M., *Rozwój zależny a badania nad geografią rozwoju* (Dependent development and studies on the geography of development), *Dok. Geogr.*, 5, 1981, pp. 24–35.

[4] Rościszewski M., On new trends of the research into the Third World Countries, in: *Third World geographical problems of development*, *Prace Geogr. IGiPZ*, 141, pp. 15–22.

and in the system of world economy. The processes are continuing. New spatial alignments and links, new dependences and new directions of the flow of goods and services have been developing. The level of the prices of oil, which is one of the main fuels and a raw material for many branches of chemical processing, largely determines the present directions of economic activities, the remodelling of their structures, and the opportunities of undertaking production activities in various countries.

The price revolution has contributed to the evolution of new relations of the costs of production, which, in turn, is a factor considered in the decision-making concerning the launching and location – in world space – of economic activities, their character and extent. Naturally, many other factors related to costs influence these decisions: labour costs, the cost of environmental protection, etc., which vary from one country to another. Last but not least, there are also political considerations. Owing to all these factors, the conditions are increasingly conducive to world-scale socio-economic development based on interdependence, they are increasingly conducive to the development of a new world organization of socio-economic space in all of its diversity.

THE FUNDAMENTAL CONFLICT IN CONTEMPORARY ECONOMY

Many conflicts accompany the establishment of a system of world economy. They are a natural consequence of the profound transformations occurring in the national or regional economic and social structures and of the establishment of new structures which are a result of these changes. One such fundamental conflict is the opposition between the striving to maximize the efficiency of economic activities on the world scale and the individual societies' aspirations to equality and affluence. The latter is particularly visible in the developed countries, whose societies are constantly striving to broaden the sphere of activity of the so-called 'welfare state'[5].

The striving to maximize economic efficiency is now of fundamental importance in the operation of, first of all, the capitalist economy. It is a consequence of the level of productive forces attained in this economy, which also brings about changes in the relations of production. In the striving to maximize economic efficiency, technological and organizational progress is promoted, the costs of production are reduced by way of reducing labour costs, checking the growth of real wages, curbing social security expenditure, etc. Thus, the aim is to limit the sphere of activity of the 'welfare state'. In the developed countries, earnings and social security payments have reached a relatively high level and involve high costs. Added to this must be the rapid increase in the costs connected with the protection of natural environment, which is a consequence of an objective need related to the functioning of the whole economy on the one hand, and the growing social consciousness of the problem on the other. All these costs are increasingly a burden on the profitability of many branches of production. They also contribute to what is often a far-reaching restructuring of production and its relocation to other regions, including the developing countries.

The above mentioned trend towards the maximization of economic efficiency is increasingly subjected to the rules which govern the world economy, including the tendency to development based on interdependence and the internationalization of the labour market. These rules and trends are often in opposition to the activities and

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[5] Cazes B., L'Etat protecteur contraint à un double manoevre, *Futurible*, 40, 1981, pp. 5–29.

goals of the 'welfare state', whose functioning is, besides, usually contained within national frontiers. The word 'usually' is used here because, on the one hand, the living standards are largely uniform in the developed countries, and, on the other, supranational groupings such as the European Economic Community introduce uniform labour legislation, and social security, and allow a free flow of labour throughout the Community. It is in the highly developed countries that we are now witnessing the trend towards limiting the scope of operation of the 'welfare state', as its costs reduce the competitiveness of many economic activities.

THE MULTINATIONALS

One of the essential features of contemporary world economic processes is the trend towards the concentration of various spheres of the economic activity. This concentration is effected first of all by means of large multinational and supranational corporations. Although multinational firms also existed in the past, and some others operated in different countries, the present corporations are a qualitatively new phenomenon. This new quality is due to the volume of assets they have at their disposal, the scope of their activity, and the fact that the growth rate of their production is higher than the production growth rate in individual countries. Corporations are involved in more and more fields of economic activities, in the spheres of both production and services. In the sphere of production, they are primarily concerned with the most modern branches of the processing industry. The firms also have great capacities of adaptation to the conditions of the countries in which they operate. This flexibility allows them to use the existing conditions in order to maximize the efficiency of their economic activities. Moreover, owing to the firms' financial resources and their capacities as regards world-scale location of their activities, the countries in which the firms operate are often unable to control their policies. The means they have at their disposal enable them to exert various kinds of pressure. Pursuing their policies within the world economy, the corporations use local conditions to draw their own profits.

Thus, this is also a new quality as regards the spatial aspects of economic activity. It consists in the establishment and implanation of functional links related to production, the spatial distribution of labour, and the flow of goods and services above formal and political divisions (between countries). These links exist both within and between the functional spaces of production and services created by the multinationals. They are qualitatively new, supranational economic sectors, which mark their presence in the global space. This activity of the multinationals greatly contributes to speeding up the development of interdependence.

The directions of the development and activity of the multinationals give rise to a lot of tensions, which, at least in part, are due to the fact of operating above formal and political divisions. Operating on the supranational plane, the corporations are relatively free to choose the location of their production activity. When locating their production, they select regions where labour costs, overall production costs, and the conditions of functioning are the most advantageous. Thus, multinational corporations (but not only them) fight the limitations resulting from the costs of operation of the 'welfare state'. These costs largely determine the directions of the remodelling of the existing industrial and also economic structure in the developed countries. The aim is to maintain and develop the spheres which are the most profitable and innovation-stimulating. On the other hand, many branches of industry, mainly those which are no longer profitable in the developed countries, are transferred into the Third World. This has far-reaching consequences for the social climate in this group of countries, causing a strong polarization of interest group, which is conducive to many conflicts.

However, considering the qualitatively new processes and regularities in the restructuring of the world economy, conflicts of this kind seem fully understandable. Supranational corporations are manifestations of the development of a new structure of the world economy, they cause its spread, bringing many countries, also the developing ones, into the sphere of its operation. Within traditional mechanisms of development, they would have no chance of becoming, in any aspect, partners of the developed countries. That is why it is frequently difficult to distinguish between the processes of dependent and interdependent development and evaluate their consequences as clearly positive or negative. It seems that these processes should be treated as a part of the natural sequence of historical development, full of internal contradictions, which determines the beginnings of a new organization of socio-economic space of contemporary world.

THREE REVOLUTIONS

One of the consequences of the concentration of economic activities connected with the establishment and operation of transnational corporations is the spread of scientific and technological progress. As it was mentioned earlier, multinationals usually operate in the most modern spheres of production, ones which are the most likely to adopt and absorb various innovations in the fields of both production and organization. This is also due to the fact that they operate under different conditions, to which they must adapt without resorting to rigid operation rules. Unlike traditional monopolies, the multinationals aim their activity mainly at stimulating demand or even generating it, which is also conducive to the development of modern branches of production. These features of the functioning of transnational corporations causes not only a far-reaching remodelling of many spheres of socio-economic activities, the character of these activities and their spatial relocations, but also the establishment of this new structure of the economy on the world scale and on the scale of countries or regions.

Of the many directions of change resulting from innovations, three are worth noting, as they exert a particularly strong influence on transformations of the production activity, which is reflected in the sphere of the organization of the economic and social life, including its spatial organization. The first concerns the spread of the automation of production processes. The use of robots is becoming more widespread, which is sometimes called the 'robotic revolution'. The second direction of change is connected with the rapid progress of the automation of the processes of management, office or bank work, several services, and the information flow. This 'bureautic revolution' is due to the spread of automated calculation techniques and techniques of transmitting information. The third direction is connected with progress in the field of biotechnology.

These three 'revolutions' (far from all the achievements in the field of technological progress) are disseminated within the supranational sectors of the economy, where the multinationals operate. Owing to the flexibility of transnational corporations, it is possible to introduce and spread the innovations under various conditions and in various organizational structures. However, the centres from which these innovations originate are basically only the developed countries. Considering the situation in terms of models, we are dealing with two types of 'centres'. In the traditional approach, this is a group of 'central' countries which in various ways dominate the periphery, which is also internally diversified. On the other hand, there is also the 'centre' of a functional character, which produces innovations to be subsequently adopted or absorbed by the 'peripheries', which are also of a functional character. It is on this plane that links of interdependence develop and are then transferred to the plane of formal and political (inter-state) relations. Owing to their ability to create and propagate production and organizational innovations, the developed countries gain certain profits. These countries are also the first to be affected by the resulting transformations. New socio-economic structures and elements of spatial organization develop in these countries.

NEW SOCIO-ECONOMIC DUALISM

Under the influence of the above described processes, a specific dualism develops in the socio-economic structure of the developed countries, including their spatial organization. A 'supranational' and a 'domestic' sector emerge[6]. In many of these countries we are witnessing a progressing re-orientation of some economic activities towards the development of the most modern and dynamic branches which operate on the global plane and are subject to the rules which govern it. At the same time, some branches of production, which are no longer profitable in the area of these countries, are subject to restrictions or even altogether eliminated (e.g. curbing the development or elimination of the textile industry, some branches of the electrical industry, remodelling the steel industry, etc.). Naturally, in many cases the governments pursue a protectionist policy in order to avoid, at least at the transitory stage of this restructuring of the industry, excessive social shock due to job cuts, qualification for new jobs and diverting labour to other branches of the economy. This causes major changes also in the sphere of functional, production, and spatial structures of whole regions.

THE 'SUPRANATIONAL' SECTOR

The establishment of a 'supranational' sector is a manifestation of the processes being currently under way in world economy. The sector covers the activities of multinationals, which employ new technologies and organizational methods, operating in the modern branches of production and services. It also embraces many other spheres of more traditional production. Owing to the character of its functioning, the activity of this sector is integrated in world rather than in national space. It is subject to world-wide competition, which means, among other things, that a reduction of the costs of production in one country influences to some extent the conditions of this activity in other countries. As the sector develops, the economies of the countries where it operates are remodelled.

One of the most important consequences of the development of this sector is the above mentioned trend towards the maximization of economic efficiency attained by operations such as the reduction of the costs of production, including labour costs. On the scale of world economy, this results in the striving to unify the diverse labour markets, currently at least as regards individual activities. This

[6] The literature lacks terms to denote these phenomena. The terms 'modern sector' or 'traditional sector', which are sometimes used, are totally inadequate. They are usually employed when analysing the economies of Third World countries. A mechanical transfer of these terms to explain development processes in the developed countries and in world economy may prove misleading. Therefore, although they may not fully pinpoint the essence of the discussed problems, the terms 'supranational sector' and 'domestic sector' are used here.

is one reason why the expenditure related to the existence of the 'welfare state' in the highly developed countries is questioned. The opponents of the idea of the 'welfare state' also point to the economic burden of growing taxation, social security payments as well as various limitations imposed on enterprises in connection with extending social services. Many economic activities in the developed countries are becoming less profitable or even altogether unprofitable. Naturally, the rising costs of production in these countries (including the growing expenditure on environmental protection) burden not only the multinationals, but also smaller enterprises which collaborate with them. This explains why the branches of production which are the most labour-consuming or unprofitable in the developed countries tend to be relocated to the countries where labour and social services cost less, and environmental protection is not considered so important (such conditions exist in the Third World countries).

Some important comments should be added to this brief presentation of the causes of changes which occur in the world-scale distribution of production. It virtually never happens that the entire activity of some branch of production is relocated from a highly developed to a less developed country. The headquarters of transnational corporations or large firms always remain in the area of the developed countries. This is due to the fact that the overall conditions in the developed countries allow an efficient functioning of such complex economic mechanisms. These overall conditions also provide for the introduction of innovations and their propagation to other areas. The fact that there are no such conditions in the less developed countries is responsible for the dependence of both whole countries and individual spheres of economic activities, despite the interdependence processes under way. As it was mentioned earlier, the 'supranational' sector also has its centre and periphery, and we must consider all the consequences of this fact.

We should also indicate briefly certain social consequences of the development of this sector. There emerges a group of people, more and more important, who are employed in this sector. They are first of all highly qualified cadres, engineers, technicians, managers, etc., who operate on various organizational levels of 'global space'. This is reflected in their mentalities, attitudes, behaviour, the perception of the world, etc., which are largely different from those of more traditionally-oriented groups.

THE 'DOMESTIC' SECTOR

As a result of the development of the production and service activities covered by the supranational sector, the socio-economic structures of countries are remodelled: a part of the population not involved in the activity of this sector remain in the spheres which satisfy more traditional needs, mainly domestic ones. This causes the establishment of a kind of a separate socio-economic sector, which is called 'domestic', even though some of its activities may also be partially externally oriented. As a result, there occurs a specific kind of 'marginalization'[7] of these activities as well as of the population employed in them. The 'domestic' sector embraces all the economic and social activities which for various reasons cannot keep up with the pace of development and satisfy the requirements of world

[7] The processes of marginalization are well known and extensively analysed in economic and social research into the developing countries. However, they are something new in an approach to the developed countries, naturally as regards the presented dualism. They are considered in research into the unevenness of regional development.

economy. They slip to the margin of this economy and are to some extent isolated from global-scale processes. These activities are more or less limited to the borders of a country or its regions. For various reasons, they are in a smaller degree subject to the influence of international competition, the penetration of modern technologies and innovations, and the institutions which deal with redistribution, which undergo particularly rapid changes in the 'supra-national' sector. The 'domestic' sector is a kind of 'bank' of the established methods of production, cultural traditions, and more conventional lifestyles. On the other hand, it carries a particularly heavy burden of costs due to the functioning of the 'welfare state'. When the 'domestic' economy is cut off from the operation of general rules and processes, it faces the risk of involutional processes, due to which a return to the conditions existing in world economy can only be made at great costs. These processes must also lead to a degeneration of the spatial structure.

The present situation of the 'domestic' sector in the developed countries produces various kinds of processes. One of the most important changes is the development, alongside the enterprises operating within the existing formal and institutional framework, of a sphere or spheres currently described as 'informal economy'.

'INFORMAL ECONOMY'

The growing costs of activity borne by enterprises in the developed countries result from the necessity of providing means for the functioning of the 'welfare state'. Hence, the tendency to avoid taxes and expenditure on social services by means of undertaking various kinds of activities outside the formal and institutional framework of a given country. These activities bridge the gap between the supply and the demand for goods and services, a shortage of which indicates that certain spheres of the economy are not functioning properly.

'Informal economy'[8] may exist in many kinds of productive activities in the field of the processing industry and services. They are usually small-scale activities connected with crafts or cottage industry, but sometimes also larger enterprises are set up. This economy grows dynamically and frequently reaches considerable dimensions. The labour force are not only the unemployed, but also low qualified workers from the poorest strata of the population. This economy also provides extra, or sometimes primary, jobs for highly qualified specialists. The products usually satisfy the standard market requirements, competing successfully with the products of formally registered enterprises.

The emergence and development of 'informal economy' should be linked with the striving to maximize economic efficiency under actual conditions of structural transformations. However, it seems an oversimplification to regard this striving as the only cause of the emergence of 'informal economy'.

The present scope of 'informal economy' and its functioning in the developed countries have not been studied in detail. The data for obvious reasons are based on estimates, and errors are bound to be considerable. Nevertheless, it is often stressed that 'informal economy' is developing rapidly to embrace fresh fields of activity and is becoming increasingly important in the economic and social life of countries. According to estimates, in the USA, for instance, the share of this type of economy in the GNP amounted to about 19% in 1976, and rose to 26.6% in 1979. Although these high figures as well as the very methods of

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[8] Amselle J. L., Economie souterraine, économie sans mystère, *Futurible*, 40, 1981, pp. 55–62.

estimation are questioned, even the critics admit that the figure is not lower than 10% of the GNP. It is estimated that 15 to 29% of value added in the Italian processing industry should be ascribed to the 'informal economy'. In many regions of the country, this kind of activity is the basis of employment and economy. The role of the 'informal economy' in France is considered smaller, but its share in the GNP is evaluated at no less than 10%. The share also varies between branches of the economy. According to estimates for West Germany, the housing repair services rendered by the 'informal' firms amount to some 80% of all these services.

Owing to insufficiently developed infrastructure of services and insufficient flexibility of production activity, 'informal economy' also functions in the socialist countries. In some cases, however, it differs in forms, scope, and fields of operation from the 'informal economies' of the developed Western countries[9].

'Informal economy' develops first of all on the margin of the 'domestic' sector. It grows dynamically, as lower costs allow it to compete successfully with formally registered enterprises. Its production is sometimes also used by the 'supranational' sector. Contrary to what some people claim, it is not purely obsolete economy. Some of its products are ultramodern. A dynamic growth of this economy means that the national economy is not operating properly and calls for institutional reforms.

SOME TRENDS IN REMODELLING THE EXISTING ECONOMIC SYSTEM

As it was mentioned earlier, the 'welfare state', the way it is organized and operates at present, seems to hamper the spontaneous trends to remodel the existing economic system. The trends are towards a maximization of economic efficiency, world-wide unification of the labour market, and a new international division of labour. One of the manifestations of these trends is the concentration of several production and service activities in large supranational corporations operating on the plane of global economy. A reduction of the role of the 'welfare state' is one of the aims of the expanding 'supranational' sector, 'informal economy', and the 'domestic' sector. The striving to limit the functioning

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[9] The relevant studies conducted in Hungary in 1979 showed that the so-called 'second economy' embraces: 1) people working, without contracts of employment, illegally employed craftsmen, who do not pay taxes, and people rendering various services within the socialized sector or outside it; 2) people working on small allotments in the countryside together with their families, or hiring workers; 3) people who draw extra profits by virtue of their functions in the socialized sector (bribes, tips, etc.); 4) people who draw profits from the secondary distribution of the population's incomes outside the socialized system (letting flats, purchase and sale of movables and immovables, granting loans, etc.). It was also indicated that the emergence and development of the 'second economy' is a normal result of deficiencies or gaps in the functioning of the 'first' or 'official' economy. Until these deficiencies are removed, we must accept the existence of the 'second economy', merely monitoring this activity so that it does not reach extreme forms (see I. R. Gabor, Węgry, problemy z 'drugą gospodarką' (Hungary, Problems with 'second economy'), *Prezentacje*, 5, 1979, pp. 75–82.

A process of including the 'second economy' into the country's economic mechanisms has recently begun in Hungary: "... the aim is to support the initiatives of people in the fields where they my turn out to be useful and legalize private initiatives in order to control them better (Les conceptions hongroises, *L'Expansion*, 5–18 June 1981).

of the 'welfare state' is seen in a number of highly developed countries (e.g. the USA, Great Britain, Sweden). It is expressed not only in concrete decisions taken by governments, but also in scientific theories (e.g. monetarism or the neoliberal economic theory).

Naturally, these strivings are opposed by a large part of the countries' population. People are unwilling to relinquish the advantages and securities obtained in the course of a long historical process. Therefore we cannot consider these transformations only in technical and economic terms.

There are various proposals aimed at restricting the scope of activity of the 'welfare state'. The most extreme of them demand a shorter period of compulsory, free education for young people, paid university education, discretionary insurances (compulsory insurances being limited or altogether abolished), an abolishment or serious limitation of unemployment benefits, etc. On the other hand, the proposals envisage a considerable reduction of taxes and social security payments borne by the employers, which influence the profitability of production. Informal and part-time work should be legalized to some extent, and the unemployed should be able to set up their own work establishments. The proposals also include a spatial dispersion of production activities, which should alleviate social tensions, aggravated by excessive concentration of workers in large plants and conurbations.

Although there are different trends and conflicting views, the scope and efficiency of state care in the developed countries are diminishing. The state is unable to fight unemployment, various forms of social pathology, environmental damage, etc.

In view of this, the changes currently taking place in the 'domestic' sector, and above all the development of 'informal economy', may be considered manifestations of a new self-organization of society on the basic level and a kind of self-defence against various processes occurring in the country or worldwide. There is plenty of evidence that the charges levelled against the operation of the 'welfare state' and the spread of 'informal economy' are not just a reaction to the objective laws and processes of economic development, market game or competition. They are not just a reaction to the inadequate functioning of the economies of the developed countries. We must also be aware that active individuals and social groups feel a deep need to show their ability to engage in activity and self-determination.

Moreover, it frequently turns out that the activity and in particular the prospect of a wider functioning of the 'welfare state' in its present forms no longer suit the views or aspirations of segments of society in the industrialized countries. The 'welfare state' is accused of imposing shallow, materialist, increasingly inadequate conformity on society. In order to face the reality, we need new initiatives, and the attitudes to life and the principles of functioning of societies must change. In some countries the state is also accused of losing its caring character and transforming into an 'oppressing state'.

Examining the socio-economic processes currently under way, some people tend to believe that this is a kind of return to the spontaneous expansion of the capitalist system in the late 18th and the 19th centuries. This analogy seems to be of little validity. The contemporary processes differ from those of the past not only in quantity, but above all in quality.

FINAL REMARKS

The present article is only a brief presentation of the trends and processes occurring in world economy. It is difficult to state now what the direction of their further development will be. They are doubtlessly a manifestation of profound, perhaps dramatic socio-economic and cultural changes under way at the end of the 20th century. They are a manifestation of development trends to which all countries, though in varying degrees, are subject.

Although the processes, and above all the directions of transformations to which they give rise, are still at an initial stage, they doubtless deserve in-depth studies to be conducted by specialists in economic and social geography. They are a most suitable object for research of these sciences. World economy is sometimes defined as "... a system which binds the national economies of countries and groups of countries which are included in it and at the same time, as one whole, influences the processes of functioning and growth of its component parts"[10]. In view of what has been said in the present article, geographers should draw conclusions from the fact that there is only one world socio-economic space. It is strongly diversified internally, but its components are variously interrelated and interconnected, they interact in various ways and with varying intensity. Together, they constitute a spatial system which is integrated and to some extent organized. The system binds simulateously these components and, as a whole, undergoes transformations and influences the evolution of these components. One consequence of these processes are and will be deep changes in spatial organization, both on the global and the local scale, and the emergence of new spatial structures.

The present historic changes in the organization of world socio-economic space justify the development of a new branch of the geographical sciences – the geography of world development problems.

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[10] Kleer J., *Gospodarka światowa*: *Prawidłowości rozwoju* (The World Economy: Regularities of Development), Warszawa 1981.

GEOGRAPHIA POLONICA 50. 1984

THE DILEMMAS OF POLAND'S SPACE

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INTRODUCTION[1]

In the history of regional studies in Poland there have been perhaps three turning-points — periods of creating new paradigms. The first paradigm emerged in the 1920s as a reflection of new problems incorporated in the reality of Polish state which in 1918 has regained its independence.

The second paradigm is a product of the 1950s, a period both of the liquidation of the first paradigm and the creation of the second paradigm as a phenomenon resulting from the interaction of the needs of the socialist state. the best traditions of Polish scholarship and the proper comprehension of the directions of development of world science.

The 1970s cannot record any achievements as regards the inhibition of the natural process of decline of paradigm II or touching off processes of creating paradigm III that respond to the challenge which Polish regional studies were facing at the turn of the 20th and 21st centuries.

Accordingly, I think the first half of the 1980s should be viewed as marking the third turning-point in the history of regional studies in Reborn Poland — a period of creating paradigm III.

In this context I should like to put forward the following concept of a paradigm.

By a paradigm I mean a set of questions about the objective reality and a set of ways and methods of answering those questions. In the concept of a paradigm we can distinguish between substantial and instrumental elements.

The role of substantial elements in creating a new paradigm consists in understanding the new problems that reality keeps bringing up and which, for such or other reason, do not fall into the field of interest of the old paradigm. Any change in the substantial elements is bound to call forth a change in the instrumental elements, or, to put it differently, to generate new concepts in methodology and research and in the organization and equipment of the scientist's workshops.

I disagree with those who maintain that the notion of paradigm comprises instrumental elements exclusively. I strongly believe that in the new conditions of the 1980s we must accord priority to substantial elements, that is to the new problems of Poland's space whose resolution is our obligation both as scholars and citizens.

On the ground of such premises and motivations I should like to attempt a definition of the fundamental dilemmas of Poland's space. The list of those dilemmas can, as I see it, be defined as follows:

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[1] See *Biuletyn KPZK PAN*, 118, 1982. Preface.

Dilemma I – Spatial order versus spatial conflicts
Dilemma II – Uniformization versus diversification of space
Dilemma III – Deterministic versus voluntaristic space
Dilemma IV – Governmental versus self-governmental space
Dilemma V – Rich versus poor space
Dilemma VI – Active versus passive space
Dilemma VII – Objective versus subjective space
Dilemma VIII – Reistic versus informational space
Dilemma IX – Development versus crisis space
Dilemma X – Past versus future space

Of course I do not claim that this is the only or the best list of dilemmas of Polish space. Conversely, I am sure the future discussion on this article will disclose a number of weaknesses and intellectual deficiencies my concept of dilemmas may contain. Yet, I should like to believe that an attempt to define the ten fundamental dilemmas of Polish space will become a significant impluse toward working out a new approach to the problems of the Polish space in the 1980s and a new paradigm of Polish regional studies.

DILEMMA I

The concept of spatial order is probably the central concept that integrates regional studies as a dynamic direction of interdisciplinary research which comprises a broad range of natural, social and technical sciences.

In 1980, K. Secomski put forward the contention that the basic provisions of the economic, social and spatial order are inseparable[2]. In 1982, Z. Pióro attempted to define the notion of 'spatial order'[3]:

"By 'spatial order' I mean: 1) a spatial logic, that is, functionality in the distribution of the elements of structure, 2) spatial transparency, clarity of the pattern, and adequacy of conjuring up distinct spatial pictures in the minds of users, 3) the preservation of the amenities of environment, 4) the optimization of movements of people and commodities, 5) the charm of the surroundings, 6) the rational ecological coefficient, or, adjusting the spatial structures to the structure of patterns of spatial behaviour". This definition includes three elements:

1) the functional element (items 1 and 4)
2) the perceptive-aesthetic element (items 2, 3, 5)
3) the behavioural element (item 6)

It seems that the concept of spatial order can be submitted to a triple interpretation:

1. the ontological interpretation, which treats spatial order as a significant attribute of the spatial reality,
2. the cognitive interpretation, which treats spatial order as a directive for organizing the processes of exploration of spatial reality,
3. the operative interpretation, which treats spatial order as a directive for organizing our practical activities in space.

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[2] K. Secomski, Planowanie perspektywiczne – gospodarka przestrzenna. Polityka i ekonomika regionalna (Long-term planning – space economy. Regional policy and economics) in: *Problemy gospodarki przestrzennej*, A. Kukliński (ed.), Warszawa 1980, pp. 11–27.

[3] Z. Pióro, Ekologia społeczna – nauka o strukturach i zachowaniach przestrzennych (Social ecology – the science of spatial structures and behavioures), in: *Przestrzeń i społeczeństwo*, Z. Pióro (ed.), Warszawa 1982, pp. 113–130.

In the past we deluded ourselves very often, or pretended to believe, that the materialization of the idea of spatial order in Poland is by definition a conflict-free process. Once such an assumption had been adopted the ultimate outcome was a neglect of empirical studies analysing the actual pictures of spatial order in Poland as well as of studies analysing the processes of accumulation of spatial conflicts. It was only in 1981 that, with the "Diagnosis of the state of Poland's space economy", studies were commenced in an attempt to answer the question about the origin, functioning and appraisal of the fields of conflict in Poland's space economy.

In this context appeared J. Kołodziejski's pioneering study entitled "The implementation of developmental targets in the conditions of growing conflicts in space economy"[4]. According to the author, "the study tackles a problem whose solution constitutes a significant element of activities toward raising the efficiency of space economy in determining contemporary development.

This follows from the following conditions:

1. In the contemporary process of development, with the growth in its multi-layer complexity, increasingly frequent and increasingly acute conflicts emerge between economic actors operating in space and using space on the one hand, and actors materializing different social and economic targets in result of the division of labour.

Such conflicts reflect a struggle for access to space, to its amenities and resources conducted from position of different mutually contradictory criteria of rationality as derivative goals represented by those actors.

The accretion of conflict situations that encumber, inhibit or restrict the implementation of social goals is, in accordance with society-wide rationality, the most immediate consequence of conflicts that have not, or have but partly, been resolved.

2. Conflicts are the most acute and frequent in the process of development of complex spatial structures in which access to 'free' space is, for various reasons, the most difficult or else the most conflict-generating factor. On the other hand, the rational development of precisely those structures decides in the highest degree about the implementation of social goals.

3. Against appearance, the most frequent conflict situations have their source not in subjective mistakes made by decision-makers but in objectively conditioned factors built into the process of contemporary development. These include:

– the spatially differentiated geographic environment whose amenities and resources create very different though often functionally incompatible conditions and limited possibilities of their location,

– the steady rise in complexity of spatial structures which makes it increasingly difficult to secure locations not degrading the amenities of space, despite the unabated social demand for such locations,

– natural contradictions in the economic process between actors representing society-wide rationality and actors representing different, mutually inconsistent, partial rationalities.

4. The rising frequency of acute conflict situations and their objective conditions creates the necessity to modify the system of functioning of space economy such that would permit their solution or neutralization in accordance with criteria of societywide rationality.

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[4] J. Kołodziejski, Realizacja celów w warunkach narastania konfliktów w gospodarce przestrzennej (The implementation of developmental targets in the conditions of growing conflicts in space economy), *Biuletyn KPZK PAN*, 120. 1982. pp. 7–51

This postulate is of great significance not only in view of the experiences gained so far but also in view of the expected exacerbation of the conflict situations – and that in many aspects – under conditions of the socio-economic crisis and the mechanism of the economic reform now being implemented.

By and large, the current – and even more so the future – illusory conviction of great many space planners and decision-makers that the plan will automatically affect the actual development in keeping with socially desirable goals is, and will be, a very damaging element".

This trend of research which consists in the analysis of conflicts in Poland's space should perhaps be supplemented with a parallel research trend geared to the actual processes determining spatial order and disorder in Poland. In this manner we can get at empirical materials enabling us to take a new look at the dilemma between spatial order and spatial conflicts. This dilemma will, of course, never be solved in the sense of a complete immersion of the spatial order in spatial conflicts or of spatial conflicts in the spatial order. The point is only that our country in the future should set off mechanisms that really diminish frequency and scale of spatial conflicts and raise the dominance of the idea of spatial order in the ontological, epistemological and operational aspects.

DILEMMA II

It is a difficult and intricate job to analyse phenomena that uniformize and diversify space[5]. In that analysis we can adopt the methodology of pure description, in that we try to answer the question about the interrelationships between processes and phenomena that in effect add to, or diminish, the scale of spatial uniformization and diversification in the given country.

I use the terms spatial uniformization and diversification deliberately to emphasize that in both cases we mean complex and differentiated sets of processes and phenomena.

It is hard to talk of uniformization or diversification *en bloc*; rather, we should decompose those phenomena, distinguishing for instance between uniformization and diversification of economic space, social space, political space and, within the framework of economic space of investment, between production and consumption spaces. Consumption space is doubtlessly a socio-economic space[6].

With such a typology at hand one can undertake two kinds of studies: 1) empirical research, to analyse the realities of the 1970s from the angles of uniformization and diversification of Poland's space; 2) prognostic research, to tentatively answer the question of whether or not the economic reform and other changes in the socio-economic system would create new relationships in our country in the society-economy-space dimension.

Intuitively one can venture the hypothesis that the economic space of Poland in the 1980s will be more diversified than it used to be in the 1970s. Two phenomena will diversify Poland's economic space in the 1980s: 1) the relative autonomy of the individual firm which will doubtlessly diversify the patterns of spatial behaviour of firms, 2) the mechanism of the price determination system

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[5] G. Jackson and others, *Regional Diversity. Growth in the United States 1960–1990*, Auburn House, Boston 1981.

[6] See J. Szczepański, *Konsumpcja a rozwój człowieka. Wstęp do antropologicznej teorii konsumpcji* (Consumption and human development. Introduction to an anthropological theory of consumption), Warszawa 1982.

which will create the problem of a geography of prices in Poland to a scale unknown since 1950.

Comparative studies in Poland's social space in the 1970s and 1980s are a more complex problem.

Above all one must answer the question whether it was uniformization or diversification that dominated the shaping of Poland's social space in the 1970s.

More involved still is the problem of a forecast for the 1980s. In this respect there were two essentially contradictory tendencies: 1) the reinforcement of trends diversifying the economic space will in effect contribute to the diversification of the social space. An analogous effect will be called forth by the mechanisms of overcoming the economic crisis, which must resolve the effectiveness versus egalitarianism dilemma in favour of the former; 2) the aspirations and expectations of broad social circles developed at the turn of the 1970s and 1980s will produce a specific pressure to take egalitarian-oriented decisions, which in effect should diminish the diversification of Poland's social space in the 1980s.

My personal view is that the Poland of the 1980s must sacrifice many an unrealistic proegalitarian sentiment on the altar of rapidly rising effectiveness.

This is not to say, of course, that I am an advocate of an anti-egalitarian social policy with all its consequences for the shaping of Poland's space. Yet, it seems that strong pro-egalitarian policy will be possible in Poland only in the 1990s, after the processes of overcoming the economic crisis have been completed and the whole national economy has been restructured.

These fragments of my article show that the problem of uniformization or/and diversification of Poland's space simply cannot be analysed in the purely descriptive convention, that is, without formulating any value judgements.

The way we shall evaluate multi-directional trends uniformizing or diversifying Poland's space depends on the value system we may adopt at the given place and time.

It is in the light of that value system that we shall evaluate the experiences of the past as well as the prognostic suggestions regarding the decisions that will shape the new face of Poland's space.

DILEMMA III

Decision-making related to the choice of a definite concept of the socio-economic development of a country involves the problem of spatial options[7] of different degrees of significance and scale.

Very often one of these two extreme positions is taken:

1) the deterministic position, which overestimates the historical value of well-established spatial patterns, especially what are called external economies, joint location economies and agglomeration economies; in this approach one has to succumb to the impact of inertia and give up attempts to create new spatial structures,

2) the voluntarist position, which overrates the freedom of manoeuvering in spatial activities and underrates the objective constraints diminishing the scale of spatial options and of locational choices.

How true the French maxim *les contrasts se touchent* is, was dramatically confirmed in the 1970s when the fundamental decisions involved in spatial options

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[7] See J. Kolipiński, *Systemy przestrzenne jako środowisko człowieka* (Spatial systems as human environment). Warszawa 1980.

and in location choices were made in a climate of deterministic voluntarism, which consisted in underrating the objective constraints in strongly industrialized regions, above all in Upper Silesia.

It is precisely in the convention of deterministic voluntarism that a monograph of the mechanisms of decision-making conducive to the location of the Huta Katowice steel plant should be written.

Polish regional studies must not shrink back from producing such a monograph, both because it has to pursue its basic task of fundamental research and because it has to furnish a work that would be a warning to all who are to take great location decisions. The content of the warning will be very simple: for mistaken location decisions one will have to be eternally responsible before the tribunal of history.

Let us trust that in the 1980s we shall discard both the concepts of determinist and of voluntarist space.

Both concepts must be replaced by the concept of dynamic possibilism which is continually on the watch-out for new spatial options in a climate of correct assessment of current and future needs of society, of the economy and of the state.

DILEMMA IV

One must certainly start with the statement that, in terms of state the space of any country is above all a governmental space. It is the space for materializing the state's fundamental functions, which is comprising the entire area of the country. The scope of the state's basic functions materialized in the governmental space is not identical to all countries regardless of their political and territorial-organization systems.

Above all let us point to the significant differences between unitary countries such as Poland, France or Sweden and federal countries such as Yugoslavia, Czechoslovakia or Switzerland.

Countries such as Spain[8] or Belgium consitute a separate case which, within a general concept of a unitary state adopt quasi-federal solutions.

The efficient functioning of society, economy and state must, however, be preceded by the recognition that the governmental space should not be a total space.

In this context emerges the concept of self-governmental space which comprises the domains in which self-government – type solutions would function more efficiently than government-type solutions. The establishment of different relations between governmental and self-governmental spaces within a given country is obviously linked with the concepts for the centralization or decentralization of government within the framework of the country's territorial organization.

In Europe we may perhaps distinguish between two concepts of territorial self-government: 1) delegated self-government, where the self-government derives its competences above all from specific prerogatives accorded by the government, 2) autonomous self-government, where beside eligible self-government also function self-government – type forms of ownership and self-government – type taxes.

In the Poland of the 1980s a new order of relationships will probably crystallize between governmental and self-governmental space as well as between delegated and autonomous self-government.

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[8] *La Espana de las autonomias (pasado, presente y futuro)*, vol. 2: *La cuestion regional en la Constitucion espanola de 1978*, Espasa-Calpe, S. A. Madrid 1981.

DILEMMA V

We must ask above all the question whether in Polish conditions we indeed face the rich versus poor space dilemma[9]. Can such a dilemma occur at all in a socialist country where the classical poles of affluence and poverty have disappeared? It seems, however, that the notions of richness and poverty have not disappeared from our vocabulary or our experience. Relevant sociological studies of the notions of richness and poverty should be carried out in Poland and in Spain. We can venture the hypothesis that the results of such studies would make us realize the deep difference between Poland and Spain as regards individual and social conditions of richness and poverty and the way these notions are perceived within the context of the different socio-economic realities in the two countries. The differences in meaning of the notions of richness and poverty between Poland and Spain, as we view it here, is linked with the egalitarian character of our society and the antiegalitarian character of the Spanish socio-economic system.

In this context it can also be stated that the rich versus poor space does indeed exist in Poland but that this dilemma has in our country a quite different meaning that it does for instance in Spain.

The question arises whether or not in Poland of the 1980s the differences between what we are sure can be termed rich space and what can be termed poor space will intensify?

DILEMMA VI

The active versus passive space problem is particularly topical in Polish conditions.

Viewed retrospectively, the basic measure for recognizing a space as active in Poland was the ability or its representatives to participate efficiently in negotiations on the allocation of investment expenditures and the ability to transform those expenditures into material facts that would strengthen the structure of the given area'a space-economic development. Yet, that matter is not at all that simple. The Katowice voivodship (province) was doubtless an active space during the 1970s. But the outcome of that activeness is rather sad. The very active but wrongly allocated investment activities in Upper Silesia resulted in a weakening rather than in a strengthening of the structure of space-economic development in that area.

On the other hand, a fundamental condition for defining a space as passive is a particular intensity of processes of decapitalization. The exploration of the spatial differentiation of those processes is a significant task to Polish regional studies in the 1980s.

When considering the active versus passive space dilemma we have not confine ourselves to investment or decapitalization processes alone.

It seems that in the Poland of 1980s we should finally take up the study of the scale, structure and spatial differentiation of processes that generate technological, economic, social and institutional innovation throughout Poland's territory.

In this approach, active is a space that generates innovation, while passive space is the one that does not generate innovation, worse still, cannot even absorb the innovations that emerged in the active space at home or abroad.

[9] This dilemma was formulated by J. Kruczała at a conference at Jadwisin, June 1982.

I firmly believe that in conditions of overcoming the economic and social crisis in Poland, studies on the formation of active and passive spaces deserve special attention.

DILEMMA VII

We are used to regard the objective approach as an indispensable attribute of scientific knowledge[10]. In this convention, the important thing is to obtain an objective picture of the studied phenomenon, that is, such a picture that is intersubjectively verifiable and thus independent of the studying mind.

Of course, the role of objective approaches in the development of science was, and will be, the decisive factor for the development of epistemological processes. This is not to say, that the study of the perception of space and environment developing on the borderland between geographic and psychological sciences should continue to remain beyond the field of interest of Polish regional studies. Important is not only an objective picture of the world, also important is how that picture is reflected in the individual and social consciousness. We can cite many examples to the effect that artificial pictures isolated from the objective reality are in some cases an extremely significant, and often dangerous mechanism govering social consciousness.

Polish regional studies in the 1980s should open an interdisciplinary research program on the perception of various kinds of space and of different kinds of environment by individuals and by our society.

Both in the scientific and the socio-political aspect it is not only important to know the mechanisms govering the objective space but also those accounting for the creation and functioning of subjective spaces which, especially in critical conflict situations, may obscure even the most conspicuous facts of objective space.

DILEMMA VIII

Both in Poland and abroad the regional studies have developed as reistic[11] research in that they deal above all with the world of things, the world of tangible objects, the world of physical objects.

It was only in the 1960s that a new concept of regional studies emerged which shifted the main point of interest from the sphere of things to that of information.

That information-focused concept of regional studies has been best developed in Sweden disclosing research problems connected above all with the flow of information, the formation of what are called contact landscapes and with the diffusion of innovation.

The new principles of functioning of our society and our economy which are now crystallizing, create a huge demand for studies which would ingeniously adapt many elements of the information-focused concept of regional studies to the specific conditions of Poland, which does not mean of course that the classical reistic trend will not maintain its dominant position in Polish regional studies in the future.

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[10] See *Biuletyn KPZK PAN*, 118, 1982.

[11] Ibidem.

DILEMMA IX

In 1981 I published a brief communication on "The Geography of the Polish Crisis" [12]. Let me quote here from that note:

"We face the question of whether or not the Polish crisis has a geographic aspect – in other words, do we face the problem of the spatial differentiation of the causes of the crisis and of its consequences? One can, after all, argue that the present crisis has an exclusively macropolitical, macroeconomic and macrosocial dimension, while the mechanisms of the causes and the manifestations of its consequences are basiclly identical throughout the national territory.

This seems to be wrong, though. The Polish crisis does have its geographic dimension too which should be tackled by regional studies.

The time horizon for studies of the geography of the Polish crisis should be determined. I propose to comprise the 1976–1985 decade by such studies and to take the detailed survey of Poland's spatial differentiation in 1975, the terminal year of the most dynamic five-year period in the history of our country as the point of reference.

The decade of 1976–1985 will probably be composed of two periods: a) the period of emergence and rise of the crisis from 1976 to 1981, b) the period of overcoming the crisis and reconstructing the national economy from 1982 to 1985.

In Polish regional studies we used to rely on the following assumptions up to now:

a) our research interest focuses on positive phenomena such as growth development, cooperation etc.; we failed to see, or preferred not to see, adverse phenomena such as especially those of regress and conflict which were becoming conspicuous in many domains of our life, including the sphere of space economy in the broad sense,

b) in view of the fairly persistent nature of the studied spatial structures and patterns, our research interest concentrates on long-run presentations. Not unjustly we used to assume that within the framework of comparative statics, or of pseudodynamic studies, it will do if we just compare changes in spatial structures over five- or ten-year intervals, and that the spatial surveys studies should be associated with consus years.

In setting out to study the geography of the Polish crisis we must discard both these assumptions. Our studies should comprise both phenomena of development and of regress in the varying short-run patterns of single years or even of months".

The studies on the geography of Polish crisis are now advanced in a comprehensive way.

From what has been said here it appears that the development space versus crisis space dilemma will constitute a significant research problem for regional studies during the 1980s. We can formulate the hypothesis that the process of overcoming the Polish crisis – the process of gradual replacement of the crisis space by the development space – will be one of a very pronounced regional differentiation.

DILEMMA X

One can perhaps say that the present is a compromise between the heritage of the past and such or other development concept society wants to pursue in the future.

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[12] A. Kukliński, Geografia polskiego kryzysu (The geography of the Polish crisis), *Życie Gosp.*, 44, 1981.

This view is particularly topical in the discussion on the problems of Poland's space. Simultaneously we bear in mind the space of the past – that shaped by the nation's historical experience – and the space of the future which will be an important element of a better fate of individuals and of society in our country.

It is particularly difficult to discuss the space of the future. The future space must involve a reconciliation of the contradiction between the need for a continuance of the positive heritage and the need for a bold openness to innovative solutions that will inspire our imagination, and our will, and will galvanize us to action, imparting in effect a new face to Poland's space.

The past versus future space will be an important or even the key problem of Polish regional studies in the 1980s. Within those studies we shall have to answer the question, should we invariably employ the historically formed methodology of long-term planning in the domain of building bridges between the space of the past and the space of the future?

I believe that the old methodology of planning the nation-wide space-economic development should be superseded by the new methodology of elaborating multi-variant scenarios for the development of Poland's space economy.

CONCLUSION

As stressed in the preliminary remarks the above-presented concept of dilemmas of Poland's space is basically tentative. Many opinions expressed in this article call for a more extensive justification. But, at the present state of our empirical research, this is not always possible, for they used to ignore totally questions that remained outside the sphere of interest of paradigm II of Polish regional studies.

I hope that Polish regional studies in the 1980s will not only furnish new answers to old questions but will not evade asking new questions or giving answers to them. This will furnish new substantial elements to Polish regional studies which shape the new face of those studies, which I have described as paradigm III of Polish regional studies at the outset of this article.

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ESSAI D'ÉTABLISSEMENT D'UN MODÈLE DE L'INFLUENCE DES ÉLÉMENTS DU MILIEU GÉOGRAPHIQUE SUR LE BILAN D'ÉNERGIE DE LA SURFACE ACTIVE DE LA TERRE

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INTRODUCTION

Le milieu géographique en tant que système spatial dynamique résulte de l'influence réciproque des subsystèmes physico-géographique et socio-économique. L'énergie solaire constitue un des facteurs principaux de l'influence réciproque de ces subsystèmes ainsi que de leur existence. Tous les processus ayant lieu dans le milieu géographique dépendent dans une grande mesure de l'énergie solaire transformée en énergie thermique dans la couche limite. Vu les propriétés physiques différentes de cette couche, il existe une grande variété de la structure de l'échange d'énergie aussi bien dans le temps que dans l'espace. La délimitation des zones relativement homogènes de l'échange de cette énergie constitue un problème important du point de vue géographique; en effet cette délimitation peut faciliter l'analyse detaillée des processus qui se déroulent dans le milieu géographique. Ce problème est d'autant plus important que l'échange d'énergie entre l'atmosphère et la surface active de la Terre (surface active est une *couche fictive, infiniment mince, à laquelle sont rapportées les propriétés radiatives et thermiques du sol réel*; Boyen, Dogniaux et Paszyński 1976) forme, à part la gravitation, la source principale du fonctionnement de géocomplexes.

LE MODÈLE GÉNÉRAL DE L'ÉCHANGE D'ÉNERGIE SUR LA SURFACE ACTIVE ET L'ÉTAT DE RECHERCHES TOPOCLIMATIQUES BASÉES SUR CE MODÈLE

L'échange d'énergie entre l'atmosphère et la surface de la Terre peut être présenté de manière la plus simple par l'équation du bilan énergétique de la surface active:

$$Q = H + LE + S$$

ou Q est le rayonnement net, H — le flux de chaleur sensible, L — la chaleur spécifique de vaporisation, E — l'évapotranspiration net, S — le flux de chaleur dans le sol.

L'équation du bilan d'énergie a servi à Paszyński (1968, 1980, 1983) à élaborer une méthode de classification des types de climats locaux. L'auteur a adopté l'estimation des valeurs relatives des composants du bilan comme fonction des propriétés physiques de la couche limite. D'après cette méthode plusieurs cartes topoclimatiques ont été établies pour des différentes régions de la Pologne. Paszyński (1973)

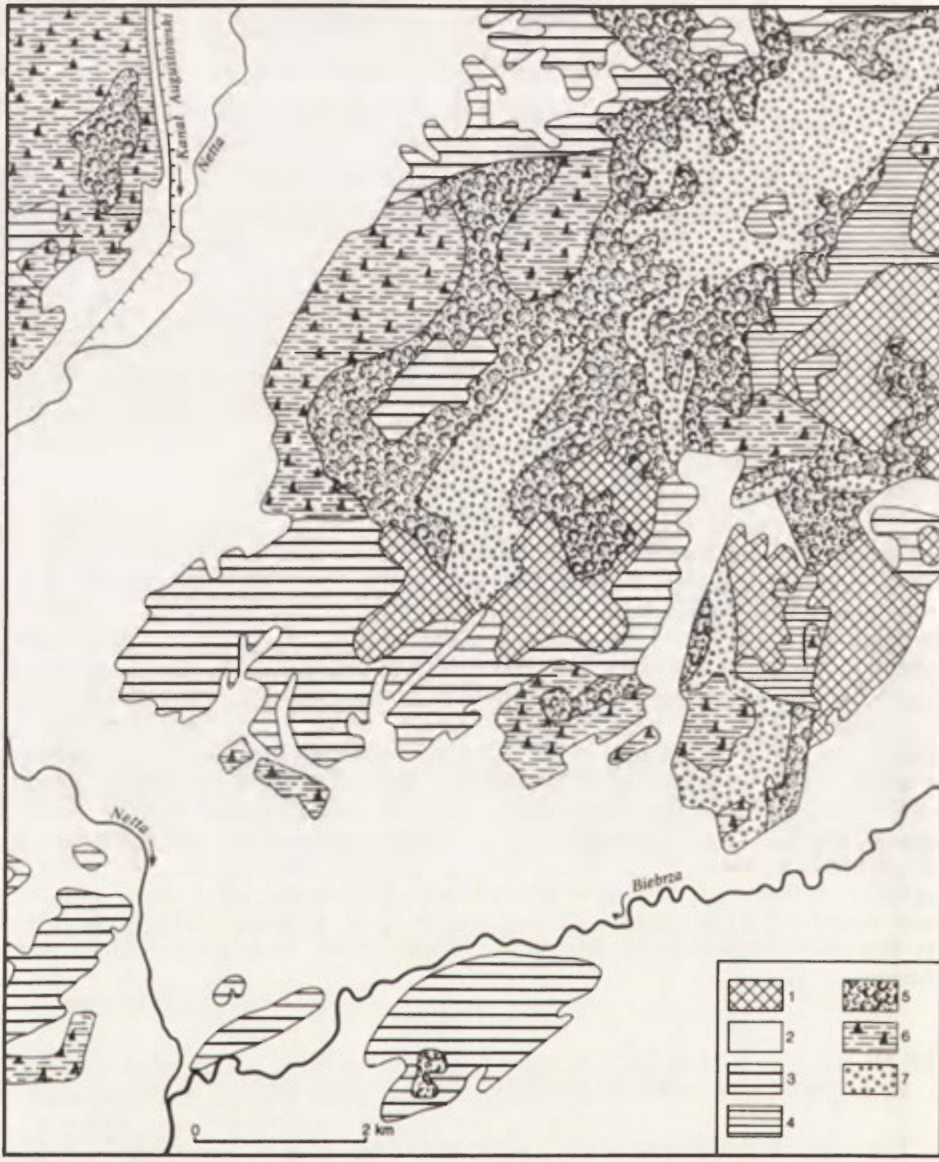

Fig. 1. Fragment de la carte des types des ensembles d'énergotops dans le Bassin de la Biebrza

1 - terrains de valeurs moyennes de l'échange d'énergie par convection, de valeurs moyennes du rayonnement global et de valeurs relativement basses de l'échange d energie par la conductivité dans le sol. Ce sont des terrains plats, élevés au-dessus du fond des vallées, avec des sols de compacité moyenne (sablonneux-argileux); 2 – terrains de valeurs relativement basses de l'échange d'énergie par convection et de valeurs relativement élevées de l'échange d'énergie par l'evaporation. Ce sont de vastes fonds des vallées situés très bas, périodiquement avec la nappe d'eau au-dessus de la surface (au printemps), couverts de végétation de prairies; 3 – terrains de valeurs relativement basses de l'échange d'énergie par convection et de valeurs moyennes des autres composants du bilan. Ce sont des terrasses des vallées, situées bas et les fragments de plateaux situés à l'altitude des terrasses; 4 – terrains de valeurs relativement basses de l'échange d'énergie par l'évaporation. Il s'agit de toutes les formes concaves où pendant les nuits claires se forment les bassins de la stagnation de l'air froid à cause de l'advection locale. A part les fonds de vallées, ce sont les petits bassins, ainsi que les éclaircies; 5 – terrains boisés de valeurs relativement basses du rayonnement terrestre des ondes longues et du rayonnement global, le sol dans la forêt étant protégé par les couronnes des arbres. L'échange d'énergie par l'évaporation et par la conductivité

a élaboré la feuille "Włocławek" et Kluge (1974) la feuille "Kielce" de la carte topographique au 1 : 100000. Tenant compte de cette méthode, un peu modifiée, les cartes de l'échange d'énergie représentant la distribution géographique des types des topoclimats, ont été élaborées pour les autres régions (Grzybowski 1980, 1981, 1983), ainsi que plusieurs cartes derivées pour les différents buts pratiques, ce qui a été décrit en détail par Paszyński (1980).

Tenant compte de la terminologie et de la hiérarchie des unités physico-géographiques introduites par Haase (1964), Grzybowski (1981, 1983) a proposé le terme *énergotope* pour le terrain ayant une structure de l'échange d'énergie relativement homogène. Les changements de la structure du bilan d'énergie dans un énergotope résultent de la variabilité quotidienne ou annuelle du rayonnement net ou bien de la variabilité de l'état de végétation. Pour les unités de la hiérarchie supérieure ont été proposés les termes *ensemble d'énergotopes* et *groupe d'ensembles d'énergotopes.*

Les connaissances générales de l'influence des propriétés physiques de la couche limite sur la structure du bilan d'énergie ont permis la distinction de ces zones d'énergotopes. Ainsi, la Figure 1 représente un fragment de la carte des ensembles d'énergotopes dans le bassin de la rivière Biebrza, au Nord-Est de la Pologne (Grzybowski 1980). Comme valeurs moyennes du chaque flux de chaleur on a adopté, conformément à Paszyński (1980), les valeurs typiques pour les terrains plats, couverts d'un gazon, et caractérisés par le ciel serein et un vent faible. Sur les terrains ou la couche a un caractère différent, les valeurs relatives des flux ont été déterminées par les écarts – supérieurs ou inférieurs – de la moyenne.

En conséquence, la détermination de la grandeur de l'échange d'énergie en valeurs absolues s'est avérée necessaire. Vu les grandes difficultés techniques pour mesurer simultanément tous les composants du bilan d'énergie en plusieurs sites du terrain, les recherches plus récentes ont été orientées vers la détermination des valeurs approximatives de chaque flux par des mesures d'un ou de deux composants seulement. Il est donc possible de déterminer les valeurs d'autres composants en appliquant un modèle représentant les rapports entre les composants du bilan thermique et le composant de ce bilan dont la mesure sur le terrain a été possible.

L'analyse de ce problème a approfondi nos connaissances concernant l'influence de l'énergie radiative sur la différenciation spatiale du milieu géographique, et l'influence des propriétés physiques de la couche limite sur les conditions climatiques locales.

RAPPORT ENTRE LES COMPOSANTS DU BILAN D'ÉNERGIE

Il résulte directement de l'équation du bilan d'énergie que la relation entre ses composants peut être variable selon les propriétés physiques de la couche limite et selon les conditions météorologiques. Les rapports entre les flux Q, H, LE et S ont été analysés, en termes quantitatifs, par plusieurs auteurs. Néanmoins la question des corrélations entre les flux exige toujours des études approfondies.

D'après les résultats des recherches effectuées dans la station experimentale de l'Institut National de la Recherche Agronomique en France Grzybowski et Itier

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est relativement élevé. Ce sont les forêts périodiquement humides se trouvant sur les terrasses des vallées; 6 – terrains de valeurs de rayonnement terrestre des ondes longues et du rayonnement global mêmes que dans la catégorie précédente, mais les valeurs de l'échange d'énergie par l'évaporation et par conductivité, encore plus élevées, surtout au printemps. Ce sont les forêts humides dans les fonds des vallées; 7 – terrains boisés avec l'échange d'énergie par conductivité relativement basse. Les autres composants varient en fonction des pentes différentes. Ce sont les forêts sèches des dunes

(1983) ont établis les équations des fonctions $H = f(Q)$ et $S = f(Q)$. Ils ont constaté que la variation journalière de la fonction $H = f(Q)$ d'une couche végétale variée (aux conditions météorologiques variables, mais toujours sur le même type du sol) peut être notée en forme de:

$$H = f(Q, P, V, h)$$

où P est l'humidité du sol et de la couche végétale, h — la hauteur de la couche végétale, V — la vitesse moyenne du vent. Lorsque $H_2 > H_1$, $f(Q_2) > f(Q_1)$ où $Q_2 > Q_1$, $f(P_1) < f(P_2)$ où $P_1 < P_2$, $f(V_1) < f(V_2)$ où $V_1 < V_2$, $f(h_1) < f(h_2)$ où $h_1 < h_2$.

Pour la fonction $S = f(Q)$, ces corrélations peuvent être notées en forme de:

$$S = f(Q, P, h, G)$$

où G est la densité des plantes. Lorsque $S_2 > S_1$, $f(Q_2) > f(Q_1)$ où $Q_2 > Q_1$, $f(P_1) < f(P_2)$ où $P_1 < P_2$, $f(G_1) < f(G_2)$ où $G_1 < G_2$.

Ces fonctions ne comportent pas tous les facteurs intervenant. On peut pourtant supposer, qu'elles présentent les corrélations les plus importantes, avec leur variabilité sur le même type du sol. On doit encore remarquer que Itier et Riou (1982) ont constaté que le rapport H/Q à 13h 00 est assez représentatif pour la valeur moyenne sur vingt-quatre heures.

LE MODÈLE DE L'INFLUENCE DES PROPRIÉTÉS PHYSIQUES DE LA COUCHE LIMITE SUR LA STRUCTURE DU BILAN D'ÉNERGIE.

Au cours des recherches ultérieures on a tenu compte de l'importance de l'humidité du sol et de la végétation sur la fonction $S = f(Q)$. On a constaté que le type du sol intervient dans la variation journalière de cette fonction surtout par l'intermédiaire de son humidité. Cela rend facile la comparaison des résultats des recherches effectuées dans les régions éloignées et différentes du point de vue litologique, mais avec l'humidité du sol semblable. L'humidité du sol et de la couche végétale représentent, avec la vitesse du vent, un des facteurs les plus importants de la variation de la fonction $H = f(Q)$.

Les relations $H = f(Q)$ et $S = f(Q)$ établies également sur les résultats des

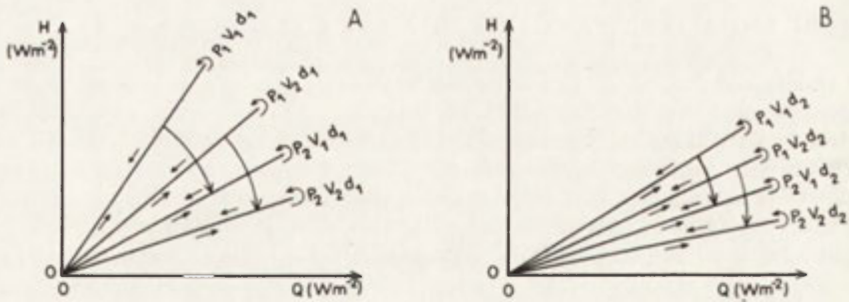

Fig. 2. Modèle général des corrélations $H = f(Q)$

A — se rapporte à l'humidite variée de la couche limite P_1 P_2 et à la vitesse du vent $V_1 > V_2$, la hauteur et la densité des plantes étant constantes (d_1); B — se rapporte aux mêmes conditions que sur la Figure A, mais à la hauteur et à la densite de la couche végétale $d_2 > d_1$. — Les grandes flèches montrent les changements de la pente des fonctions à cause des différentes propriétés du milieu géographique. Les petites flèches montrent la direction du cours journalier de la fonction $H = f(Q)$: l'augmentation du rayonnement net jusqu'à midi et ensuite sa diminution jusqu'au zéro

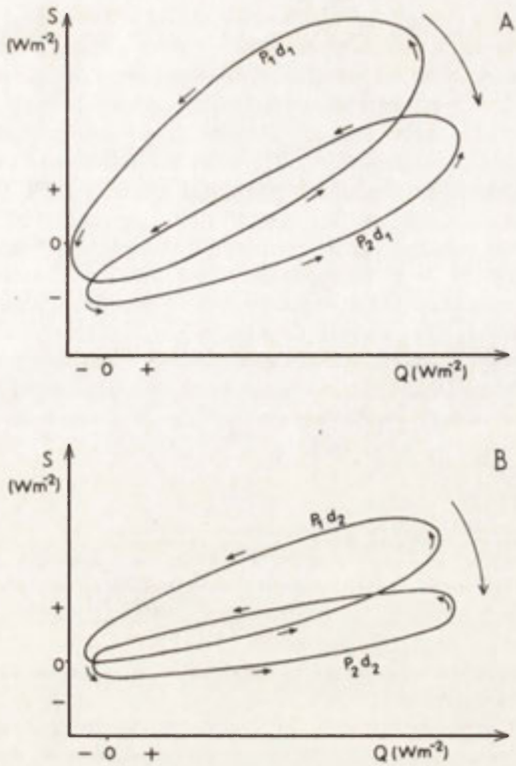

Fig. 3. Modèle général des corrélations $S = f(Q)$

A – se rapporte à l'humidité variée de la couche limite P_1 – P_2, à la hauteur et à la densité constantes de la couche d_1; B – se rapporte aux mêmes conditions que sur la Figure A, mais à la hauteur et à la densité de la couche végétale $d_2 > d_1$. La signification des flèches comme sur la Figure 2

mesures effectuées dans d'autres stations (Grzybowski 1982) ont servi à l'auteur pour établir un modèle préliminaire de l'influence des propriétés physiques de la couche limite et des éléments météorologiques sur la structure du bilan d'énergie. Ce modèle est composé des combinaisons des plusieurs facteurs influant, d'une façon qui nous semble décisive, sur la pente des fonctions $H = f(Q)$ et $S = f(Q)$. Ce modèle a été établi pour chaque corrélation separément (Fig. 2 et 3). La première – présentée sur la Figure 2 – prend en considération l'influence de l'humidité du sol et de la hauteur de la végétation et celle de la vitesse du vent sur la variation journalière de la fonction $H = f(Q)$. Il en résulte qu'avec une valeur stable du flux Q, l'augmentation de l'humidité du sol, la réduction de la vitesse du vent, l'accroissement de la hauteur de la couche végétale, provoquent une diminution du flux de chaleur sensible (H). Le modèle semblable a été établi pour la fonction $S = f(Q)$ mais tenant compte du caractère ellipsoïdal de la variation journalière de cette fonction (Fig. 3; rapport S/Q et leur évolution journalière correspondent a l'onde journalière amortie, cas classique étudie par de Vries 1975). Il en résulte, que avec les valeurs déterminées du Q, l'augmentation de l'humidité de la couche végétale avec le sol et l'accroissement de la hauteur et la densité des plantes, provoquent la baisse de la grandeur du flux de chaleur dans le sol. L'axe court de l'ellipse ("largeur" de l'ellipse) diminue avec l'augmentation de l'humidité du sol et de la couche végétale.

Le modèle ci-dessus est très simplifié et il devrait être élargi. Il peut pourtant être utile pour l'établissement des cartes de l'échange d'énergie de la surface active. Selon cette méthode, le premier pas vers la distinction des énergotopes consisterait à mesurer le flux de rayonnement net (Q), la vitesse du vent et les propriétés physiques de la surface active, surtout l'humidité du sol, sur plusieurs points du terrain étudié. Ensuite, en admettant que, dans les différentes conditions physico-géographiques, la pente des fonctions $S = f(Q)$ et $H = f(Q)$ (Fig. 2 et 3), correspond aux valeurs concrètes de la hauteur de la couche végétale, de l'humidité du sol etc., on peut lire les valeurs concrètes, bien qu'approximatives, des flux H et S. Les travaux sur la désignation de l'axe des coordonnées et de la grandeur d'erreur sont en cours. On n'a pas établi le modèle séparé pour la fonction $LE = f(Q)$, car le flux de chaleur latente n'est pas mesuré directement, étant calculé comme le reste du bilan. Pour cette raison, après avoir calculé les valeurs approximatives des flux S et H, on peut aussi, à partir de l'équation du bilan d'énergie, estimer la valeur approximative du flux de chaleur latente.

REMARQUES FINALES

Le modèle ci-dessus peut être appliqué pour les terrains plats et dégagés. En cas de terrains inclinés, il faut prendre en considération certaines corrections, par exemple celles proposées par Kondratiev, Pivovarova et Fedorova (1978). Sur le terrain boisé se sont les couronnes des arbres qui constituent la surface active. Dans nos recherches nous avons négligé le rôle de la chaleur "artificielle" produite par l'activité humaine.

Il résulte du modèle présenté sur la Figure 2, que la diminution du rayonnement net jusqu'au zéro, provoque le changement de la direction du flux de chaleur sensible. C'est sans doute une simplification, car, à cause d'inertie thermique de l'air, la modification journalière du flux H est retardée (décalage de phase). Le modèle concerne en principe l'échange d'énergie pendant le jour. Pendant la période nocturne la variabilité des composants du bilan est réduite et, comme suite, les corrélations entre eux sont assez faibles. Tenant compte, d'après Itier et Riou (1982) que le rapport H/Q à 13h 00 est représentatif sur vingt-quatre heures, on peut utiliser notre modèle pour estimer la moyenne journalière du flux H à partir des valeurs calculées pour 13h 00.

Les recherches préliminaires ont demontré qu'il est possible de comparer les résultats des mesures du bilan d'énergie effectuées dans des sites même eloignés, à condition que les parcelles analysées soient suffisamment grandes pour qu'il s'y forme une couche limite spécifique. Parmi les facteurs biotiques modifiant les corrélations entre le flux Q et les autres composants du bilan d'énergie il faut noter aussi les phases phénologiques qui jouent un rôle important. Notre modèle se rapporte en principe à la phase du plein développement de la végétation.

Dans les conditions d'un milieu géographique changé par l'activité humaine, les modifications locales des valeurs des flux resultent du type d'aménagement. Par exemple la culture des plantes de petite hauteur intervient dans la structure du bilan d'énergie d'une façon différente que la culture du maïs. Ce dernier, lors de la phase de maturation peut exercer une influence sur la structure du bilan semblable à celle du chaume (Grzybowski et Itier 1983).

Il existe un grand nombre d'ouvrages concernant le problème de l'échange d'énergie sur les couches limites différentes. Il nous manque pourtant une analyse d'une repartition spatiale des types de l'échange d'énergie. Notre programme des recherches effectuées au Département de Climatologie de l'Institut de Géographie et d'Aménagement du Territoire à Varsovie est orienté vers la détermination du rôle de l'échange d'énergie dans la répartition des géocomplexes.

Le modèle présenté peut également servir comme point de départ pour la classification des types du bilan d'énergie. Elle sera pourtant différente par rapport aux autres classifications, par exemple celle de Geiger (1961). Cette différence résulte du fait que notre classification a été effectuée à partir de propriétés physiques de la couche limite (comme dans la méthode de Paszyński 1968, 1980, 1983) et des données concernant certains éléments météorologiques, tandis que la classification de Geiger (1961) est basée sur les types des masses d'air. Ainsi, notre modèle devrait être utile pour des travaux effectués dans des échelles locales.

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ON THE ROLE OF RELIEF IN DIFFERENTIATING CLIMATIC CONDITIONS OF THE POLISH CARPATHIANS

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AN OUTLINE

Regional studies on the physicogeographical environment of the Carpathians and divisions based on geomorphological, climatological, geobotanical, hydrological and other criteria usually underestimate the exceptional position of the Low Beskid range (*Beskid Niski*). There is a general unity of views on the fact that the boundary between the West and East Carpathians (2,000–2,600 m a.s.l.) must undoubtedly run within the area of the biggest depression (the Dukla Pass 502 m a.s.l.) and narrowness of the arc of the Carpathians, i.e. in the Low Beskid range (*Geomorfologia Polski*, 1972, Kondracki 1978). On the other hand, only few authors (Mihailescu 1963) recognize that transversal depression in the arc of the Carpathians as an individual unit. Therefore, it is necessary to examine environmental features within the Low Beskid range itself as this area must have been marked with interactions of physicogeographical processes occurring both in the West and in the East Carpathians (Starkel 1979). For the purposes of regionalization, this requires an analysis of domination of features of those units of high rank in the examined groups of mountains. The second attribute of the geographical environment in the Low Beskid range and its foreland is an intensified energy and mass exchange in the meridional direction. The Beskid range makes the movement of air masses easier along the N–S axis, which finally modifies the regional atmospheric circulation bringing in characteristic thermal and humidity effects. It is also of great importance for migrations of plant species across the barrier of the Carpathians.

The last decade brought about interesting results of investigations on climate in that area (Hess *et al.* 1977, Obrębska-Starklowa 1977, Michna 1978, Michna and Paczos 1978), as well as geobotanic and hydrologic characteristics of that area. Such studies make it possible to have a fresh look at the climatic position of the Low Beskid range in relation to the West and East Carpathians. Therefore, the aim of the present article is to show the distinct character of climatic conditions of the transversal depression in relation to the West Carpathians, and, next, to present the functional characteristics of some environmental elements dependent on climate in those units. The second part of the task is to verify still fragmentary, because of scarcity of observations, results of climatological research.

THE LOW BESKID RANGE IN TO-DATE CLIMATIC REGIONALIZATIONS OF THE MOUNTAINS

Criteria for marking out climatic boundaries between the West and East Carpathians differed in the past half-century. They included: concentration of isarithms pointing to the change in the intensity of phenomena, values of isogradients in definite intervals, the exceeding of selected threshold values for different climatic elements or groups of elements, ratio of duration of thermal seasons and distribution of precipitation in those seasons and the persistence of snow cover, as well as dependence between climatic parameters and phenological indices.

In 1938 E. Romer delimited West- and East-Carpathian climatic domains on the basis of duration of thermal seasons and features of distribution of precipitation during the year, marking out the boundary between them along the western end of the Low Beskid range (Romer 1947). In 1949 the same author pointed to the great regional differentiation of climatic conditions in that part of the Carpathians. He revealed an important feature of the position of the Low Beskid range in the shadow of the Tatra Mts and the High Beskid range (*Beskid Wysoki*), and, therefore, he divided that group of mountains into two parts. He included the western part into the Spisz area with low values of climatic gradients (G 2), while the remaining areas east of the Dukla Pass to the East Beskid range (F 10). The foreland of the Low Beskid range, i.e. the Jaslo-Sanok Basin (*Doly Jasielsko-Sanockie*) characterized by monotonous climatic conditions were included by Romer in the large inter-Carpathian Sambor-Sącz area with low values of climatic gradients (G 3).

One of the keynotes of climatic regionalization carried out by Okolowicz (1974) was to show the climatic interaction of units bordering on each other in the Carpathians. The climatic typology was prepared on the basis of thermal-precipitation conditions in the main seasons of the year, and this made it possible to delimit regions of medium-high mountains with different intensity of maritime and continental influence in the climatic region of the mountains. The boundary of the so-called moderately modifying influence of continental climate runs along the Biala Dunajcowa river, thus separating those regions protruding in an eastward direction which are characterized by a greater mean annual amplitude of air temperature, fairly late and relatively short spring, long summer and winter which is also quite cold and marked by persistent snow cover, particularly on uplands. Michna (1978) supplements those features with variability of air temperature from day to day and from year to year. In Okolowicz's regionalization the Jaslo-Sanok Basin is shown as a separate climatic region where the influence of mountains surrounding them is becoming noticeable next to the intensifying features of continentality.

The authoress was induced to mark out the boundary between the western and eastern pheno-climatic domain along the Biala Dunajcowa river by studies on the dynamic and periodicity of development of phenological phenomena in the Upper-Vistula river basin and their connections with the differentiation of climatic conditions (Obrębska-Starklowa 1977). The boundary is in line with the time of simultaneous bursting into flowers by elder (*Sambucus nigra*) and black locust (*Robinia pseudacacia*), which shows the balance of maritime and continental influence. The stage of the two species bursting into flowers is characterized by the so-called phenomenon of interception of dates depending on regional differentiation of frequency and intensity of maritime and continental polar air masses advection (Smirnov, after Schnelle 1955).

CHARACTERISTICS OF THE INVESTIGATED AREA

Comparative climatic studies in the External Carpathians were carried out in two vertical profiles spreading from 200 to 1000 m a.s.l. (Figs 1 and 2), the first one representing main morphological features of the Polish West Carpathians and the second one running across the Low Beskid range and its foreland.

Fig. 1. Distribution of climatological stations included in the study

Numbers of stations: 1 – Kraków, 2 – Wieliczka, 3 – Libertów, 4 – Myślenice, 5 – Maków Podhalański, 6 – Markowe Szczawiny, 7 – Mszana Dolna, 8 – Luboń Wielki, 9 – Rabka, 10 – Raba Wyżna, 11 – Rdzawka, 12 – Turbacz, 13 – Czarny Dunajec, 14 – Nowy Targ, 15 – Poronin, 16 – Ciężkowice, 17 – Płaszkowa, 18 – Jaworzyna Krynicka, 19 – Krynica – Góra Parkowa, 20 – Wysowa, 21 – Biecz, 22 – Jasło, 23 – Krosno, 24 – Iwonicz, 25 – Rymanów, 26 – Barwinek, 27 – Komańcza, 28 – Sanok, 29 – Lesko

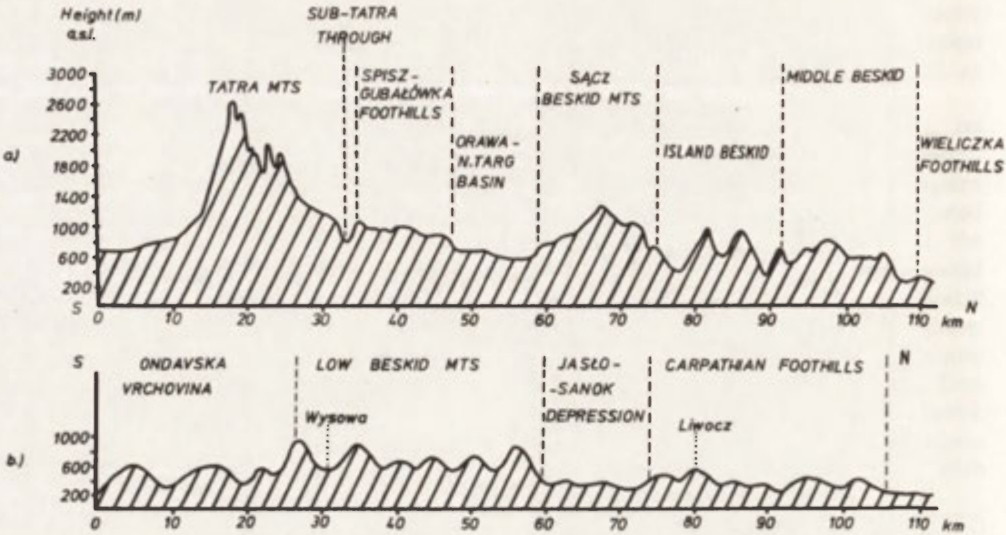

Fig. 2. Vertical profile across the Polish Carpathians

a) along the meridian 20° λE, b) along the meridian 21.5° λE

The relief of the West Carpathians (along the meridian 20° λE) is characterized by considerable differences in altitude and relative height as well as the clear-cut steepness of slopes. The zone of uplands of the Foothills (*Pogórze*) is narrow there and separated from the Medium-High Beskid range (*Beskid Średni*) by an escarpment some 500 m high. In that Beskid range the differences of height a.s.l. amount to 400–600 m. At the back of that part of the West Carpathians there is a barrier of high mountains, i.e. the Tatra Mts and Slovakia's mountain ranges bordering on the Tatras. The lowering of Podhale is running between those mountains and the Beskids.

The vertical profile along the meridian 21.5° λE shows the widest zone of the Foothills in the whole Carpathians and a narrow zone of low and medium-high mountains. The Foothills zone (similarly as in the whole West Carpathians) is separated from the Sandomierz Basin (*Kotlina Sandomierska*) by an escarpment some 150 m high. The difference in relation to the West Carpathians is determined by easy inclinations and small differences of height a.s.l. in the zone of upland relief (up to 150 m). In the inner part, the zone is lowered forming the basin of Jaslo-Sanok. The Low Beskid range rises over the zone of the Foothills with an escarpment some 500 m high in the western, and 300 m high in the eastern part of the range. Differences of height a.s.l. amount to 200–400 m in the mountains. Sections of valleys similar to meridional ones are prevailing. Relative heights are greater on the Slovak side; the southern slope of uplands shelves to the Cisa river valley down to 100 m a.s.l. The Low Beskid range together with its foreland form as if a gate in the arc of the Carpathians which makes it possible for the influence from the South to penetrate up to the Nida Basin in the North.

The area covered by the said profiles is situated in the pluvionival climate in moderate warm and moderate cold vertical climatic zones. Mean annual temperature varies there from some 8 °C to 4 °C. In the West Carpathians the moderate warm vertical climatic zone spreads from 290 to 690 m a.s.l., while the moderate cold one rises up to 1120 m a.s.l. along the meridian 20° λE. The

TABLE 1. Continentality indices demonstrating the seasonal changes of air temperature along the meridians 20° and 21.5° λ E

	Altitude (m)	Profile western	Profile eastern
Kerner's coefficient	300	2.5	2.1
	500	4.7	4.2
	800	7.9	7.4
Thermodromic quotient	300	1.8	1.4
	500	3.5	3.1
	800	6.0	5.6

average position of isotherms in those profiles is lowering by some 60 m in an eastward direction (Obrębska-Starkel 1981).

Absolute values of thermal continentality indices (Table 1) calculated on the basis of equations of multiple regression describing dependences on parameters of geographical situation (altitude a.s.l., geographical latitude and longitude) are also decreasing in an eastward direction. The closeness of connections with those parameters is evidenced by determination coefficients ranging from 86 to 88 per cent. Valley and basin bottoms are characterized by greater continentality than the average values which take no account of the influence of relief form at a given altitude (Kerner's coefficient: Zakopane 4.8, Jaslo 0.2). In ridge positions the oceanity of climate increases together with altitude (Kerner's coefficient: Luboń Wielki 9.0, Jaworzyna Krynicka 7.8)[1].

Values of continentality index based on precipitation changes are surprising (Table 2). Though according to Vemic's and Hrudicka's criteria, they are stressing the transitory nature of Poland's climate between the oceanic and continental ones, they are strongly subjected to local influence and only slightly depend on co-ordinates of geographical situation (determination coefficients from 23 to 31

TABLE 2. Continentality indices demonstrating the seasonal changes of precipitation along the meridians 20° and 21.5° λ E

	Altitude (m)	Profile western	Profile eastern
Hrudička's coefficient	300	23.0	21.7
	500	21.8	20.5
	800	20.0	18.7
Vemic's coefficient	300	71.9	70.0
	500	71.8	69.9
	800	71.6	69.7

[1] In view of lack of stations on the main watershed of the Low Beskid range, data from Jaworzyna Krynicka situated nearby in the Beskid Sądecki range were adopted for the watershed.

per cent). The two continentality indices shown in the Table 2 refer in their content to the seasonality of precipitation during the year. This feature distinguishes the regime of precipitation in the West Carpathians from that in the East Carpathians, the first one showing greater annual amounts of precipitation. In the profile along the meridian 20° λE, owing to greater differentiation of relief, quotients of precipitation amounts in autumn by precipitation amounts in spring oscilate from 85 per cent in Cracow to 95 per cent in the northern end of the Orawa-Nowy Targ Basin (*Kotlina Orawsko-Nowotarska*). In the eastern profile, in the lowering of the Jaslo-Sanok Depressions, they amount to 95 per cent, while in the Low Beskid range they become even in the mentioned seasons. The ratio of summer precipitation to winter precipitation in the West Carpathians also changes from 280 per cent in Cracow to 200 per cent on the ridge of the Beskids; in the eastern profile it is close to 230 per cent in the conditions of both upland relief and low mountains relief.

Thus, the influence of relief type accounts for the fact that continentality indices based on precipitation changes are even higher in the western profile than in the eastern one. Kostrakiewicz (1980) points to high values of Vemic's coefficients (> 70 per cent) occurring in enclaves in the bottoms of valleys of the Sola, Raba, Skawa and Dunajec rivers, and Mączak (1959) introduces the value of 76 per cent, which is the highest for Poland, in the middle part of the Dunajec river basin. In the eastern profile Vemic's coefficients range from 66 to 74 per cent.

The confrontation of those facts concerning the features of spatial distribution of thermal continentality indices and continentality indices based on precipitation changes may lead to the conclusion that the parts of the Carpathians under comparison differ primarily in the nature of thermal conditions. Annual and seasonal amounts of precipitation, on the other hand, depend, to a greater extent, on the influence of local conditions, including particularly orographic ones.

Heat in the mountains is a major factor differentiating bioclimatic and hydrologic phenomena. Therefore, particular attention is attached here to the analysis of features of thermal regime of the West Carpathians and the Low Beskid range.

MATERIALS AND METHOD OF WORK

Climatological source materials included daily values of extrema of air temperature from 29 stations in the years 1951–1970. Eight stations in every profile were situated on convex relief forms, the remaining ones (6 and 7) were situated in concave relief forms. At the first stage of studies, the authoress calculated multiple correlation coefficients and equations of linear multiple regression for the dependence of thermal characteristics on parameters of geographical situation (altitude, geographical latitude and longitude) for each profile separately and separately for every category of relief in every profile. Here, however, the question occurred as to what thermal parameters can show the influence of topography of the mountains in mesoscale precisely enough, i.e. not only the influence of altitude, but also of dimensions of a mountain massif, geometrical shapes of concave relief forms and the direction of their course. In the compared vertical profiles, mutual relation of areas of medium-high mountain relief and upland relief was also important. It is difficult to specify the influence of those factors on mesoclimate on the basis of standard climatic characteristics like, for instance, mean annual and monthly values of elements. Therefore, it became necessary to employ frequency characteristics for different elements. Multiple correlation was calculated for: mean annual air temperature, mean temperature of different months, mean extrema of temperature, and values corresponding to the first and ninth decile of extrema of temperature[2]. On the basis of a variance analysis and Snedecor's *F*-test, high significance of those dependences was stated at the level of 1 per cent, or even 0.1 per cent.

THERMAL CONDITIONS IN THE WEST CARPATHIANS AND THE LOW BESKID RANGE

In the examined two decades the absolute minima of air temperature occurred in concave relief forms, the minimum in Sanok (314 m a.s.l., eastern profile) amounting to −39.0°C was lower by 1.5°C than the value from Poronin (800 m a.s.l.), being an absolute minimum in the western profile. On convex relief forms, the lowest minimum in the eastern profile reached −32.9°C in Ciężkowice (280 m a.s.l.) and, in the western profile, −29.5°C in Libertów (320 m a.s.l.).

Absolute maxima of air temperature in concave relief forms were similar: 35.7°C in Biecz (260 m) and 36.0°C in Myślenice (295 m). On convex relief forms they rose to 36.2°C in Ciężkowice and 39.9°C in Wieliczka (215 m).

This makes it possible to state that in the conditions of relief of the Low Beskid range, more intensive sporadic drops of air temperature can be observed than in the West Carpathians.

To render differences in extreme values in the discussed parts of the Carpathians, the authoress chose pairs of stations situated at a similar altitude there and representing similar categories of relief. Tables 3 and 4 show differences in values between absolute ranges of variation of maxima and minima of air temperature in different months. An absolute range of variation of monthly maxima on convex relief forms is greater from December through June in the Beskid's part of the West Carpathians than in the Low Beskid range (compare Luboń – Jaworzyna Krynicka), with particularly big difference (≥ 5.0°C) occurring in December and January, April and June. In the Foothills zone (cf. Wieliczka, Jasło) greater variations of maxima of temperature occur only from November through January. In concave relief forms differences in maxima variations do not show distinct annual regularity in the discussed profiles. Only in February, in the bottoms of the Foothills and Beskid valleys the values of those differences are very high (from 4.7 to 6.8°C).

An absolute range of variation of minima of air temperature (Table 4) shows many cases for both categories of relief forms when it is greater in the eastern profile than in the western one. In valleys, this can be mainly noticed during the growing season, while on the watersheds of the Foothills – almost during the whole year. This is probably determined by heat radiation conditions in the Jasło-Sanok Basin where there are small differences of height a.s.l. between low hummocks and shallow depressions. On the ridges of the Low Beskid range, in the period 1951–1970 minima were changing in a generally smaller interval than in the Beskids in the West (except for April, July and August).

An analysis of differences between mean daily amplitudes understood as a range

[2] For fear that data from Nowy Targ representing an intermontane basin with a high degree of continentality might complicate the image of the discussed dependences, calculations for concave relief forms in the West Carpathians were repeated twice: for the first time with regard to data from Nowy Targ, for the second time – after eliminating them. This did not significantly influence the estimation of unknown values according to equations of linear multiple regression.

TABLE 3. Range of variation of the absolute maxima air temperature (in °C) on chosen climatological stations in western and eastern vertical profiles (data from the period: 1951–1970)

Station	Altitude (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Luboń Wielki	1024	32.1	34.4	30.3	33.2	31.9	29.5	23.0	21.6	24.2	26.8	27.8	31.7
Jaworzyna Krynicka	995	24.8	31.4	25.0	30.0	28.6	22.1	22.2	20.1	22.1	23.4	27.8	26.7
Difference		7.3	3.0	5.3	3.2	3.3	7.4	0.8	1.5	2.1	3.4	0.0	5.0
Wieliczka	215	32.2	37.2	33.3	28.1	28.3	27.0	27.2	23.1	22.9	28.5	32.4	36.9
Jasło	240	25.4	34.6	32.2	28.7	27.2	27.6	22.7	22.5	22.5	24.7	26.3	32.8
Difference		6.8	2.6	1.1	−0.6	1.1	−0.6	4.5	0.6	0.4	3.8	6.1	4.1
Myślenice	295	30.9	38.6	34.4	29.0	27.5	27.3	23.8	22.5	24.2	27.2	30.1	34.8
Krosno	282	27.3	33.9	31.6	29.5	28.0	27.2	22.7	24.9	22.2	25.1	27.6	35.1
Difference		3.6	4.7	2.8	−0.5	−0.5	0.1	1.1	−2.4	2.0	2.1	2.5	−0.3
Maków Podhalański	350	27.1	37.7	31.9	29.2	29.4	26.5	22.6	22.2	26.5	27.8	29.1	31.0
Rymanów Zdrój	360	25.9	30.9	27.3	29.8	26.7	27.3	20.0	22.3	21.4	26.2	26.9	32.1
Difference		1.2	6.8	4.6	−0.6	2.7	−0.8	2.6	−0.1	5.1	1.6	2.2	−1.1
Mszana Dolna	410	26.0	35.4	32.1	29.4	26.7	26.7	24.3	23.0	25.0	26.8	28.2	34.5
Barwinek	420	26.2	29.8	29.4	28.3	25.9	26.4	20.1	24.1	21.3	24.8	26.1	28.5
Difference		−0.2	5.6	2.7	1.1	0.8	0.3	4.2	−1.1	3.7	2.0	2.1	6.0

TABLE 4. Range of variation of the absolute minima air temperature (in °C) on chosen climatological stations in western and eastern vertical profiles (data from the period: 1951–1970)

Station	Altitude (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Luboń Wielki	1024	27.2	32.1	26.0	23.3	23.5	20.2	16.0	16.3	19.5	22.5	24.3	29.5
Jaworzyna Krynicka	995	27.8	30.6	24.9	25.4	22.2	19.7	18.6	18.3	16.7	20.7	24.2	28.2
Difference		−0.6	1.5	1.1	−2.1	1.3	0.5	−2.6	−2.0	2.8	1.8	0.1	1.3
Wieliczka	215	32.0	25.5	33.9	19.5	21.3	20.3	13.6	17.1	18.7	21.6	27.9	37.3
Jasło	240	37.1	41.0	37.6	21.3	21.4	18.8	13.4	18.6	19.0	23.1	29.4	40.8
Difference		−5.1	−5.5	−3.7	−1.8	−0.1	1.5	0.2	−1.5	−0.3	−1.5	−1.5	−3.5
Myślenice	295	34.9	38.1	38.8	24.7	20.3	19.9	14.1	15.4	19.2	20.7	28.3	41.2
Krosno	282	34.4	43.3	35.7	19.2	22.7	21.7	15.6	19.0	20.2	22.1	28.3	38.0
Difference		0.5	−5.2	3.1	5.5	−2.4	−1.8	−1.5	−3.6	−1.0	−1.4	0.0	3.2
Maków Podhalański	350	36.9	39.9	36.8	18.7	20.4	18.3	15.2	18.1	19.5	21.5	31.0	29.2
Rymanów Zdrój	360	34.0	38.9	42.8	21.6	24.1	18.7	18.3	18.9	19.4	24.3	31.4	33.9
		2.9	1.0	−6.0	−2.9	−3.7	−0.4	−3.1	−0.8	0.1	−2.8	−0.4	−4.7
Mszana Dolna	410	33.0	39.9	38.0	19.9	18.1	18.4	14.0	16.8	18.9	21.3	29.9	40.8
Barwinek	420	36.6	38.3	34.1	21.0	24.9	19.4	16.5	20.2	22.6	24.8	33.3	37.9
Difference		−3.6	1.6	3.9	−1.1	−6.8	−1.0	−2.5	−3.4	−3.7	−3.5	−3.4	2.9

TABLE 5. Difference between the mean monthly maxima and mean monthly minima of air temperature (in °C) on chosen climatological stations in western and eastern vertical profiles (data from the period: 1951–1970)

Station	Altitude (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Luboń Wielki	1024	5.4	6.0	7.1	7.4	8.2	8.2	7.9	7.6	7.4	6.6	5.4	7.1
Jaworzyna Krynicka	995	5.7	5.7	5.8	6.9	7.6	7.4	7.3	7.2	7.0	6.2	4.8	8.0
Difference		−0.3	0.3	1.3	0.5	0.6	0.8	0.6	0.4	0.4	0.4	0.6	−0.9
Wieliczka	215	7.0	7.5	8.4	10.4	10.7	11.0	10.8	10.9	10.8	10.1	6.9	6.3
Jasło	240	6.1	6.7	8.5	10.5	11.2	11.5	11.4	11.1	10.9	9.3	5.7	4.8
Difference		0.9	0.8	−0.1	−0.1	−0.5	−0.5	−0.6	−0.2	−0.1	0.8	1.2	1.5
Myślenice	295	7.1	7.8	8.7	10.4	10.9	11.0	11.1	11.0	10.8	9.8	7.3	6.0
Krosno	282	6.0	6.6	7.9	10.5	11.1	11.5	11.3	11.4	10.5	9.1	5.7	4.8
Difference		1.1	1.2	0.8	−0.1	−0.2	−0.5	−0.2	−0.4	0.3	0.7	1.6	1.2
Maków Podhalański	350	9.4	10.0	10.1	10.8	11.6	11.8	11.6	11.7	12.1	11.1	8.5	7.5
Rymanów Zdrój	360	6.5	7.2	8.2	11.0	11.7	11.9	11.3	11.3	11.0	9.4	6.0	4.3
Difference		2.9	2.8	1.9	−0.2	−0.1	−0.1	0.3	0.4	1.1	1.7	2.5	3.2
Mszana Dolna	410	8.6	9.6	10.0	10.9	11.8	11.9	11.8	12.0	11.9	11.1	8.1	7.5
Barwinek	420	6.6	7.4	9.0	11.5	12.3	12.4	12.2	12.2	11.6	9.5	6.0	5.4
Difference		2.0	2.2	1.0	−0.6	−0.5	−0.5	−0.4	−0.2	0.3	1.6	2.1	2.1

of variation between mean monthly maximum of temperature and mean monthly minimum of temperature (Table 5) proves that the range of variation of extremes in the growing season is slightly greater in mountain valleys and Jaslo-Sanok Basin in the eastern profile than in the western one.

Thus, even such a rough analysis of air temperature as the confrontation of extremes from pairs of stations in the profiles leads to the conclusion that it is necessary to investigate the features of distribution of frequency of daily maxima and minima of temperature more thoroughly in the two decades. It seems that the most useful for this purpose are values of two extreme deciles, the differentiation of which testifies to qualitative climatic changes or proves other causative determinants (Nosek 1954).

Average values of elements referring to the Foothills (49.8° φN, 300 m a.s.l.) and to the mountains (49.5° φN, 500 and 800 m a.s.l.) were calculated for equations of multiple regression describing the dependence of air temperature on parameters of geographical situation. This was possible owing to similar values of standard errors of estimation of unknown values characterizing the temperature regime in different months. The results of calculations were the basis for determining average differences in thermal conditions between the West Carpathians and the Low Beskid range (Table 6). The size of those differences can be connected with relations occurring in the pattern of basic relief types in a given meridional cross-section. According to values of determination coefficients, it should be stated that the influence of altitude, and geographical latitude and longitude accounts for 80–98 per cent of variations of different thermal parameters. On the other hand, the rest of variance which remains unexplained may be determined mainly by the character of relief within the Foothills and Beskids.

The confrontation of differences of mean annual and mean monthly temperature in both profiles makes it possible to state that thermal conditions are being shaped differently on convex relief forms and differently in concave relief forms. The sign of differences testifies to this fact. The absolute value depends on the influence of relief types at the confronted altitudes a.s.l. (Table 6).

The Low Beskid range and bottoms of the Jaslo-Sanok Basin reveal air temperature being higher by 0.2–0.6°C on the average during the year. This principle does not apply only to ridges of the West Carpathians Foothills which are warmer by 0.6°C than low hummocks in the Depressions. This results from morphometric differences in the zone of upland relief of the Polish West and East Carpathians which exert their influence on the conditions of circulation and heat exchange in the interior of valleys. This becomes visible, first of all, when air temperature inversion occurs in the Jaslo-Sanok Basin. When the weather situation is conducive to radiation, a broad cold air reservoir is formed in the foreland of the Low Beskid range as the low ridges do not interfere with horizontal air exchange between the neighbouring valleys (Obrębska-Starklowa 1973). This is also evidenced by plus values of differences of mean monthly air temperature in the majority of the year. In the zone of the West Carpathian Foothills where the systems of elevations are more distinctly shaped, there are some orographic barriers which determine the intensity of horizontal and vertical heat exchange. At night, on the other hand, they weaken horizontal exchange, while the vertical exchange, which takes the form of a gravitational flow of cold air from wide surfaces of slopes, supplies the cold reservoir and leads to intense cooling of valley bottoms (cf. Klysik 1980).

The directions of valleys in the Low Beskid range account for the act that the second factor influencing privileged thermal conditions are föhn effects which are more frequent in that part of the Carpathians and are occurring from October through May (Lewińska 1958, Obrębska-Starklowa 1973, Hess *et al.* 1977). Lewiń-

TABLE 6. Differences between the values of thermal parameters in the transversal cross-section through Polish Carpathians along the meridians 20° and 21.5°λE on convex (1) and in concave (2) relief forms*

Months	Latitude °φ	Altitude (m)	Mean monthly temperature (°C)		Maximum of air temperature (°C) Mean monthly		First decile		Ninth decile		Minimum of air temperature (°C) Mean monthly		First decile		Ninth decile	
			1	2	1	2	1	2	1	2						
Jan	49.8	300	0.6	0.1	0.3	2.0	0.5	0.8	0.4	2.9	0.4	−0.9	2.0	−0.4	1.4	−0.6
	49.5	500	1.1	0.4	2.1	3.4	1.6	1.7	2.0	3.8	−0.3	−1.3	−0.6	−1.5	0.1	−1.4
	49.5	800	1.1	–	4.0	–	0.4	–	1.9	–	0.2	–	−0.4	–	0.6	–
Feb	49.8	300	0.1	−0.5	0.8	2.7	0.3	1.5	0.2	2.9	0.5	−1.7	1.9	−5.0	−0.1	−0.4
	49.5	500	0.0	−0.2	1.8	3.5	1.3	1.8	1.9	4.2	−0.3	−1.8	−2.2	−5.5	0.1	0.1
	49.5	800	0.1	–	1.7	–	1.7	–	1.9	–	1.6	–	−1.6	–	0.4	–
Mar	49.8	300	−0.6	−0.6	0.1	1.6	4.7	3.1	2.4	2.4	2.5	−0.8	−0.7	−1.2	−0.3	−0.1
	49.5	500	0.2	−0.1	1.4	2.0	5.8	4.1	1.4	3.1	1.5	−0.4	−1.5	−0.7	0.0	0.5
	49.5	800	0.2	–	2.0	–	6.0	–	1.8	–	1.9	–	−1.0	–	−0.2	–
Apr	49.8	300	0.8	−1.2	0.4	0.0	0.1	−0.2	0.4	0.4	1.6	−1.5	−1.2	−1.5	0.6	−1.3
	49.5	500	0.5	−0.6	0.8	0.4	0.9	−0.3	1.0	1.5	−0.2	−2.3	−0.8	−1.6	−0.1	−0.6
	49.5	800	0.8	–	1.4	–	0.6	–	1.1	–	0.3	–	−0.5	–	−0.6	–
May	49.8	300	0.5	−0.2	0.1	0.2	0.3	1.2	0.4	1.5	0.2	−1.0	1.0	−0.4	−0.2	−1.7
	49.5	500	−0.1	0.1	0.1	0.3	−0.3	0.8	0.7	1.3	−0.9	−0.5	0.5	−0.3	−2.3	−0.6
	49.5	800	−0.1	–	0.3	–	−0.4	–	0.8	–	−1.0	–	−0.6	–	−1.2	–
Jun	49.8	300	0.5	−0.8	0.2	0.5	−0.7	0.5	0.9	1.2	0.4	−1.2	1.6	−0.4	0.8	−0.7
	49.5	500	0.1	−0.4	0.5	0.8	−0.5	0.3	0.9	2.1	−0.7	−0.8	−0.1	0.5	−1.4	−0.4
	49.5	800	0.1	–	0.6	–	−0.3	–	1.1	–	−0.9	–	−1.0	–	−0.7	–
Jul	49.8	300	0.3	−0.7	0.1	0.0	0.3	−0.1	0.8	0.2	−1.6	−0.3	1.4	0.0	0.2	−0.7
	49.5	500	−0.4	−0.3	0.1	0.2	−0.2	−0.5	0.8	0.9	−2.8	0.2	−1.1	−0.6	−1.5	−1.1
	49.5	800	−0.4	–	0.4	–	0.3	–	1.1	–	−2.8	–	−0.6	–	−1.1	–

Aug	49.8	300	1.1	−0.7	1.2	−0.2	0.7	−0.2	0.5	0.6	0.3	−1.1	0.7	0.2	0.1	−1.3
	49.5	500	0.4	−0.3	1.1	0.1	0.4	−0.1	1.6	1.0	−0.8	−0.8	−1.3	0.4	−1.0	−1.2
	49.5	800	0.6	–	1.5	–	0.7	–	1.3	–	−0.5	–	−1.0	–	−0.6	–
Sep	49.8	300	−0.1	−0.6	0.3	0.8	0.8	1.3	0.5	0.2	0.0	−1.3	0.7	−1.5	0.4	−0.8
	49.5	500	−0.9	−0.2	0.6	1.3	0.2	1.3	1.5	1.3	−1.2	−0.9	−0.7	−1.1	−0.6	−0.4
	49.5	800	−1.1	–	0.6	–	0.3	–	1.5	–	−1.3	–	−0.6	–	−0.8	–
Oct	49.8	300	0.5	−0.1	0.4	0.8	0.8	0.5	0.7	2.0	0.2	−1.0	1.0	−0.9	−0.3	−1.3
	49.5	500	−0.2	0.2	1.2	1.6	0.7	1.0	1.8	2.4	−0.9	−1.1	0.2	−0.4	−1.4	−1.6
	49.5	800	0.2	–	1.1	–	0.8	–	1.8	–	−0.5	–	0.1	–	−0.1	–
Nov	49.8	300	−0.6	0.0	−0.5	1.1	1.3	1.2	0.4	1.0	−0.5	−1.0	−0.2	−1.3	−1.1	−2.0
	49.5	500	−0.4	0.1	0.4	0.8	1.0	1.4	1.8	2.2	−0.5	−1.3	−0.3	−1.1	−1.8	−2.5
	49.5	800	−0.2	–	0.5	–	1.1	–	2.1	–	−0.2	–	−0.1	–	−0.5	–
Dec	49.8	300	−0.2	−0.4	0.2	0.8	0.4	1.4	0.0	0.4	−0.4	−1.9	0.3	−2.7	−0.4	−1.0
	49.5	500	0.3	−0.2	1.4	1.5	1.8	1.1	0.1	2.0	−0.1	−2.2	−0.4	−2.8	−0.3	−0.6
	49.5	800	0.4	–	0.6	–	1.0	–	1.1	–	0.2	–	−0.3	–	0.3	–
Year	49.8	300	0.6	−0.6												
	49.5	500	−0.4	−0.2												
	49.5	800	−0.3	–												

* Table 6 lacks data for valley bottoms at the altitude of 800 m, as those forms do not reach that height in the Low Beskid range.

ska (1967) sees the reasons for higher temperature in valley bottoms when compared with other Carpathian valleys in their opening to the South. In her opinion the effects of an increase in air temperature in given orographic conditions are a permanent feature, while on a regional scale, they depend on the relative height of the gate through which the air flows from the South.

The cold season of the year and transitional seasons in the Low Beskid range are characterized by considerable temperature variation from day to day. Thermal contrasts are particularly intensive in February (Hess *et al.* 1977). Apart from warm and dry southerly winds of a föhn character, in the period from November through February there occur single days and cycles of days with a southerly wind at a velocity of over 5 m/s bringing in the coolness by several degress (Obrębska-Starklowa 1959).

This genetically differentiated influence of advection which shapes the temperature regime accounts for the fact that in the mountain part of the Low Beskid range the differences between mean monthly temperature in relation to the West Carpathians are smaller than in the Foothills part. According to T. Niedźwiedź (1981) the highest plus thermal anomalies in the Carpathians occur together with the following synoptic situations: $S+SW_c$ and $S+SW_a$[3]. The $S+SW_c$ situations prevail in February (20.6 per cent); they also largely contribute to the shaping of weather in March (10 per cent) and April (14 per cent). The $S+SW_a$ situations prevail in January (15.5 per cent). During the time of their prevalence, a sharp climatic boundary is becoming to be noticeable at the Foothills Threshold and is being expressed by increased gradients of temperature and air humidity.

During the whole year, values of differences of mean maxima of temperature between profiles clearly testify to the poor heating of the Low Beskid range. The influence of relief forms does not play any major part there. What deserve attention are big differences of mean temperature maxima in January and February and small ones from April through July.

Minima of temperature, on the other hand, remain under an overwhelming influence of relief. Mean minima in valley bottoms are higher during the whole year; they frequently exceed 1 °C. Data for convex relief forms also reveal a similar tendency. Absolute values of differences in concave relief forms vary in the zone of the Foothills and the Beskid ranges. In the Jaslo-Sanok Basin – apart from the winter period – attention is attracted by favourable conditions for intensive heating of depression bottoms in April, May and June. This is already reflected in the early thawing of ground in the last ten-day period of March and vegetation growth speeded up by 5–10 days in relation to the western profile, and later in the fast progress of phenological stages in relation to the West Carpathians (Obrębska-Starklowa 1977).

Also in autumn, higher mean minima can be noticed on the ridges and in the upper part of slopes in the Low Beskid range. Possibly, the reason for this is the favourable arrangement of precipitation, nephological and insolation conditions developing from early summer. The western part with the flow of air masses from NW and N prevailing from May, receives amounts of precipitation higher by some 100 mm in the growing season. Besides, in summer the C_a and K_a situations, accounting for 16.3 per cent in the Carpathians, bring 15 per cent more fine days in he Low Beskid range than in the West Carpathians. Condtions

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[3] Capital letters in the typology of synoptic situations stand for directions of advection, index a – for high pressure systems, index c – for low pressure systems, K_a – for anticyclonic wedge; C_a, C_c – high pressure and low pressure over centre southern Poland, respectively.

of sunshine duration are also more favourable. During the time of prevalence of $S+SW_a$, $E+SE_a$ and C_a+K_a situations, accounting in summer for over 25 per cent of cases altogether, diurnal totals of sunshine duration are higher by about one hour in the Low Beskid range (Niedźwiedź 1981). A similar value for those areas is interpreted as a mean difference of sunshine duration in the Climatic Atlas of Poland (*Atlas klimatyczny Polski* 1973). On the other hand, mean monthly cloudiness in the eastern part of the Polish Carpathians in July and August is one of the lowest in Poland and accounts for 55 per cent (Warakomski 1963).

In those conditions in summer, with smaller differences of height a.s.l. of relief, and greater accessibility of the whole area to advection from S and SW, and also with the accessibility of the Jasło-Sanok Basin to advection from E and SE the plus thermal anomaly is more strongly marked in the eastern part by increased values of minima of temperature.

This tendency in the distribution of extremes also shows itself as a result of an analysis of extreme values of deciles (Table 6). Their most significant features are as follows: the values of the ninth decile of maximum temperature increasing together with altitude a.s.l. underline the difference between thermal conditions in the Foothills and Beskid part in both profiles. From the point of view of mesoclimatic processes, on the other hand, what deserve attention are, first of all, differences of the first and ninth decile of minimum temperature. Those deciles are positively higher in the Low Beskid range, especially in case of the low decile in February.

Taking into account the occurrence of very low absolute minima of temperature and relatively high values of the low decile of the minimum of temperature in the Jaslo-Sanok Basin and valley bottoms of the Low Beskid range, one can state that great differences of values of the discussed element occur in the lower section of the cumulative curve. Therefore, in the lowest intervals of frequency of minimum of air temperature including 10 per cent of the investigated statistical population of sample, one may expect greater variation of minima in the Low Beskid range than in the West Carpathians, which seals the conditions of existence of organisms with a definite stamp.

It is only in April that values of the ninth decile show a positive increase of minima in that Beskid range in relation to the West Carpathians. This tendency prevails till November irrespective of relief form.

DISCUSSION OF THE OBTAINED RESULTS

Hydrographic investigations carried out by Ziemońska (1973), Dobija (1981) and Tlałka (1982) proved that the Low Beskid range differs from the West Carpathians in seasonal variation of outflow. According to Ziemońska that Beskid range belongs to the eastern macroregion which is characterized by a considerable prevalence of outflow in the winter half-year increasing in an eastward direction from 55 to 67 per cent. The domination of winter outflow over the summer one is particularly characteristic for the Foothills [4]. Dobija rightly sees the causes of pre-

[4] Ziemońska (1973) points to the apparent contradiction which consists in including the Low Beskid range in the East Carpathians on that basis. In literature, an increased winter outflow is considered to be a feature of rivers with the oceanic or mediterranean regimen. In that part of the Carpathians, the increased winter outflow depends on orographic conditions which determine modification of atmospheric circulation, local features of heat balance and conditions of snow cover's thawing.

valence of winter outflow in the distribution of thermal conditions, i.e. length and degree of severity of the winter period, amount of snowfall and in the course and intensity of thaws. On the other hand, he proved that annual amounts of precipitation had little influence on the size of outflow.

This characteristics is supplemented by Leśniak (1980) who dealt with snow conditions in the Upper Vistula river basin. She arrived at a conclusion that compact groups of medium-high and high mountains in the western part of the Carpathians (with the advection of air masses from *W* and *SW* prevailing in winter) are a barrier which catches a considerable part of atmospheric precipitation. In the Low Beskid range, and mainly in its concave relief forms, the snow cover becomes stabilized later and disappears earlier. That part of the Carpathians is also characterized by lower values of probability of occurrence of a snow layer of a definite height in relation to the West Carpathians and the Bieszczady Mts. Valley bottoms in the Low Beskid range and the adjoining Foothills are characterized by the greatest variation of coefficients of snow cover stability (Leśniak 1981).

The authoress is of the opinion that those facts prove the influence of higher – in relation to the West Carpathians – minima of temperature, which results in lesser stability of the snow cover, especially in valley bottoms. The run-off of melting snow during thaws in the middle of winter is the result of transformation of general circulation streamlines and is connected with an increase of air temperature extremes depending on the intensity of föhn effects.

Another interesting issue is the question of boundaries between the discussed spatial units. An interesting attempt was made here by Dobija (1981) who correlated outflows in the adjoining catchment basins. The boundary of regions with a prevailing influence of continental climate separates the Beskid ranges east of the Biała Dunajcowa catchment area, and the Foothills east of the Dunajec river basin. Tlałka (1982) marks this boundary – with reference to low water stage types – with a watershed between the Biała Dunajcowa river and the Ropa river. Earlier, Leśniak (1980) marked the boundary between the West and East Carpathians on the basis of spatial differences in snow cover.

Most valuable records of differentiation of climatic conditions on the border line of the West Carpathians and the Low Beskid can be obtained from floristic investigations. Święs (1980) proved that though the Low Beskid range had mixed West and East Carpathian vegetation, nevertheless, its area was marked by the occurrence of such typically East Carpathian species as *Aposeris foetida* and *Festuca drymeja*, a plant of a steppe origin, resistant to drought and big temperature drops, occurring exclusively in that area. The mesoclimatic differentiation of valleys in the Low Beskid range was utilized by thermophilous species. Those species are growing in the parts very close to mountain ridges, i.e. within the thermal belt of the slope. They came mainly from the Danube river basin along river valleys, overcoming the transversal lowering of the Carpathians. There are also two newcomers from xeromorphic environments from the submediterranean zone of Europe and from Eastern Europe. The following species deserve particular attention: *Rosa gallica, Polygonatum officinale, Litospermum officinale, Nepeta nuda* (Pawłowski 1977).

Święs (1980) thoroughly examined the geobotanical orientation of the Low Beskid range and stated that the boundary separating the domination of West Carpatian from the East Carpathian elements (Fig. 3) runs along the line of ridges.

Out of those features of the phenological regime which testify to the distinct character of the Low Beskid range and increasing continental influence, one should mention: earlier beginning of the bursting into flowers by locust in relation to elder and earlier bursting into flowers by lilac (*Syringa vulgaris*) in relation to horse chestnut (*Aesculus hippocastanum*), which is typical for areas situated south

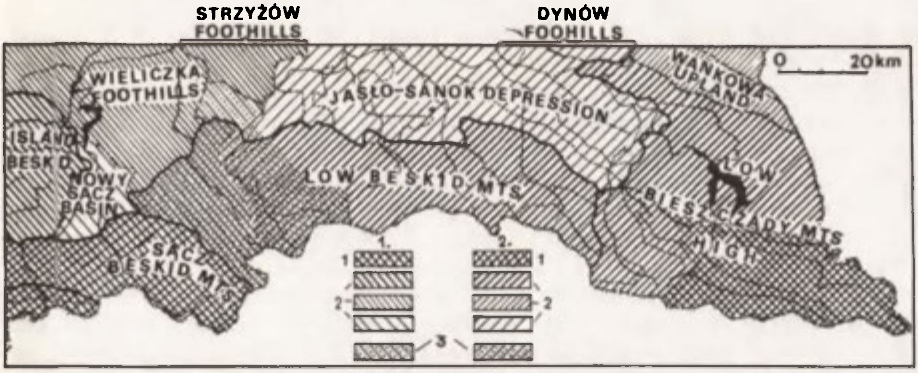

Fig. 3. Geobotanical position of the Beskid Sądecki range, the Low Beskid range, the Bieszczady Mts and the adjoining Carpathian Foothills according to Święs (1980)

1 – Province of the West Carpathians in the most typical (1.1) and ever less typical (1.2) areas, 2 – Province of the East Carpathians the most typical (2.1) and ever less typical (2.2) areas, 3 – transitional area between the Province of the West Carpathians and the Province of the East Carpathians

of the Carpathians (Fig. 4). The vegetation course of cultivated plants in the Low Beskid range is marked by a tendency to shorten stages of development from the beginning of the vegetation till the time of oat heading and from oat heading till spring grain harvest and to shorten the whole growing period. The speeded up ripening of grains characteristic of full summer in the Low Beskid range reflects the activity of masses of continental origin. Those features were also discovered by Kurpelova (1969) who included the southern slope of the Low Beskid range in the domain of continental climate within the transitional climate of the temperate zone.

To sum up one should stress that differences of hydrological processes and floristic phenomena in the Carpathians are determined by thermal conditions with a characteristic system of features. One may suppose that the distinct climatic character of the Low Beskid range in relation to groups of the West Carpathians is refected in an increase of thermal continentality indices, greater absolute air temperature amplitudes, greater range of variation of minima of temperature in many year's periods and lower range of variation of maxima. Smaller differences

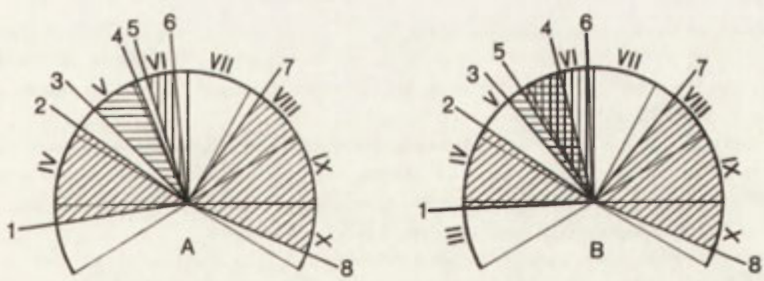

Fig. 4. Phenological vegetative period in the Wieliczka-Gdów Foothills (A) and in the Strzyżów Foothills (B) at 400 a.s.l. (according to Obrębska Starklowa 1977)

1 – beginning of the growing season, 2 – beginning of foliation of linden (*Tilia parvifolia*), 3 – beginning of winter rye (*Secale cereale*) heading, 4 – beginning of bursting into flowers by elder (*Sambucus nigra*), 5 – beginning of bursting into flowers by black locust (*Robinia pseudoacacia*), 6 – beginning of oat (*Avena sativa*) heading, 7 – beginning of harvests of spring barley (*Hordeum distichum*), 8 – end of the growing season

of relative heights and lack of bigger barriers for the development of horizontal and vertical air and heat exchange in relation to the West Carpathians account for the fact that the warming and cooling processes on the mesoclimatic scale influence the characteristic distribution of extremes. Maxima are characterized by lower values both mean and extreme ones, determined by the first and ninth deciles; minima, on he other hand are higher than in the West Carpathians. In the extreme sections of the cumulative curve for the minimum temperature, the dispersion of absolute values is greater than in the West.

In general, great variation of minima of temperature in the winter season, and fairly high maxima of temperature occurring periodically during the föhn effects are the reason for little stability of snow cover and thawing floods. In the summer period the lower diurnal air temperature drops exert their influence on the more even diurnal course of temperature, increasing evaporation, and speeding up the sequence of phenological stages of wild and cultivated plants.

Those features of thermal conditions are connected with conditions of relief which, on a regional scale, modifies atmospheric circulation in that part of the Carpathians, and, on the local scale, influences the intravalley circulation. Big differences of thermal regime occur between the zone of the Foothills and the interior of low mountains. One should suppose, then, that special pattern of relief types which is not repeated in other parts of the arc of the Carpathians, determines the climatic individual character of the Low Beskid range which together with its foreland seems to be raised to the rank of a unit equivalent to the West Carpathians. The western boundary of the physico-geographical unit runs close to the Ropa and Biala Dunajcowa rivers watershed while its eastern boundary is still unidentified because of lack of data on the climate of the Bieszczady Mts.

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SPATIAL AND TEMPORAL DIFFERENTIATION OF FLUVIAL SEDIMENT YIELD IN THE VISTULA RIVER BASIN

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STATE OF RESEARCH ON THE PROBLEM

The first, more detailed study on the intensity of fluvial sediment yield in the Vistula river catchment was carried out by Jarocki (1957) on the basis of results of hydrological measurements from the years 1946–1953. His calculations revealed that, according to data from the Tczew gauge, the average index of suspended sediment yield in that catchment amounted to 8.0 $t/km^2/y$ at that time.

As in the 1950s the number of stations for measurements of suspended sediment yield was small, there were attempts to determine the spatial differentiation of erosion in an indirect way. The basis for such indirect estimations was provided by a qualitative assessment of the intensity of soil erosion in Poland made by Reniger (1950). It was assumed that there was a direct dependence between soil erosion and fluvial sediment yield. Such an assumption has been made by hydrologists (Dębski 1958, 1959, Brański 1975), and by specialists dealing with studies on soil erosion (Reniger 1956, Sadurska 1964, 1977) not only in Poland but also abroad (for example: Fournier 1960, Tixeront and Cormary 1965). With this assumption and on the basis of very few hydrological measurements it was possible to calculate indices of fluvial sediment transport which qualitatively correspond to definite classes of intensity of soil erosion. Skibiński's calculations (1959), which referred to more homogeneous practical data, proved that the erosion index calculated in that way amounts, on the average, to 30.4 $t/km^2/y$ for the whole of Poland. On the other hand, according to Dębski's calculations (1958, 1959), which took into account the different practical data, an average index for Poland amounted to 52.5 $t/km^2/y$. Owing to the fact that the latter author also made use of results of measurements of the volume of the Vistula river submarine deltaic cone, it was possible for him to state that ca 30 per cent of sediments transported by rivers is carried away to the sea; the index of suspended sediment yield in the Vistula river basin defined in such a way amounted, according to Dębski (1959), to 14.9 $t/km^2/y$.

A much more detailed study of spatial differentiation of fluvial sediment yield was carried out by Brański (1972, 1975) who employed only hydrological data from the years 1956–1965. This was possible owing to the fact that in that period measurements of suspended sediment yield were already carried out in many gauging stations; Brański could already take into account 10-year data from 61 stations situated in the Vistula basin. The study showed that an average index of suspended sediment yield from that basin amounted to 7.0 $t/km^2/y$.

So far, less attention has been paid to differentiation of sediment yield in time, and this issue practically has not been examined at all for the whole of the Vistula basin. Therefore, the present paper is primarily concerned with the differentiation in time. To this end, an analysis of 20-year series of measurements (1952–1971) has been carried out for chosen partial catchments and for the whole Vistula basin. As a matter of fact, they provide a basis for examinations of short-period changes, depending primarily on climatic fluctuations. The influence of other factors, including also man's activity, was totally of lesser importance in this respect in catchments under examination and in the analysed 20-year period.

Further considerations on spatial and temporal differentiation refer, practically, to fluvial suspended sediment transport, as we have much broader measuring material to define such transport, since sediment transport is easier to be measured. According to such a scope of considerations, the notion of "fluvial sediment yield" used in the title and the text of the paper refers only to that part of eroded material which is transported in the form of suspended load. This part is prevailing in the Vistula basin quite clearly. In earlier studies it was assumed that transport in the form of bed-load in the lowland part of the basin accounts for only 3 per cent (Jarocki 1967). Recent studies proved, however, that this share is much greater and amounts to about 30 per cent (Brański and Skibiński 1968). Recently, even 43 per cent have been assumed for a section of the Vistula mouth (Cyberski 1982). Data for mountainous areas are very divergent – in extreme cases the share of bed-load was estimated to account for even 70 per cent (Brański 1971, Gładki and Madeyski 1975). Most probably, however, it is much lower and ranges from 5 to 15 per cent (Figula 1966, Wiśniewski 1972, Froehlich 1975).

DIFFERENTIATION OF FLUVIAL SEDIMENT YIELD IN SPACE

The first, more detailed maps of spatial differentiation of fluvial sediment yield in Poland were made in an indirect way, through reference to a cartographic image of potential soil erosion presented by Reniger (1950). Out of two elaborations made with the use of that method by Dębski (1958, 1959) and Skibiński (1959), the latter should be considered more convincing at present.

The map made by Skibiński (Fig. 1) showed that the highest, but at the same time most differentiated indices of fluvial sediment yield in the Vistula basin, i.e. ranging from ca 10 to 160 t/km²/y occurred in the zone of south-Polish uplands. At present, one may estimate that calculations of such an intensity of the process under consideration for an upland part of the basin were clearly overstated. Most probably, this primarily resulted from the fact that in the initial study by Reniger (1950), the degree of danger of soil erosion of loess deposits was overstated. Apart from thick proper loesses, also thin loess-like covers, much less sensitive to water activity, were included to those deposits by the authoress of the study. The whole mountainous, i.e. Carpathian part of the basin is shown in Skibiński's map as undifferentiated, within one interval of the index of suspended sediment yield from 70 to 100 t/km²/y. This value is clearly underestimated, particularly when confronted with upland areas. It seems that this resulted from the fact that in her initial study Reniger (1950) understated the influence of the intensity of dissection of mountainous areas on the development of soil erosion. The remaining, i.e. lowland part of the Vistula basin fell within the range of the lowest index of suspended sediment yield from 0 to 5 t/km²/y in that map. Such an assessment proved to be fully justified and corresponds to results of subsequent studies.

A different image of spatial differentiation appears in a map worked out by Brański (1972, 1975) on the basis of results of hydrological measurements of

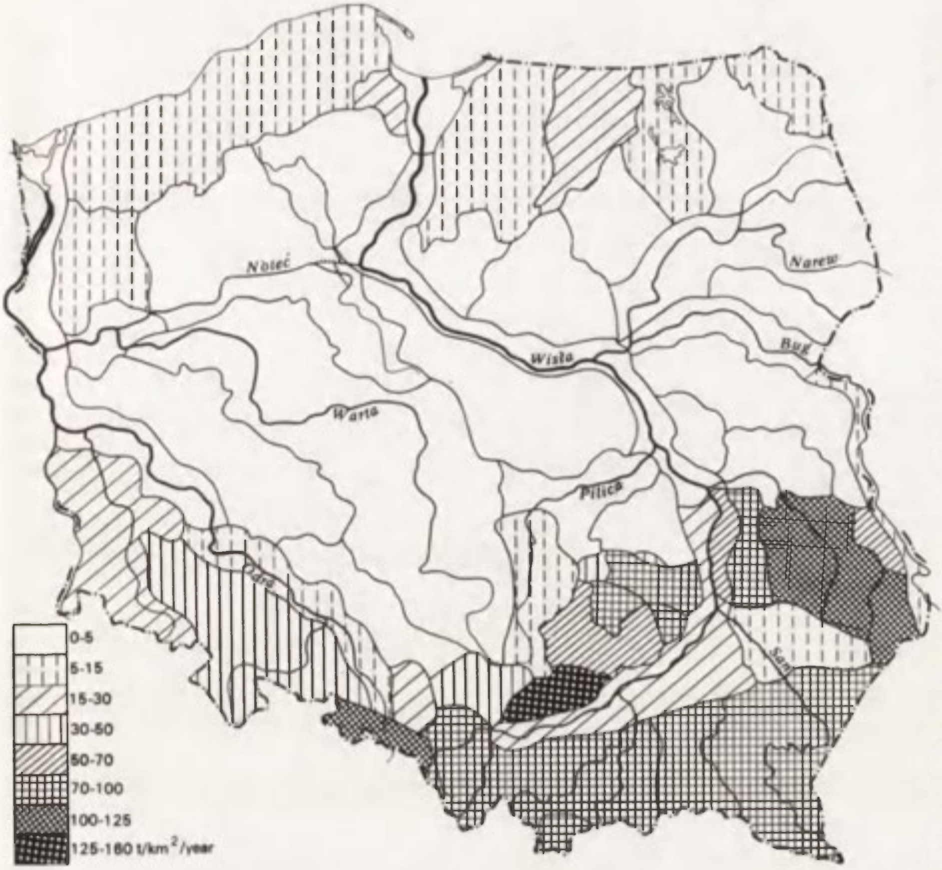

Fig. 1. Intensity of fluvial sediment yield in Poland according to estimated calculations by Skibiński (1959), referring to a study on limits of potential soil erosion by Reniger (1950)

suspended load in the years 1956–1965 (Fig. 2). In spite of the fact that this image is less readible—also due to considerable gaps in the shape of the catchment for which there were no measuring data—still, undoubtedly, it corresponds to reality to a greater extent. From the latter point of view, its disadvantage is the fact that it simultaneously includes catchments greatly differing in size from ca 100 to 14000 km^2. This makes it significantly more difficult to interpret it because data from catchments which differ in size to that extent are incomparable. If, while interpreting the map, we omit catchments with areas smaller than 1 000 km^2, the differentiation of fluvial sediment yield will be as follows:

a) mountainous part of the Vistula basin with suspended sediment yield indices in the interval ca 30–180 t/km^2/y;

b) zone of depressions belonging to the tectonic foreland and uplands including the Świętokrzyskie Mts with indices from ca 3 to 45 t/km^2/y;

c) lowland part of the basin with indices 0.5–5.0 t/km^2/y.

The spatial differentiation determined in such a quantitative way is, then, close to that schematically outlined in a map of fluvial erosion of continents by Fournier (1960). It can be also noticed that similar indices of the intensity of that process are characteristic of basis orographic elements (mountains, uplands, lowlands) in

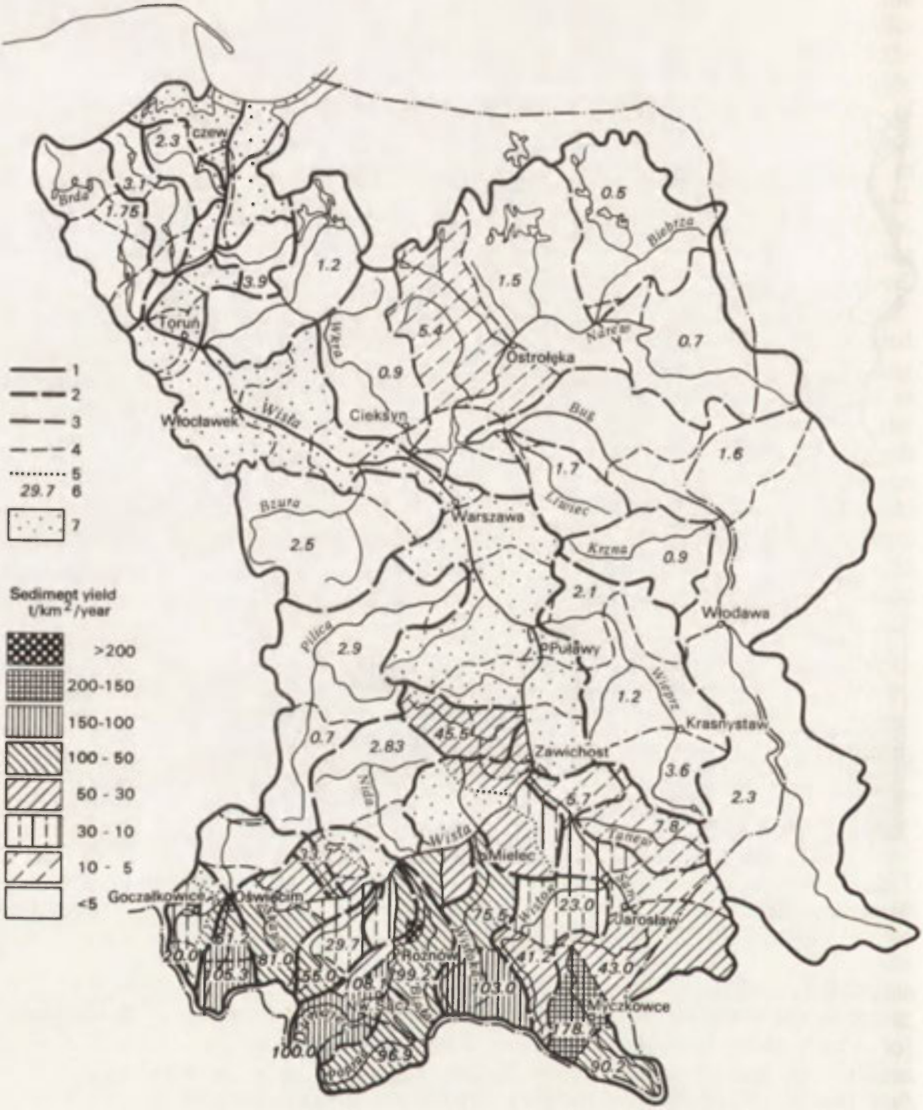

Fig. 2. Intensity of fluvial sediment yield in the Vistula river catchment calculated on the basis of results of suspended sediment yield measurements in the years 1956–1965 (according to Brański 1972)

1 – boundary of the Vistula basin, 2 – boundaries of catchments of the 2nd order, 3 – boundaries of catchments of the 3rd order, 4 – boundaries of differential catchments, 5 – boundaries of catchments without suspension measurements, 6 – indices of fluvial sediment yield in t/km²/y, 7 – catchment of direct tributaries of the Vistula river not included in suspension measurements

those parts of the Dnieper and Dniester basins which border on the investigated area from SE. This seems to be indicated by a very simplified version published for Ukraine (Budkina *et al.* 1972).

Average indices of fluvial sediment transport were calculated by the author of the present paper for the three parts of the Vistula basin delimited in that way by means of a method of weighed means on the basis of data referring only to medium-size catchments with areas of 0.9–9.0 thousand sq. km. The results are following: a) mountaineous part with an area of 21500 km^2 and average index amounting to 97.2 t/km^2/y; b) foreland part including uplands with an area of 55500 km^2 and an index amounting to 8.7 t/km^2/y; c) lowland part with an area of 117000 km^2 and an index amounting to 2.1 t/km^2/y. This shows that the intensity of the discussed process in mountainous areas is ten times greater than in upland ones and fifty times greater than in lowland ones. Extreme indices of intensity of suspended sediment yield for the whole basin in medium-size catchments are to each other as 1:358, according to Brański's (1972) data.

Data referring to such a generalized image prove that rivers with catchments of 1–10 thousand sq. km in the Vistula basin carry 2814000 t of suspended load a year on the average. Since in the years 1956–1965 the Vistula river in Tczew, i.e. just above its mouth to the Baltic Sea, transported 1360000 t a year on the average (Brański 1975), then, the whole basin loses 48 per cent of suspended load carried by medium-size rivers to the sea. The remaining 52 per cent of suspension material remains on valley bottoms of those rivers and the Vistula river itself. One may suppose that similar changes (losses caused by transitional deposition) occur during transport from small rivers with catchments smaller than 100–200 km^2 to medium-size rivers. The acceptance of such an assumption has been justified by results of research on small catchments in mountainous and upland areas (Sadurska 1964, 1977, Figula 1966, Brański 1975). With this assumption it is possible to calculate the total amount of suspended load carried by all rivers, including the small ones, which amounts to ca 5.5 million t a year on the average in the Vistula basin. Only 1.36 million t out of that amount, i.e. about 25 per cent, is discharged by the Vistula river to the sea. The specific index of such a total suspension yield in the Vistula basin, i.e. the index of gross suspended sediment transport, amounts to 28 t/km^2/y, and the index of amount of suspended sediment discharge to the sea, i.e. net suspended sediment transport (= balance of processes of fluvial erosion and accumulation), only to 7 t/km^2/y.

Spatial differentiation of suspended sediment transport could be examined further, i.e. with regard to catchments smaller by a successive order of value, i.e. with areas smaller than 1–2 km^2. In practice, however, this would be impossible because of lack of appropriate measuring data. However, still a more significant difficulty seems to result from the fact that while examining so small catchments we would deal not so much with suspended sediment yield in rivers as primarily with sheet erosion, i.e. with mechanical denudation on a microscale. Thus, on farmland, this would be mainly soil erosion. It is doubtless that indices of the intensity of soil erosion on farmland which includes the majority of the Vistula basin, are much higher than the amounts of suspended load carried by rivers (Gerlach 1976). However, there are too limited definite measuring data to allow definitions of appropriate relations. Therefore, it is only possible to assume that only a small part of sediments carried during soil erosion gets to rivers. This has been stated for quite a long time now on the basis of studies carried out in different geographical regions (Roehl 1962, Makkaveev 1974, Dedkov *et al.* 1977, Trimble 1977). Basing oneself on an extrapolation of results of our considerations on spatial differentiation of suspended sediment transport while passing from big rivers through medium-size ones to small ones, one may assume that only about 10 per cent of sediments displaced as a result of soil erosion (mechanical denudation) is carried away to the sea from the Vistula basin.

The relation between the intensity of soil erosion, or more precisely speaking—sediment production connected with that erosion, and the intensity of fluvial sediment transport, greatly changes in space. In case of small catchments, quite a reverse dependence can be frequently observed. In partial catchments, with soil erosion developing more intensively, fluvial sediment yield may be lower many times than that in directly adjoining and less eroded catchments. This also happens even when catchments show similar physiographic features and are characterized by similar land use (Sadurska 1983). What is very often ol essential importance in such cases is the differentiation of character and way of utilization of a valley bottom through which sediments are transported from slopes to the river channel. Still greater differentiation of the discussed relation may be connected, of course, with a distinct character of methods of land use in the whole area of different catchments.

DIFFERENTIATION OF FLUVIAL SEDIMENT YIELD IN TIME

Permanent, 20-year series of suspension measurements are characteristic of very few water gauges only. The author of the present paper chose three out of them, with medium-size catchments, representing mountainous areas (the upper Dunajec river above Nowy Sącz in the West Carpathians—catchment of 4341 km^2), upland areas (the upper Wieprz river above Krasnystaw in the SE part of the Lublin Plateau—catchment of 3003 km^2) and lowland ones (the Wkra river above Cieksyn in NW part of the Mazovian Lowland—catchment of 4880 km^2). Apart from them the author also took into account the data referring to the whole Vistula basin (water-gauge measurements in Tczew—catchment of 193866 km^2), and, for comparison, data from a small upland catchment (the upper Bystra river above Wojciechów water-gauge in NW part of he Lublin Plateau—catchment of 36.6 km^2).

Owing to an easy access to already published data, it was possible to take up studies for the 20-year period 1951–1970. However, since measurements of suspension had been started in the two out of those gauging stations as late as 1953, it was impossible to describe the 20-year period with regard to decades, but only as the period 1952–1971. Complete series of measurements for such a 20-year period were collected for water-gauges in Tczew, Nowy Sącz and Wojciechów; for Cieksyn and Krasnystaw water-gauges the series were 19-year ones (1953–1971)[1].

Data from measurements were confronted for climatic years and proper seasons of the year (winter: December-February, spring: March-May, summer: June-August, autumn: September-November). In such an arrangement mean monthly, seasonal and annual indices were calculated for precipitation, run-off and fluvial sediment yield (Fig. 3–7).

The described 20-year period may be considered representative from a hydrological point of view. Detailed analyses carried out for the 20-year period 1951–1970 proved that average flows in the Vistula basin were very close at that time to average „normal" ones, i.e. those calculated for he period 1901–1971 (Stachy *et al.* 1977). This resulted from the fact that hydroclimatic phenomena in the years 1951–1970 were fairly differentiated in time, with alternating more intensive

[1] Measuring data for four water-gauges were collected by the State Hydrological Service and were published in the years 1958–1975 (Hydrological Yearbooks of the State Hydrological Institute). At the Wojciechów gauging station, measurements were carried out by the Institute of Soil Science and Cultivation of Plants in Puławy; results of an analysis of a 20-year series of measurements of that water-gauge were published separately (Sadurska and Maruszczak 1983).

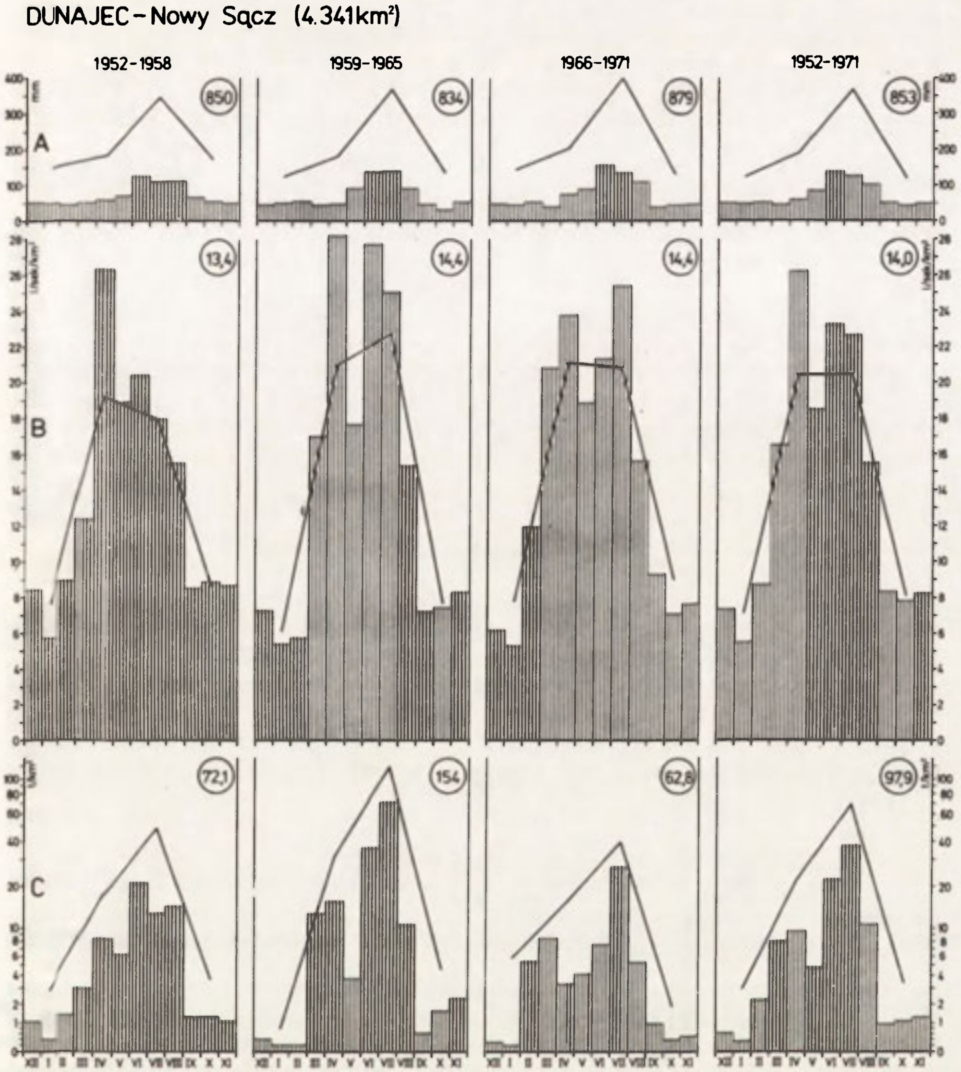

Fig. 3. Mean monthly values (column diagrams), mean seasonal values (broken lines) and mean annual values (numerical indices in circles) in five investigated catchments in three subperiods and in the whole investigated 20-year period

A – atmospheric precipitation. B – specific discharge. C – specific sediment yield. Atmospheric precipitation according to data from the following measuring stations: Szczawnica Zdrój (the upper Dunajec catchment). Zwierzyniec (the upper Wieprz catchment). Żuromin (the Wkra catchment). Tarnów (the Vistula catchment). Antopol (the upper Bystra catchment)

features of continentality and oceanity. The alternation of intensity of those features is very characteristic of a transitional 'Polish' variety of the moderate climate typical of the Vistula basin. To illustrate the variability more precisely, the investigated period was divided not into decades, obtained mechanically, but into 6–7-year subperiods: 1) 1952–1958 with continentality features marked more clearly; 2) 1959–1965 – slightly less humid; 3) 1966–1977 – clearly most humid one and

WIEPRZ – Krasnystaw (3.003km²)

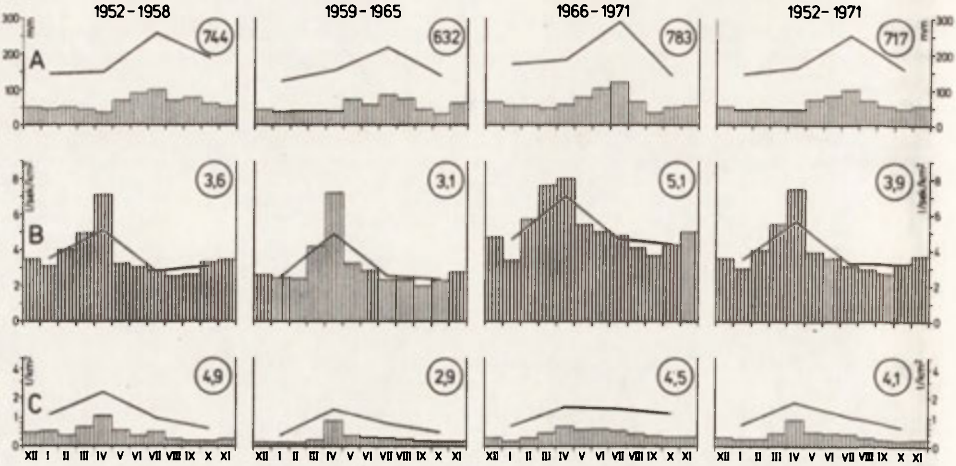

Fig. 4. For explanations see Fig. 3

with most strongly marked oceanity features. Mean indices for those three subperiods and for the whole 20-year period[2] are shown graphically in Fig. 3–7.

Those data show that fluvial sediment yield is characterized by a far greater temporal variability than atmospheric precipitation and run-off. This is illustrated by the simplest variability coefficients in the form of relation between annual maxima of data (max) and annual 20-year average (a). Such a variability measure ranges from 1.4 to 1.7 for precipitation $\left(\frac{P_{max}}{P_a}\right)$ in the five catchments under analysis, from 1.4 to 1.8 for average run-off $\left(\frac{R_{max}}{R_a}\right)$, and from 2.0 to 5.0 for suspended sediment transport $\left(\frac{SS_{max}}{SS_a}\right)$. Average values of those indices for precipitation (1.48) and run-off (1.62) are similar, and 2.5 times higher for suspended sediment transport (3.73). This explicitly proves that the group of factors determining the intensity of sediment transport is much more complex than in case of precipitation or run-off.

To obtain a broader picture of variability, the annual, monthly and diurnal indices, extreme in the whole 20-year series, were confronted (Table 1). In case

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[2] Our data for the years 1952–1971 differ considerably from those calculated by Brański (1975) for the decade 1956–1965 and presented in his map (Fig. 2). Those differences result not only from temporal separateness of series of measurements. For Branski's calculations included correction coefficients (k) describing dependence between the amount of suspended load measured in permanent stations for collecting water samples and the mean value for the whole water gauging cross section. Those coefficients for water-gauges described in the present paper amounted to: 0.736 – Nowy Sącz, 1.137 – Krasnystaw, 0.795 – Cieksyn and 1.444 – Tczew. Since they were calculated for he years 1956–1965, they were not taken into account when data from the years 1952–1971 were examined. It was possible to disregard those coefficients, as the aim of our considerations is to define variability in time and not an absolute intensity of sediment transport.

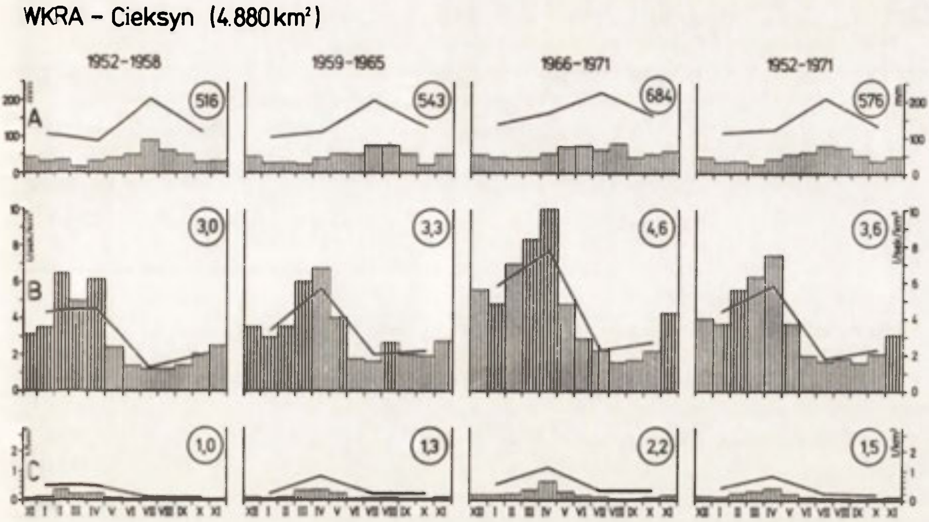

Fig. 5. For explanations see Fig. 3

of diurnal data, ranges of indices of suspended sediment yield are 20–50 to 3000 times higher than run-off indices. With such a great variability every calculation of relation between the value of sediment transport and run-off are of no general importance. It has been pointed out for a long time that there is no direct relation (Jarocki 1957). It is being emphasized that even for different flood rises those relations are shaped in a different way (Froehlich 1975). On the basis of analyses of many years' measuring series, it was stated that, from the point of view of that relation, there were no years similar to each other. In the light

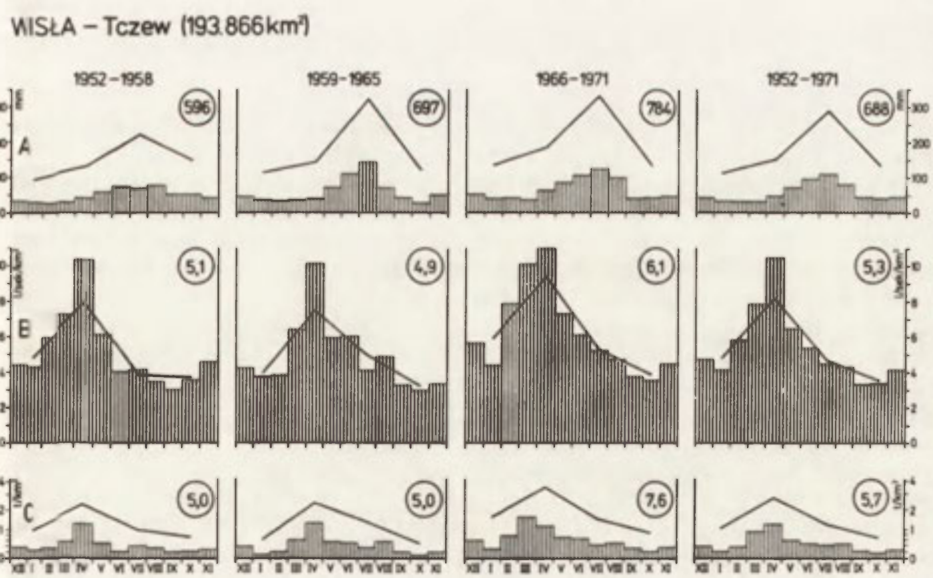

Fig. 6. For explanations see Fig. 3

TABLE 1. Chosen parameters characterizing catchments analysed in the Vistula basin and

Catchment and gauging station	Area of catchment (A) km²	Altitude a.s.l. of extreme points in metres		Dissection index $\frac{H_{max}-H_{min}}{\sqrt{A}}$ in %‰	Forested area index in %‰	Average specific discharge l/s/km²
		H_{max}	H_{min}			
The upper Bystra river (NW part of the Lublin Plateau) – Wojciechów	36.6	245	182	1.04	1.6	3.17
The upper Dunajec river (West Carpathians) – Nowy Sącz[a]	4341	2655	276	3.61	39.0	14.04 (13.31)
The upper Wieprz river (SE part of the Lublin Plateau) – Krasnystaw	3003	385	174	0.39	22.0	3.38
The Wkra river (NW part of the Mazovian Lowland) – Cieksyn[b]	4880	226	77	0.21	15.0	3.59 (3.59)
The Vistula river (Poland) – Tczew	193 866	2665	0.6	0.60	25.0	5.32

[a] Indices in parentheses were calculated with disregard to the year 1960 characterized by extremely high suspension

[b] Indices in parentheses were calculated with disregard to the year 1970 characterized by extremely high suspension

of those data one can say that also within the 20-year series of measurements from the Vistula basin, no years with similar variability can be found.

With such a great variability, however, a strong seasonal rhythm of suspended sediment yield is becoming pronounced. During one season of the year with a maximum intensity, rivers carry 40–70 per cent of an annual total of sediment transport and 22–38 per cent in the culminating month (Table 1). In the dominant part of the Vistula basin, the maximum occurs in the spring season when a strong mechanical erosion connected mainly with snow melting develops on agricultural land. Only in the mountainous part of the basin, a strongly marked seasonal maximum occurs in summer. The great intensity of mechanical erosion in the mountains depends on abundant precipitation at that time, which causes summer floods characteristic for the Carpathian part of the Vistula basin (Ziemońska 1973). The summer maximum of suspended sediment yield is most strongly marked in the West Carpathians and particularly in their highest parts which include the catchment of the upper Dunajec river. In the East Carpathians, i.e. in the San river catchment, the maximum of river outflows is clearly shifted to the spring period. Correspondingly, the summer maximum of suspended sediment yield is much less pronounced.

indices of temporal differentiation of run-off and fluvial sediment transport in the years 1952–1971

Relation between extreme run-off (in the years 1952–1971)			Average suspended sediment yield	Relation between extreme indices of suspended sediment yield (in the years 1952–1971)			Season and month with highest sediment transport with share of mean annual transport in %
annual ones	monthly ones	diurnal ones	$t/km^2/y$	annual ones	monthly ones	diurnal ones	
1 : 3.7	1 : 17	1 : 385	29.1	1 : 39	1 : 2221	1 : 226 714	Spring – 76.3 March – 33.9
1 : 2.4 (1 : 2.4)	1 : 38 (1 : 34)	1 : 367 (1 : 367)	97.9 (81.5)	1 : 29 (1 : 13)	1 : 20 161 (1 : 6194)	1 : 666 942 (1 : 334 858)	Summer – 70.9 – (59.9) July – 38.1 (June) – (22.0)
1 : 2.7	1 : 17	1 : 85	4.1	1 : 7.4	1 : 241	1 : 3399	Spring – 42.7 April – 22.0
1 : 3.9 (1 : 3.2)	1 : 46 (1 : 24)	1 : 143 (1 : 75)	1.5 (1.3)	1 : 13 (1 : 7.7)	1 : 311 (1 : 115)	1 : 2068 (1 : 2068)	Spring – 53.3 – (44.7) April – 24.7 (March) – (17.3)
1 : 2.2	1 : 11	1 : 26	5.7	1 : 4.7	1 : 129	1 : 1465	Spring – 47.4 April – 22.0

discharge (480 $t/km^2/y$)

discharge (4.88 $t/km^2/y$)

Having the general characteristics of spatial variability, one should pay more attention to major specific features of each partial catchment out of the three analysed ones. Phenomena of extreme intensity of fluvial sediment yield and conditions of their formation will be also presented against that background.

The mountainous catchment of the upper Dunajec river is characterized by the greatest suspended sediment yield and that yield's greatest variability. This is determined by the highest precipitation and run-off (Fig. 3) and the greatest intensity of dissection (Table 1). At the same time the role of dissection seems to be peculiar if one remembers that a large part of that area is covered with forests, meadows and pastures where the dimensions of mechanical erosion are insignificant; arable land accounts only for 30 per cent of total area. It is also of some importance that rivers are alimented in 50–70 per cent by surface run-off which exerts a decisive influence on the development of mechanical erosion. With a strongly marked seasonal, 'normal' rhythm – i.e. in the light of data average for the 20-year period – its intensity changes within very big limits in different years. Once in a few years (1955, 1958, 1962, 1965, 1970) the seasonal rhythm shows increased intensity – in a culminating month suspended sediment yield accounts for 90–130 per cent of mean annual yield. Only once, i.e. in 1960, the seasonal

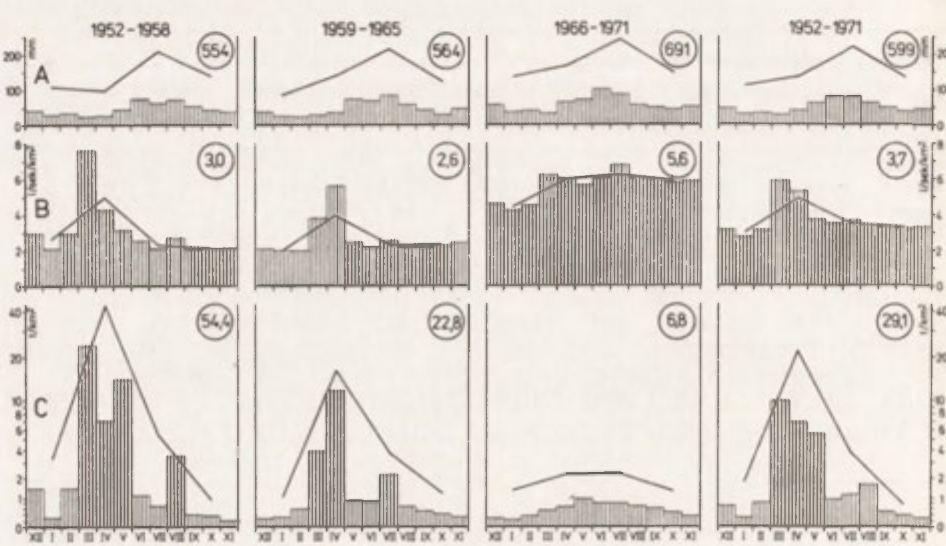

Fig. 7. For explanations see Fig. 3

rhythm showed excessively increased intensity – in the culminating month, i.e. in July the river transported over four times as much suspended load as in the whole average year. On July 27, 1960 the intensity of fluvial sediment yield episodically reached catastrophical dimensions – diurnal suspended sediment yield was twice as high as the average annual yield (10.2 per cent of general sediment transport for the whole 20-year period). This was determined by an exceptional arrangement of climatic conditions – high precipitation occurred as early as June, and in July 1960 the monthly total was three times as high as the normal 20-year one. On July 13, torrential rains occurred on vast areas – diurnal totals considerably exceeded 100 mm; on July 25 and 26, when the ground was already oversaturated with water, there occurred rainstorms with an intensity amounting to 60–90 mm per twenty-four hours. Not only in the Dunajec river catchment but also in other catchments of the West Carpathians the intensity of erosion was catastrophically high in July 1960; the amount of course rubble translocated from slopes to valley bottoms at that time locally amounted to several thousand m^3/km^2 (Ziętara 1968). Therefore, one may be of the opinion that the intensity of fluvial sediment yield in the upper Dunajec catchment in 1960 was catastrophically high in the scale of several dozen years or maybe even in a hundred years.

The upland catchment of the upper Wieprz river. The intensity of fluvial sediment yield is over 20 times lower than in the mountainous catchment. This is accounted for by not so much lower precipitation (Fig. 4) as, primarily, by dissection which is several times as weak; in the version shown in Table 1 the dissection index is almost 10 times lower there. What is also very significant is the fact that the share of surface run-off is much smaller and amounts to 30–40 per cent only. In such conditions, suspended sediment yield is relatively small, despite the fact that the degree of forestage is much lower, and the share of arable land twice as high as in the Dunajec catchment. The seasonal rhythm of suspended sediment yield is different, with a strong spring maximum connected with snow melting which is far less strongly marked and shows lesser variability from year to year. It had been only three times over the 20-year period that the rhythm had occurred with the intensity increased to that extent (1953, 1956, 1964) that in the culminating month, i.e. in April or March, suspended sediment yield accounted 40–110 per cent of the average annual yield. In each of those cases the great intensity of erosion was determined by typically seasonal phenomena connected with exceptionally rapid occurrence of snow melting. The highest diurnal suspended sediment transport recorded on April 5, 1964, accounted for only 25 per cent of the average annual one (1.32 per cent of general sediment transport for the period 1953–1971). It can be estimated, then, that in the investigated 20-year period in he upper Wieprz catchment, the intensity of fluvial sediment yield did not reach catastrophical dimensions in any year in the scale of several dozen years.

The lowland catchment of the Wkra river. The intensity of sediment transport is 65 times lower there than that in a mountainous catchment and almost three times lower than in an upland one. It corresponds to lower precipitation (Fig. 5) and the intensity of dissection. The forestage index is lower than in an upland catchment but there are more meadows and pastures, which is connected with the fact that the share of arable land is similar. However, the share of surface run-off in supplying the rivers is much greater (40–60 per cent) and this creates a greater potential danger of development of erosion. The seasonal rhythm of suspended sediment yield, with a strong spring-thawing maximum, is similar to that in an upland catchment. Still, it is characterized by greater variability from year to year, which can be connected with considerable supply of surface run-off. In the analysed period the seasonal rhythm occurred several times with increased intensity (1953, 1962, 1964, 1965, 1971)—during the culminating month the river transported 40–70 per cent of average annual sediment transport. In 1970 the rhythm occurred in an excessively intensified form—in the culminating month, i.e. in April, the suspended sediment yield was almost twice as high as the average annual yield. This was connected with the course of climatic conditions in the winter-spring period which was quite untypical of that area. From the end of November 1969 to the beginning of April the snow cover had continuously persisted. Considerable resources of water accumulated in that cover and extremely high precipitation in April 1970 made the mean monthly flow of the Wkra river be over four times higher in that month than the normal one for the 20-year period. The diurnal suspended sediment yield, however, did not reach catastrophical dimensions either then or at any other date; the highest diurnal index accounted for only 0.72 per cent of total sediment transport for the whole period 1953–1971. It can be supposed, then, that the intensity of fluvial sediment yield in the Wkra catchment in 1970 did not reach catastrophical dimensions in the scale of several dozen years.

The Vistula river catchment. Since lowland areas are prevailing in that catchment, the seasonal rhythm with the characteristic spring maximum of sediment transport shows features similar to those in the Wkra catchment. However, that rhythm occurred with increased intensity slightly more often (1952, 1956, 1962, 1964, 1966, 1967); in the culminating months suspended sediment yield accounted for – similarly as in the Wkra catchment – 40–70 per cent of the annual average yield. Apart from that, the increased intensity of the seasonal rhythm was marked only once, i.e. in 1960, in an untypical arrangement, as the seasonal maximum occurred in summer, with the culmination in August. This was caused by an abundant flow of sediments from the mountainous part of the Vistula basin, which seems to confirm the hypothesis that erosional devastations in the upper Dunajec catchment in July 1960 had catastrophical features at least in the scale of several dozen years. Sediment transport in the Vistula river did not occur with excessively increased intensity in only one year. It is possible that in the present century such intensity occurred during the known spring flood in 1924 when on the deltaic cone of the Vistula river the dimensions of accumulation were several times greater than average annual ones (Łomniewski 1960, p. 401). In the years 1952–1971 no episodes with catastrophical intensity of fluvial sediment yield were recorded either; the maximum registered diurnal value accounted for only 0.27 per cent of sediment transport for the whole 20-year period.

The catchment of the upper Bystra river is presented parenthetically, for comparison only, as an example of a small basin. In spite of the fact that it belongs to medium-dissected upland areas (Sadurska 1983) it is characterized by a relatively high fluvial suspended sediment yield (Table 1). This is accounted for by almost total deforestation of the area and the occurrence of a narrow valley bottom, and, as a result, big supplies of products of soil erosion directly to the river channel (Sadurska 1964). The seasonal rhythm at the spring maximum of sediment transport typical of uplands is marked more strongly there than in the mountainous catchment of the Dunajec river. It occurred twice with such an increased intensity (1952, 1954) that in the culminating month the suspended sediment yield accounted for 130–160 per cent of the annual mean. The rhythm was excessively intensified three times (1956, 1958, 1964)—in the culminating month the suspended sediment yield was 2–4 times greater than the average annual yield. In the culminating months the majority of suspended load was outflowing during 1–2 'climatic' days. If during five culminating months in those years the river had transported 64.5 per cent of the toal amount of suspended load from the whole 20-year period, as much as three fourth of that (48.7 per cent) fell on the seven "climatic" days. During five such days the dimensions of diurnal transport exceeded the annual mean. The frequency of diurnal episodes with such a catastrophical intensity of erosion is much higher there than in the mountainous catchment of the Dunajec river. Those episodes occur most frequently in a typically seasonal arrangement, i.e. they are connected with exceptionally rapid snow melting. Only one of the episodes occurred in a non-seasonal arrangement, though it happened on a spring day, May 14, 1958. The extreme intensity of erosion for the whole 20-year period was measured then. On that day the Bystra river carried 14.9 per cent of the total amount of suspeneded load transported in the years 1952–1971. That disastrous episode was connected with torrential rain (25 mm) which occurred in the conditions of exceptionally delayed initial stages of cultivated plants vegetation (Sadurska and Maruszczak 1983).

CONCLUSIONS

1. Hydrological measurements of medium-size rivers with catchments of 1–10 thousand square kilometres carried out in the years 1956–1965 proved that indices of fluvial sediment yield within the Vistula basin were very different. In the mountainous part of the basin they amounted to ca 97 t/km^2/y on the average, in the zone of foreland depressions and uplands—to 9.0 t/km^2/y, and in the zone of lowlands to 2.0 t/km^2/y. The relation between extreme indices for a catchment of that size was 1 :358.

2. The amount of suspended load carried by rivers is changing very strongly depending on the size of catchments under examination. Data from measurements from the years 1956–1965 prove that 1.36 million tones of suspended load a year, on the average, was carried away to the sea by the whole Vistula catchment. When we take into consideration the medium-size rivers, it appears that the amount of average suspended sediment yield amounted to 2.8 million tones, and

when we take into account rivers with small catchments (below 100 km^2), that amount may be estimated as 5.5 million t. The above figures indicate that total fluvial suspended sediment yield (= gross sediment yield) in he whole basin is four times bigger than suspended load carried away by the Vistula river to the sea. This proves that three fourth of fluvial suspended load remains within the basin on the way from the smallest rivers to the Vistula mouth.

3. When we take into consideration the smallest catchments of less than 1 km^2, we are dealing not so much with concentrated fluvial suspended sediment yield as rather with mechanical erosion developing on the surface. On farmland which includes the majority of the Vistula basin, this will be mainly soil erosion. An extrapolation of results of studies on spatial differentiation of fluvial suspended sediment yield makes it possible to estimate that, during soil erosion in that basin, sediments are carried on the surface and their quantity is approximately 10 times greater than that carried away by the Vistula river to the sea. However, the relation between the intensity of soil erosion and the amount of sediments carried by the rivers greatly varies in space depending on ways of catchment land use, leading physiographic features of catchments, the character of valley bottoms, etc. Soil erosion is one of the basic links in the complex process of sediment translocation from watersheds through slopes and valley bottoms to river channels. The fluvial sediment yield, on the other hand, represents as if a balance of processes of erosion and accumulation, changing dynamically within the catchment. One should not assume that there is a direct dependence between them. It is particularly impossible to either directly assess the intensity of soil erosion on the basis of results of measurements of fluvial suspended sediment yield or to quantitatively determine the spatial differentiation of fluvial sediment yield according to ranges of different classes of intensity of soil erosion.

4. Analyses of 20-year series (1952–1971) of suspension measurements proved that the intensity of fluvial sediment yield changes in time within very big limits. The relation between 20-year extreme diurnal values ranges from 1 : 1 465 (the whole Vistula river catchment) to 1 :666942 (the upper Dunajec mountainous catchment). With such exceptional variability, however, a strong seasonal rhythm is noticeable. In a climatic season of the years with the greatest intensity of erosion, rivers carry 40–75 per cent of suspended load transported, on the average, annually. In the mountainous part of the basin this maximum falls in summer, while in the upland and lowland ones – in spring.

5. In the mountainous part of the basin in medium-size partial catchments the great majority of sediment transport falls at the time of summer flood freshet connected with abundant precipitation. Such precipitation occurs with increased intensity once in several years and with excessively increased intensity once in several dozen years. With an excessively increased intensity of seasonal rhythm, erosion episodically reaches catastrophical dimensions. At that time the river is transporting more suspended load during twenty-four hours than in 1–2 average years.

6. In the upland and lowland part of the basin the share of sediment transport is much smaller in medium-size catchments at the time of spring freshets connected with snow melting. The frequency of years with increased and, particularly, excessively increased intensity of the seasonal rhythm is also lower in such catchments. This is accounted for by the fact that, contrary to abundant summer precipitation in the mountains, spring snow melting does not occur simultaneously in larger upland areas, but is very strongly differentiated locally. Only in the case of small catchments (of less than 100 km^2) in upland areas, the dominant part of sediment transport occurs in the form of short episodes of several days – frequently characterized by a catastrophical intensity of erosion – connected with exceptionally rapid thawing occurring once in several years. The frequency of catastrophical epi-

sodes may be much higher in such small upland catchments than in mountainous medium-size ones. Some of those episodes are connected, at the same time, with torrential rains occurring exceptionally not in summer but at initial stages of cultivated plants vegetation; in the catchment of the upper Bystra river a catastrophical episode of that kind was recorded, with diurnal sediment transport corresponding to nearly 3-year mean. Catastrophical erosional devastations of that kind do not play a major part in medium-size upland catchments, as torrential rains occur usually within a very limited spatial range.

7. Owing to great spatial and temporal differentiation of fluvial sediment yield, one should be very careful while drawing conclusions about the intensity of that process on the basis of short-term series of measurements. This refers, in particular, to any attempt to confront the adjacent catchments on the basis of measuring data from different years.

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THE EFFECTS OF HUMAN ACTIVITY ON CHANGES IN THE LOWER VISTULA CHANNEL

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INTRODUCTION

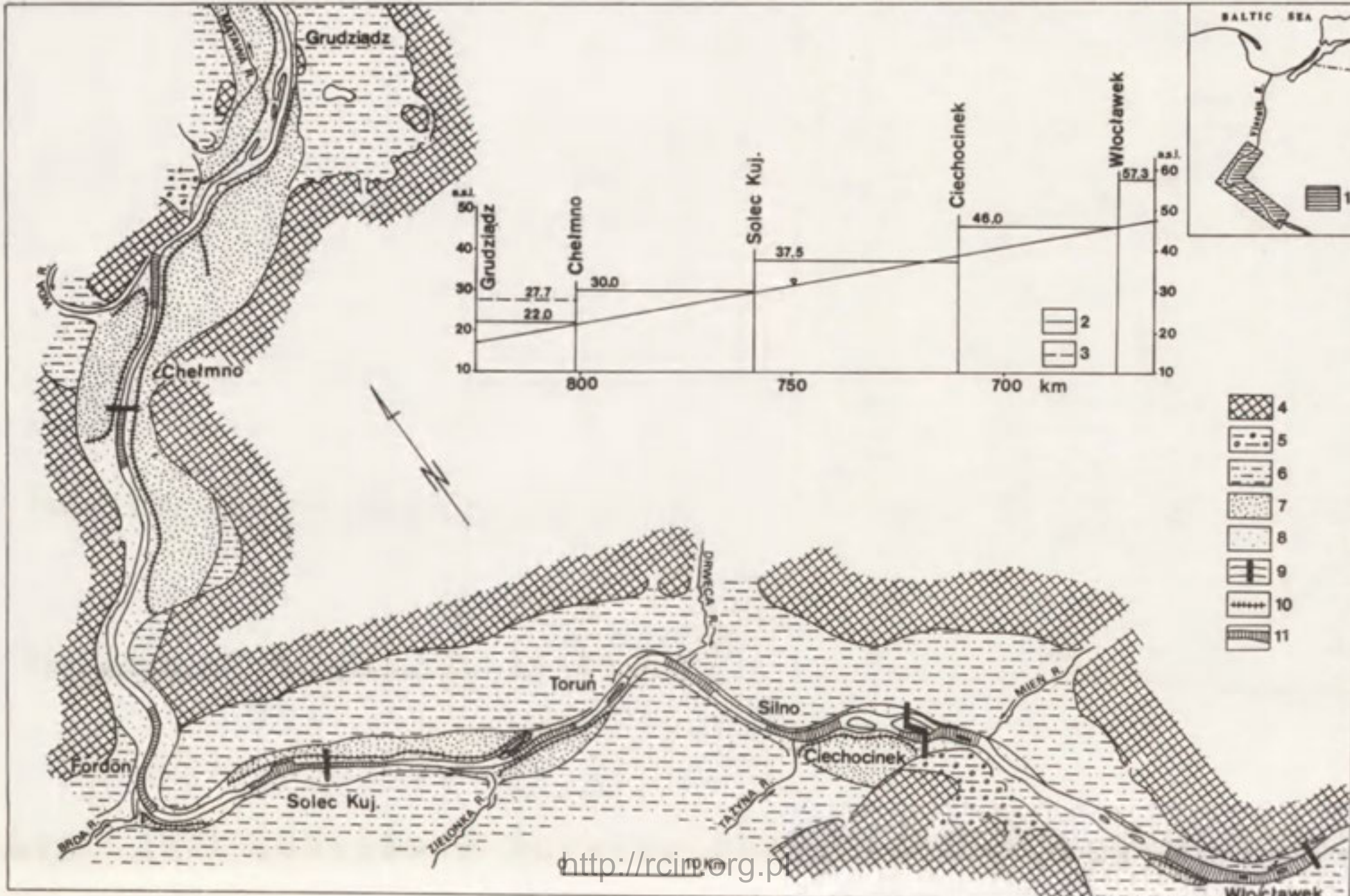
The development of river channel regarded as a macroform with the complex of mezoforms, depends, first of all, on hydrological conditions of the river, being a function of the climate. Beside this leading factor, still many other factors exist, which modify the course of processes, in particular: geologic structure, tectonic movements, vegetal cover. To the factors modifying the action of flowing waters, also human interference effects should be assigned. Particular importance assumed these effects particularly in case of the Vistula river in the last century, when the intensive works on the Vistula channel regulation began.

The aim of the paper is to determine both qualitative and quantitative changes of the Vistula channel under the impact of human activity. This problem is discussed against the background of changes of the river channel types and of the channel mezoforms connected with them. The morphometry and dynamics of the most typical channel mezoforms have been determined. Changes which occurred in the channel in consequence of building of the first link of the Lower Vistula cascade, i.e. the Włocławek dam, are characterized. Some possible changes of the channel in case of cascading the Vistula river are presented.

In the analysis we mainly used situation and elevation maps and bathymetric plans of the Vistula channel at the scale of 1:5000 and 1:10000 as well as interpreted air photographs. The method of successive comparisons was applied at that. At determination of measurable values (among other things, parameters of forms, debris balance) on the basis of the bathymetric plans and channel cross-sections executed with the use of echo sounder, the planimetric and mathematical method was applied. In such a way the Vistula channel in the Włocławek-Grudziądz sector comprised with the analysis since the moment of execution of the general design of its regulation, which occurred in the middle of the 19th century. Only selected cartographic materials were used in the paper (Fig. 1).

DEVELOPMENT OF THE VISTULA VALLEY FLOOR TILL THE COMPLETION OF REGULATION WORKS

The Vistula channel, together with the flood plain, lies in fluvial and fluvioglacial sandy formations. The flood plain, as an integral part of the river bed accompanying the river channel in the shape of narrow bars, was formed in the Holocene period (Wiśniewski 1976). This fact was confirmed by the study carried



BALTIC SEA
1
Grudziadz
Chelmno
Solec Kuj.
Ciechocinek
Włocławek
a.s.l.
27.7
22.0
30.0
37.5
46.0
57.3
800
750
700
km
2
3
4
5
6
7
8
9
10
11
Grudziadz
Chełmno
Toruń
Silno
Ciechocinek
Fordon
Solec Kuj.
Włocławek
DRWĘCA R.
MIEN R.
10 km

out by Drozdowski an Berglund (1976) on the area of the Lower Vistula valley below the Fordon locality. Its age was established by dating of sediments of the flood plain with the use of ^{14}C method in the first case for 4940 ± 65 BP and in the second – for 6969 ± 75 BP. Such considerable range of age of the superficial part of the flood plain at least from the Atlantic to the contemporary period, occurred, according to the authors mentioned, in consequence of meandering of the river due to maritime transgressions. According to Kozarski and Rotnicki (1978) also the Prosna river since the Boreal period was of the character of meandering river with the tendency to a continuous lowering of the river channel in the course of time. From late glacial to Boreal conditions typical of braided river predominated there. Such development tendency of lowland rivers was observed also by Starkel (1977) basing on opinion of many authors. Also Falkowski (1967) described the type of meandering Vistula river in its middle sector since the Holocene till the 17th century. This author is also of the opinion that in the Boreal period the maximum incision of the meandering river could reach the depth of about 15 m below the flood plain surface. This value could be probably regarded as the maximum one also in the Vistula sector under study, as the 13-meter deep incision (at a medium water level) was formed in the course of measurements. Therefore, older fluvial and fluvioglacial formations underwent 'mixing'.

A meandering river of almost stabilized debris transport conditions changed its channel position. The meander development possibilities on the area under study were considerably restrained by higher terrace horizons and the moraine upland adjoining the flood plain (Fig. 1). Therefore, in the Holocene period till the 17th century (Falkowski 1967) the Vistula sector under study would be mainly of the limited meandering type. Since the 17th century, according to Falkowski (1967) distinct changes have occurred in the fluviodynamical processes of the Middle Vistula sector. The author is of the opinion that the Vistula river underwent transformation from the meandering into braided river type under the effect of the economic activity of man, manifesting itself, first of all, in the area deforestation. Since the transformation process comprised the whole Vistula basin, the river sector under study should be transformed as well into the braided type. Braided rivers are characterized by an overload of the transported debris, wide water level fluctuations (e.g. in Toruń levels by 7 m higher as compared with present medium levels were recorded) and considerable water table gradients. Then a number of bars, mainly mid-channel ones, separated by numerous lateral arms were formed in the channel (Fig. 2). The formation of bars depended on local hydraulic conditions of the channel. It has been confirmed, among other things, by cartographic materials from the 19th century plotted prior to the channel regulation and quoted in the works of Babiński (1981, 1982), Koc (1972, 1975), Kopczyński (1982), Tomczak (1971). In braided rivers unfavourable conditions existed for the formation of stable forms of the type of islands or fixed side bars due to a considerable fluctuation of water levels and local water table gradients. Nevertheless, under such conditions islands could be formed by way of cutting off a part of the flood plain during

Fig. 1. Situation and morphological map of the Vistula valley in the Wloclawek-Grudziądz sector

1 – investigation area, 2, 3 – longitudinal profiles of the Lower Vistula cascade according to the variants II and I (after Biegała 1980), 4 – moraine upland, 5 – eroded flood plains, 6 – higher terrace horizons (4–6 after Drozdowski 1974, Tomczak 1971 and Wisniewski 1976, simplified), 7 – flood and above-flood plain protected by flood control dykes, 8 – flooded areas during high water levels, 9 – existing and planned dams, 10 – flood control dykes, 11 – sectors comprised with a detailed analysis

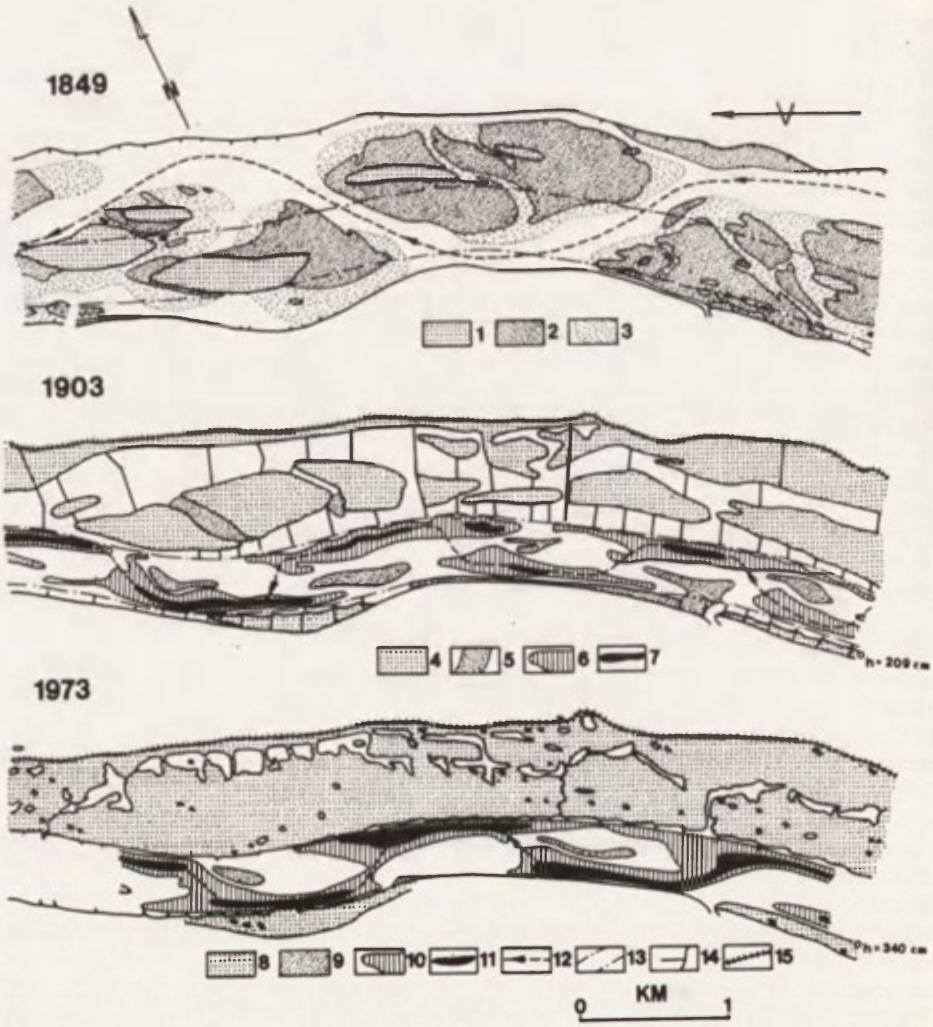


Fig. 2. Situation and morphological maps of the Vistula channel in the vicinity of Solec Kujawski for 1849, 1903 and 1973

1 – islands, 2 – emerged bar fragments, 3 – submerged bar fragments, 4 – islands and fixed side bars, 5 – emerged bars, 6 – depth of over 1.95 m, 7 – depth of over 5 m, 8 – newly formed flood plain, 9 – diagonal bars – depth to 1 m, 10 – depth of over 3 m, 11 – depth of over 5 m, 12 – current line, 13 – current regulation zone, 14 – river groynes, 15 – flood control dykes

high water levels or by means of fixing side bars, which, however, were quite few under these conditions.

Numerous sand bars and considerable variability of the channel made difficult the navigation on the Vistula. These conditions became still more difficult with the growth of the number and tonnage of river vessels. Therefore, in such a situation it became necessary to carry out regulation works.

EFFECT OF THE CHANNEL REGULATION ON THE CHANNEL PROCESSES IN THE VISTULA

The general regulation plan presented in 1830 by eng. Sewerin, assumed that the Lower Vistula sector should have the meandering course and the channel width should be of 377 m. This purpose could be reached by the construction of river groynes, several ten or several hundred meter in length (maximum 630 m). Moreover, the flood control dykes, considerably restraining the channel processes, should be built. This plan, however, was realized only partly due to a weak interest on the part of governments of the invader state. A certain enlivening of works after the great flood of 1855 was recorded. The highest intensity of regulation works took place in the period 1880–1892, till the outbreak of the World War I, particularly in the Prussian part of Poland, from the Tązyna river mouth downwards the Vistula. However, the regulation results were not satisfactory for the navigation. The water way at low water levels was confined to the width of 20–30 m and the depth of 0.7–0.8 m. It was maintained then that often better navigation conditions existed in the upper sector of the Tązyna mouth than in the lower, regulated sector (Koc 1975). At that time the opinion was widespread that such state could be caused by an excessive straightening of the current line and by too great channel width leading to the formation of bars and fixed sand banks. Later on a slight correction of the channel width, from 377 to 375 m, and in the sector from the Silno locality to the Drwęca river mouth – to 300 m, took place. However, it appeared as early as in the course of realization that this correction did not contribute to an improvement of navigation conditions either.

The realization of the Vistula regulation design resulted to greater or lesser extent in changes of the channel, depending on the intensity of regulation works. Already in the course of initial works on construction of river groynes, many islands or flood plain fragments were destroyed or deepened in the newly traced water way (Fig. 2). Moreover, in consequence of partition by groynes of lateral arms of the channel, integration and reinforcement of many islands and bars took place. In such a way a new hydrodynamical system of the river began to form, manifesting itself most distinctly in the linear erosion forms caused by the concentrated and accelerated water flow in the current zone defined by the groynes. In this connection the newly released kinetic energy of the river began to erode and then to carry the sandy material from the channel bottom.

The planimetric measurements carried out basing on bathymetric plans for 1903, 1944 and 1973, proved lowering of the channel, which was most intensive in the initial phase of the regulation. Thus, the Vistula channel depth measured from the mean many-year water levels for the sector of 5 km in length near the Solec Kujawski locality, amounted in 1903 to 2.02 m and in 1944 to 2.89 m, whereas in the following 30-year period it was lowered by 0.17 m only (Fig. 3). So it can be presumed that the linear erosion process would be checked at present upon ceasing intensive regulation works.

Sediments eroded from the channel bottom were then transported in the form of dragged debris either downwards the river or along the direction of zones between groynes, where the debris accumulation took place. It follows from the schematic channel cross-section assumed as a mean for the 5 km long sector (Fig. 3) that in the period 1903–1973 the channel bottom erosion resulted in accumulation of 2.39 million m^3 (478 m^2 × 5000 m) of the eroded material, of which 0.48 million m^3 (15.9%) were accumulated in the zone between groynes and the remaining 84.1% were transported downwards the river or accumulated outside the

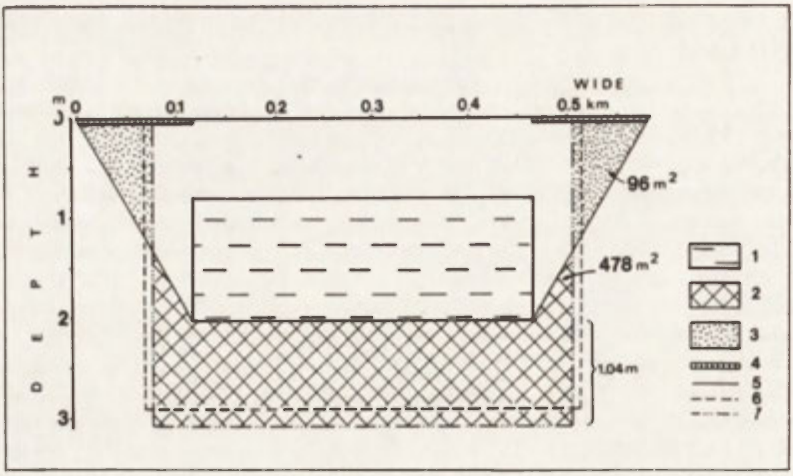


Fig. 3. Schematic cross-section of the Vistula channel in the vicinity of Solec Kujawski
1 – planimetred cross-section of the Vistula channel for 1903. 2 – eroded bottom material in the period 1903–1973. 3 – bottom material accumulated in the zone between groynes in the period 1903–1973. 4 – river groynes. 5–7 schematic cross-sections of the channel for 1903. 1944 and 1973, respectively

channel, on the flood plain. Filling up the zones between groynes with the material of sandy sediments resulted in a narrowing of the channel by 162 m. on the average (Fig. 3).

In consequence of filling up the zones between groynes, the area of which underwent a continuous rise due to the debris accumulation and lowering of the current zone, a new flood plain was formed. According to calculations of Koc (1975), in the sector from the Płock syncline to the Drwęca mouth, the water area of the Vistula narrowed more than twofold in the period 1876–1940, i.e. to about 20% of the whole area of the valley. In such a way about 370 hectares of land were gained. This new flood plain does not constitute any uniform area. There are areas, the heigth of which corresponds with the former flood plain, with which they join making thus difficult their distinguishing. On the other hand, there are sectors situated lower than the former flood plain, with numerous little pools of the old (abandoned) river channel (Fig. 2). According to Koc (1975), a considerable dynamical variability of the river, is responsible for the differentiation of the flood plain area; he wrote: "... where the river accumulation was weaker, the new flood plain was preserved in fragments. On the other hand, where the areas of old river arms were quickly filled up with sediments, to 4 m in thickness, under the effect of more numerous groynes, they were levelled with the surface of former islands of flood plain fragments". At present the process of formation of new flood plains ceased or is continued to an inconsiderable extent due to checking of the linear erosion.

Narrowing of the channel of medium or low water levels and its meandering resulted also in changes in the arrangement of channel mezoforms. Before the start of the regulation works mid-channel bars, distributed disorderly, constituted predominant forms. At present the leading forms are diagonal bars with pools, typical for rivers with a negative or stabilized balance of debris.

Diagonal bars corresponding with the channel size are formed in the period of high water levels. Along with lowering of the water table cutting of these forms and their dissection into smaller elements, the agglomerations of which are identified in the course of time with mid-channel bars, take place. The formation of diagonal bars is accompanied by negative forms – pools. The spatial differentiation and size of these both mezoforms depend on water flow, debris transport and channel morphometry. At the same time they constitute an index of the channel development under the effect of regulation works. In case of the channel regulation unequal in space and time, a different arrangement of pools and diagonal bars can be observed.

Four, and not two (Fig. 4 A and B) after Apollov (1963), arrangements of pools and bars (Fig. 4 – Babiński 1981) were distinguished on the area under study. With them navigation conditions on the Vistula are closely connected. It concerns particularly the channel bottom state in the low water periods, when difficult flow conditions occur between particular pools. Taking this fact into consideration, the navigation difficulty degree on the Vistula would increase from the A to the C situation (Fig. 4). The D situation is most inconvenient (undesirable) in the period of low water levels due to a considerable width and tortuosity of the channel. The channel bottom in the above period is, true, similar to that of the C situation, nevertheless, quick changes in the current course occur due to an intensive process of the bend bar transformation, occurring in the period of high water levels. The above state undergoes radical changes during flood, when this sector is transformed into a fragment of the meandering river. Then from pools of the A arrangement a deep trough along the concave bank and a bend bar along the convex bank are formed.

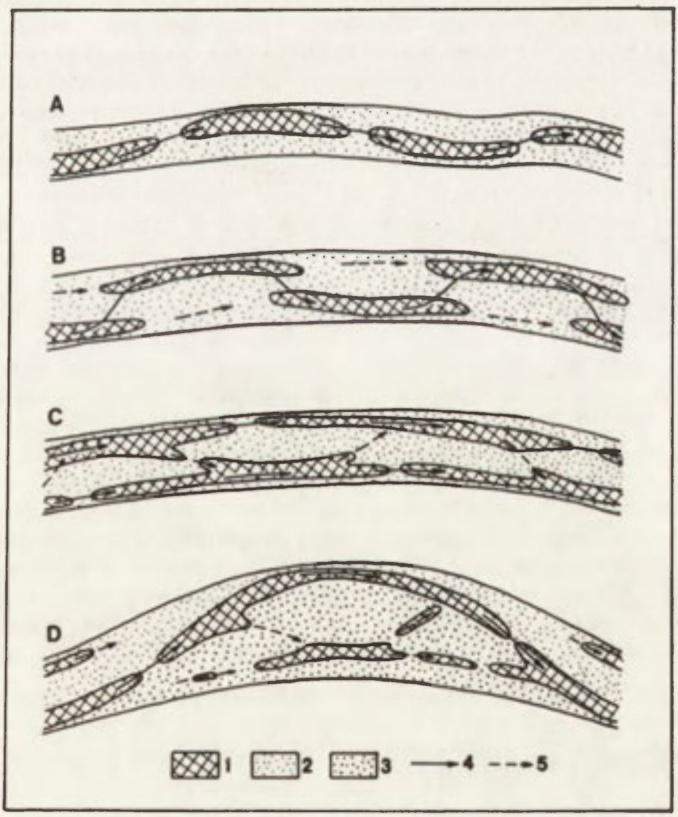


Fig. 4. Arrangement types of the Vistula channel mezoforms

1 – pools, 2 – bars, mainly diagonal ones, 3 – bend bar, 4 – main river currents, 5 – currents of a reduced dynamics

Most often the B and C arrangements of pools in the Vistula sector under study can be found (Fig. 4). These two situations differ, first of all, by hydrodynamical conditions of the river. In case of the B situation defined by Jarocki (1957) as the channel bottom arrangement of overlapping pools, the current course is tortuous due to its passage through depressions in diagonal bars. Beside the main current there are also less dynamical currents along the channel banks or along the line defined by heads of river groynes. Other hydrodynamical conditions occur in the C situation, where two mutually parallel bank currents are main ones, while the interpool currents are less dynamical and not always occur (Fig. 4). The case of C mezoform arrangement is particularly representative for straight channel sectors, especially in the period of very low water levels. Still an intermediary arrangement of the mezoforms, not shown in Fig. 4, occurs. The current zone in these sections runs one time according to the B situation and some other time according to the C situation of the channel (Fig. 4).

The A arrangement of mezoforms (Fig. 4), defined by Jarocki (1957) as that of shifted pools, is rarely encountered in the Lower Vistula channel. It follows mainly from the fact the mezoform arrangement type is characteristic of rivers with a negative debris balance and with a narrow zone of the current. These conditions are almost totally fulfilled in the sector of an accelerated erosion below the Włocławek dam (Babiński 1981, 1982).

Differentiation of the arrangement of channel mezoforms (Fig. 4) makes the morphometry determination very difficult. Only their approximate characteristics, mainly for B and C types and the medium and low water levels, would be possible. The analysis of bathymetric maps of the channel and the geodetical measurements of bars (Fig. 1) have proved that the length of diagonal bars amounted to 1–2 km and their width – to 0.2–0.4 km, whereas for pools these parameters are accordingly 1–2 km (mean 1.5 km) and 0.1–0.3 km. The height of the area of diagonal bars amounts to 0–3 m for the medium water level and the depth of pools – to 4–13 m below the medium water level. The distance between the current passages from one bank to another is, on the average, about 1 km. It has been found by means of the method of comparison of the channel bottom situations and by the geodetical measurements that the translocation rate of mezoforms is 0.2–0.6 km a year (0.4 km, on the average), nevertheless it can reach 1 km a year.

The above channel situations, except for the A situation, showed that the regulation assumptions limiting the width of channel of medium water levels to 375 m did not prove to be correct. The channel of the above dimensions would be too wide for formation of the A arrangement, of a desirable current passage between pools. Also, too small curves of the current zone in some river sections made that in the period of low water levels very unfavourable navigation conditions corresponding with the C situation would be formed in the channel bottom (Fig. 4). Therefore, abandonment of the introduction of regulation corrections and still more postponement of investments connected with the maintenance of existing hydrotechnical structures (resulting, among other things, in checking supplementation works on repair of the destroyed fragments of structures) can result in returning the channel to its previous wild state. This problem could be solved to a full extent by building of the Lower Vistula cascade.

CHANGES OF THE VISTULA CHANNEL BELOW THE WŁOCŁAWEK DAM

The Włocławek dam is the first and up to now the sole structure of that type in the designed Lower Vistula cascade (Fig. 1). The partition of the Vistula channel by the Włocławek dam, which occurred in October 1968, led to changes in the development of channel processes. They manifested themselves particularly in a growth of the linear erosion intensity and in intensified lateral erosion of islands and banks of the channel. This problem is presented in the works of Babinski (1982), Babinski and Glazik (1980), Bittner (1976), Machalewski *et al.* (1974), Szupryczyński (1976, 1981) and of other authors.

The main cause of the lateral erosion intensification was an artificial shifting of the current line from right to left bank. In consequence of this change, the channel regulated and stabilized in the previous period, should adapt itself by means of shifting the meandering zone of the current to new hydrodynamical conditions of the river. This shifting resulted in changes in the morphodynamical arrangement of the channel bottom in the relation diagonal bars – pools as well as in a growth of the rate of recession of banks of the islands and the channel. Adaptation of the channel bottom to new hydrodynamical conditions resulted also in a destruction of some groynes and lateral walls. In this connection the necessity of certain changes arose in the situation of hydrotechnical structures, so as to permit an excessive destruction of islands and channel banks. The process of intensive lateral erosion resulting from the artificial shifting of the current line was distincly marked in the sector of about 11 km in length. Below this sector, a stabilization of the channel was observed which resulted from the adaptation to

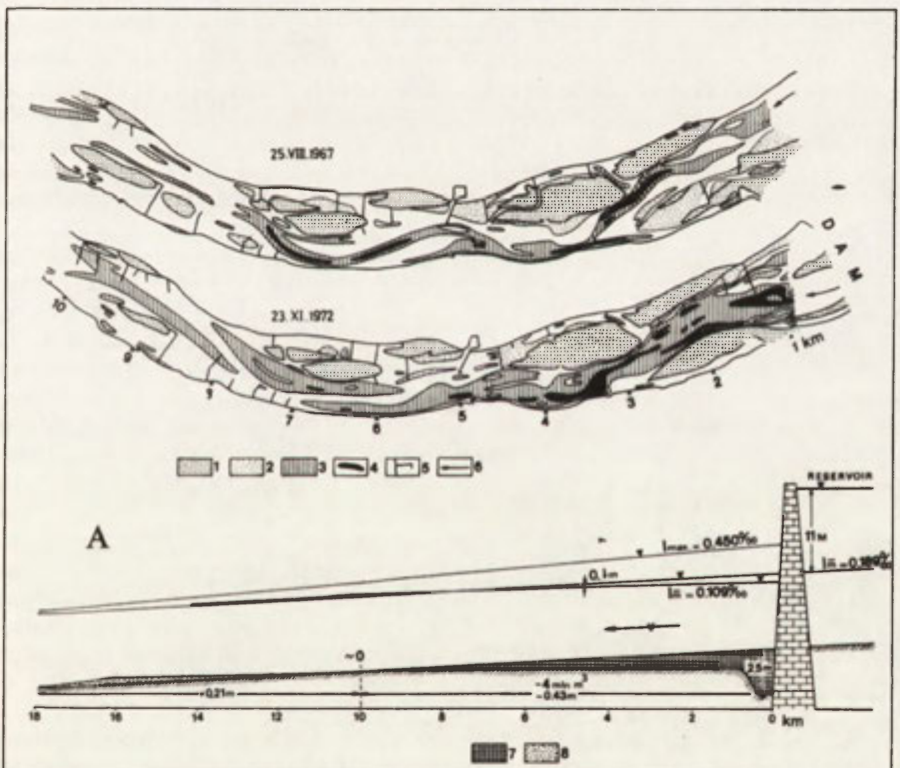


Fig. 5. Morphological sketches and changes (A) of the Vistula channel bottom below the Włocławek dam

1 islands and fixed side bars. 2 lateral bars. 3 depth of 2 4 m. 4 depth of over 4 m. 5 river groynes. 6 main direction of river currents. 7 linear erosion zone. 8 accumulation zone.
I water table gradient

new hydrodynamical conditions of the channel in relation to those before building the dam.

The greatest channel changes resulting from partition of the Vistula by the dam, occurred in the form of intensified linear erosion (Fig. 5). A direct cause of the linear erosion intensification was and continues to be the high and instantaneous river energy increments connected with daily water level fluctuations. These fluctuations can reach 3 m and are still perceptible at the distance of 200 km below the dam (Machalewski *et al.* 1974). Rapid water discharges from the reservoir through weirs and turbines within the 10-km sector result in a decrease of the water table gradient, which can reach instantaneously the 2.4-fold higher values (up to 0.45‰) as compared with the mean many-year value before the impoundment period. This fact proves a growth of the kinetic (velocity) energy and the potential (mass) energy. Thus, a powerful energy is formed below the dam, which is used by waters for grooving and deepening of the channel.

The linear erosion process occurring below the dam was the most intensive in an initial period of action of the reservoir and in its closest vicinity, translocating downwards the river in the form of the "erosion wave". It has been found that in the 4-year period of action of the Włocławek reservoir to the 10th kilometer below the dam over 15 million m^3 of material were eroded from the channel bottom, over 11 million m^3 of which were accumulated. It means that in that sector the 4 million m^3 of material were eroded, what resulted in a lowering of the channel bottom by almost 0.43 m (Fig. 5). The greatest lowering of the channel bottom occurred in the close vicinity of the dam. At that distance of 670 m from the dam the channel bottom was lowered by about 2.5 m in relation to the situation before the impoundment period. From this place the linear erosion process decreased asymptotically downwards the river and at the distance of 10 km from the dam it was equal to zero (Fig. 5). In connection with the above unequal course of the channel bottom deepening process the channel gradient decreased in the above 4-year period by 0.08‰.

The sand and gravel material eroded from the channel bottom below the dam was deposited in its main part at the distance of about 10 km below the dam. During 4 years since the moment of the channel partition by the dam the channel bottom in the above sector of 8 km in length rose by more than 0.2 m (Fig. 5). Moreover, a part of the eroded material was deposited in the bank zone between groynes. This fact together with the constant tendency to lowering of the channel bottom resulted (similarly as in case of execution of regulation works, but at higher intensity of the process) in rising and fixing side bars. In such a way a new flood plain was formed in the sector of 10 km in length, with the surface by 0.5–1.0 m lower than that of the former flood plain.

The Vistula channel partition by the dam resulted also in changes of the mechanical composition of sand and gravel deposits forming the channel bottom. A direct cause of the changes was and continues to be a selective outwash of the material downwards the river due to high river energy increments. An indirect effect on the channel bottom granulation changes exerts the dam through progressing linear erosion, denuding older formations, usually of coarser granulation and of less rounded grains. In consequence, the coarsest material was retained at the dam (e.g. in 1973 at the distance of 0.3 km below the dam the mean weighed diameter of sand grains amounted to 5.088 mm for 3 samples) and farther downwards the river gradually finer material was deposited (at the 9th kilometer the mean for 6 samples was only 0.613 mm in size). The diameter of sand grains calculated as a median $d_{50\%}$ at the distance of 4.5 km below the dam, increased from 0.39 mm to 0.51 mm (Babiński 1981). The character of these formations and the process of the selective outwash and rounding of grains during their migration downwards the channel bottom explain the 6%-tual growth of the rounding indices in the sector of 10 km below the dam.

As follows from investigations below the Włocławek dam, an erosion sector in the bar-free channel and an accumulation sector typical of braided rivers were formed. Similar processes can develop also after construction of other dams of the Vistula cascade. In the sector analyzed the further three dams (Ciechocinek, Solec Kujawski, Chełmno) and according to the variant II an additional fourth dam (Grudziądz), if possible, are planned (Fig. 1). In either variant an underimpoundment due to a lack of the lower reach support could occur. In the variant I it would take place below the Solec Kujawski dam in the sector of 17.5 km and below the Grudziądz dam – of 10.5 km in length, in the variant II – in both cases in the sector of 5 km in length (Biegała 1980). These underimpoundments would undoubtedly lead to the development of processes like those, which occurred below the Włocławek dam, but of a less intensity. A weakening of the above actions would be possible, among other things, owing to the possibility of the river outflow regulation. Therefore, regulation and dredging works should be carried out to ensure appropriate conditions for the navigation.

SUMMARY

The Vistula channel underwent several transformations in its development. Yet, the most rapid changes occurred since the middle of the 19th century under the human interference effect. The regulation works narrowing the channel and straightening its line resulted in changes of the channel processes transforming the river from the braided type into the limited meandering type. The channel of medium water levels was deepened with its simultaneous narrowing at the cost of the newly formed flood plain. A further interference in the form of the channel partition by the dam of Włocławek led on the one hand to an intensification of the linear erosion in the by-reservoir zone, and to the formation of an accumulation zone of the braided river type between the erosion section on the other. A strong linear erosion process, similarly as in case of regulation, led to the formation of a new flood plain. Furthermore, an artificial shifting of the current line in the dam zone from the right to the left bank released the process of lateral erosion of islands and channel banks, tending to adaptation of the previously regulated channel to new hydrodynamical conditions. In view of an unfavourable effect of the Włocławek dam on navigation conditions and on agricultural lands below the dam, it would be purposeful to accelerate construction of the Ciechocinek and Solec Kujawski dams. Building of the cascade would result, depending on the intensity of works and the cascade direction (upwards or downwards the river) in the Vistula channel changes steadily decreasing with the structure, improving considerably the navigation at simultaneously controlled water flow.

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INFLUENCE OF DAM RESERVOIRS ON CHANGES OF WATER CONDITIONS IN THE LOWER VISTULA VALLEY

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1. INTRODUCTION

Building of river cascade results in significant changes in the geographic environment. Hydrological conditions and the course of river channel processes and on by-reservoir areas also water, microclimatic, pedologic and vegetation conditions undergo transformation. The degree of human interference into environment depends, first of all, on technical parameters of cascades, local geomorphological, hydrological and pedological conditions and on applied methods of counteracting negative consequences of the river impoundment.

The interest in the river cascade influence on environment arose in Poland only in 1950s. Cascades constructed, first of all, in mountain and submontane regions and few objects of such type on lowland rivers, were comprised with the respective investigations. One of these objects is the Włocławek dam on the Vistula given over to operation in 1970, which constitutes the first link of the planned Lower Vistula cascade.

Two variants of the hydrotechnical structure on the Lower Vistula are discussed in the paper. Results of many-year investigations on the Włocławek dam influence on environment, and particularly on hydrological conditions of the river and of adjoining areas, are presented. An attempt to determine changes in water conditions of the Lower Vistula valley after completion of building of the cascade was undertaken.

2. LOWER VISTULA CASCADE

The national hydroenergy resources amount to 12 milliard KWh, of which only 14% (1.7 milliard KWh) are utilized. As many as 53% of home resources fall for the Vistula. In the sector of the Vistula from Warsaw to the Baltic Sea, called conventionally the Lower Vistula, as many as 33% of water resources of this country and about 63% of the hydroenergy potential of the Vistula are concentrated. It is to mention here that the Włocławek power plant produces, on the average, 640 million KWh a year, i.e. about 40% of the total production of power plants of the country (Sobczak 1981).

The concept of canalization of the Vistula and utilization of its energy potential arose in 1930s. Two variants of the hydrotechnical structure of the Lower Vistula were assumed. They are presented in a map (Fig. 1) and in longitudinal profiles of the river (Fig. 2).

In the Vistula valley sector from Warsaw to Włocławek dam, building of three

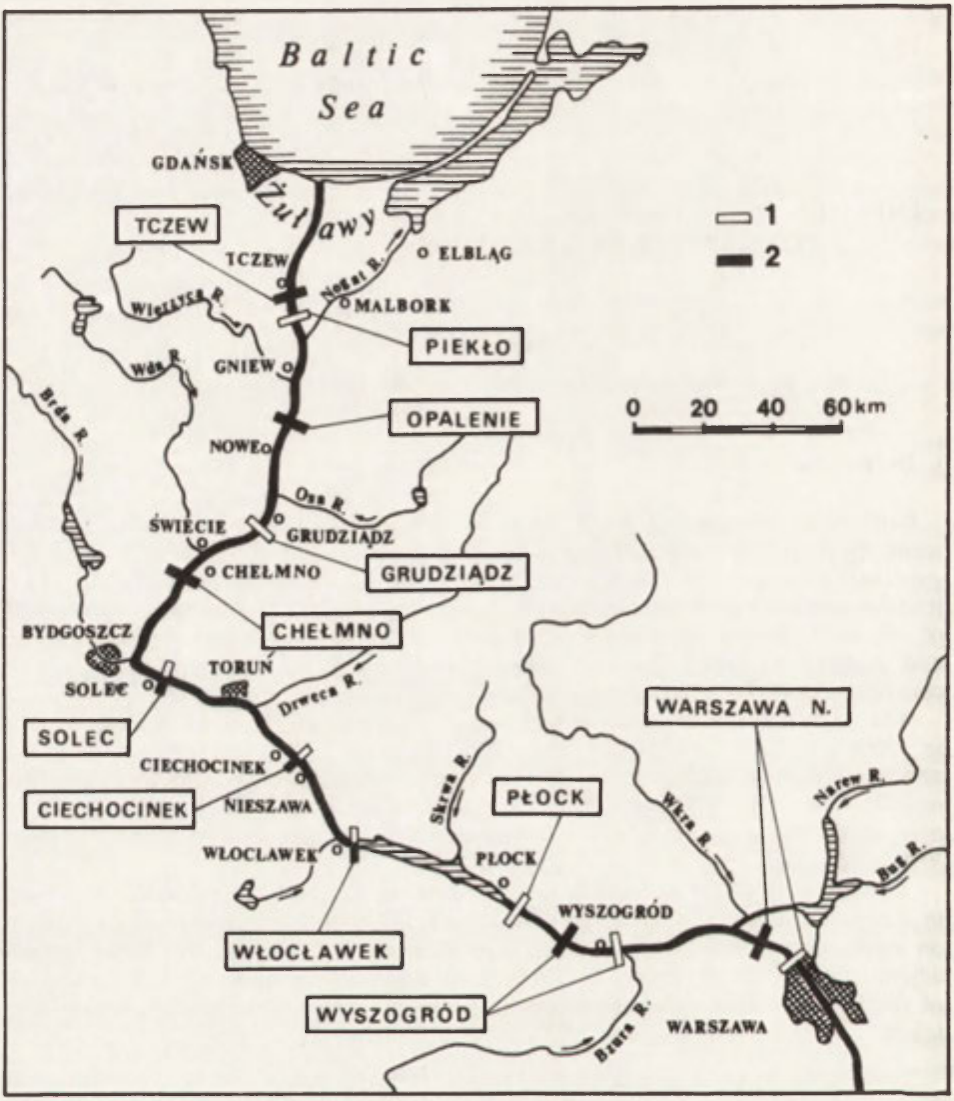

Fig. 1. Layout of dams in the Lower Vistula cascade (after Biegała 1980)
1 – variant I, 2 – variant II

further dams is planned in the variant I and of four dams in the variant II. In the latter variant, greater difficulties would arise in protection of lower situated left-bank areas of the valley against negative consequences of the river impoundment. It follows from the parameters of the Wyszogród dam, which would impound the Vistula by more than 11 m in relation to its medium water level (about 7.5 m above the maximum level). In the Bzura mouth and near the Wyszogród town the impoundment level would exceed by about 4 m the maximum water level in the Vistula. It would make impossible leading the Bzura waters by gravity to the reservoir, while the underimpounded sector of the river below the dam would undergo intensive linear erosion processes. In the variant I the Vistula impoundment in the Wyszogród dam axis would amount less than 8 m in relation to the medium

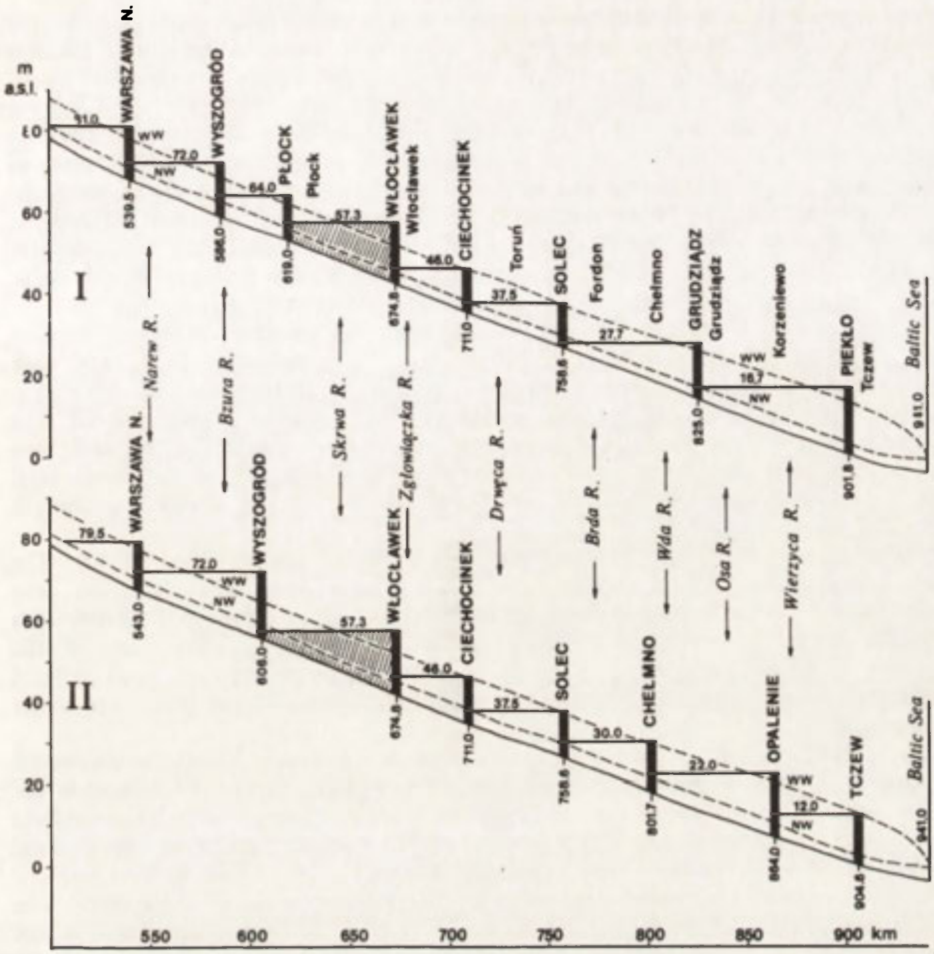

Fig. 2. Longitudinal profiles of the Lower Vistula cascade (variants I and II) against the background of the extreme water levels in the river

WW – the highest water level recorded, NW – the lowest water level recorded

water level (about 3.5 m below the maximum level). The location of the dam would not lead to any hydrographic changes near the Bzura mouth, it would facilitate drainage of the left-bank areas of the Vistula (Kampinos Primaeval Forest) and ensure a better lower reach support by the Plock dam located below.

Below the Włocławek dam building, first of all, the Ciechocinek and the Solec Kujawski dams are planned. Location of the dams and impoundment levels of the reservoirs are identical in both variants of the cascade. The river impoundment would not hinder the outflow by gravity of Zgłowiączka and Drwęca river waters. A considerable rise of the Vistula water level would occur near ancient towns of Nieszawa and Toruń (by 5.5 m and 2 m, respectively), what could endanger the lower situated old-town buildings.

In the sector from Solec Kujawski to the Baltic Sea a building of two dams is planned in the variant I and of three dams in the variant II. A remarkable fault of the variant I are the underimpounded 20 km long sectors of the river below the Solec and Grudziądz dams, which after construction of the dams would require dredging and regulation. The Piekło dam located disadvantageously in the vicinity of partly depressive Żuławy region areas (marshlands of the Vistula estuary) would impound the river by about 12 m. It is the maximum impoundment height in the cascade. The Grudziądz dam would raise the water level near the Chełmno town by 5.3 m and near the Wda mouth – by 6.0 m. It would result in considerable difficulties in leading of the Wda waters by gravity, whereas the town of Świecie at the Wda mouth would lie partly below the water level in the reservoir. Also leading out the Wierzyca waters in the vicinity of the town of Gniew, where the Piekło dam would impound the Vistula by more than 6 m, requires solution. On the other hand, no significant hydrographic changes would occur at the mouth of the Brda (Fordon) and the Osa (Grudziądz) rivers.

The variant II ensures, in the Vistula sector in question, a better support of the dams by reservoirs located below. More advantageously the Tczew dam is located, the impoundment of which is by 4 m lower than that of the Piekło dam. Near the Wda and Wierzyca mouths no hydrographic changes would take place, whereas near the Brda mouth the water level would rise by less than 2 m. The fault of the variant II consists in a high increase of the water level in the Vistula near the town of Grudziądz (by 4.7 m) and at the Osa mouth (by 5.7 m).

The choice of the cascade building variant is not accomplished as yet. The location of dams and the impoundment levels are not fixed definitely, either, and can undergo corrections in consequence of further studies. According to assumptions of the design, the width of reservoirs would be limited in wider parts of the valley by lateral dams running partly along the lines of existing flood control dykes. It would be necessary for protection of agricultural lands and areas under buildings.

The total capacity of power plants installed in the Lower Vistula sector would amount to 1300 MW, the annual electric energy production – to about 4 milliard KWh. The cascade would transform the river into an important water thoroughfare, accessible for 1500-ton barges. It would supply the industrial enterprises with water, what would ensure a more reasonable utilization of underground water resources. It would create also good conditions for the intensification of agriculture. The planned building of irrigation canals would reduce the water deficiency in the regions adjoining the medium sector of the cascade, lying in the zone of the lowest atmospheric precipitations in Poland.

It is to stress that the Włocławek dam is operated already for 12 years as an independent object. The operation of the dam under conditions of a disorder in the river channel above the reservoir and below the dam, affects negatively the environment and results in a number of unfavourable economic consequences. It limits the potential possibilities of the dam operation for energy, flood control and navigation purposes in the river sector below the dam. Such a situation follows from economic difficulties of this country and is unique in the world. In Europe (USSR, FRG, France) and in the USA all cascades on large rivers (Volga, Dnieper, Rhine, Rhone, Ohio, Tennessee, etc.) are built according to the band system (one cascade after another), or even several cascades simultaneously.

3. INFLUENCE OF THE WŁOCŁAWEK DAM ON HYDROLOGICAL CONDITIONS OF THE VISTULA

3.1. HYDROLOGY OF THE RESERVOIR

In the 35-year period (1919–1954) mean flow in the Vistula at Włocławek amounted to 933 m^3/s, the ratio between the maximum (8305 m^3/s) and the minimum flow (141 m^3/s) was 1 :59 at the amplitude of water levels of 651 cm. In the dam cross-section the river was impounded by 10.7 m and near Płock – by 2.5 km (Fig. 3). The impoundment resulted in the formation of a reservoir of 70.4 m^2 in size, mean depth of 5.5 m, length of 58 km and the maximum width of 2.4 km.

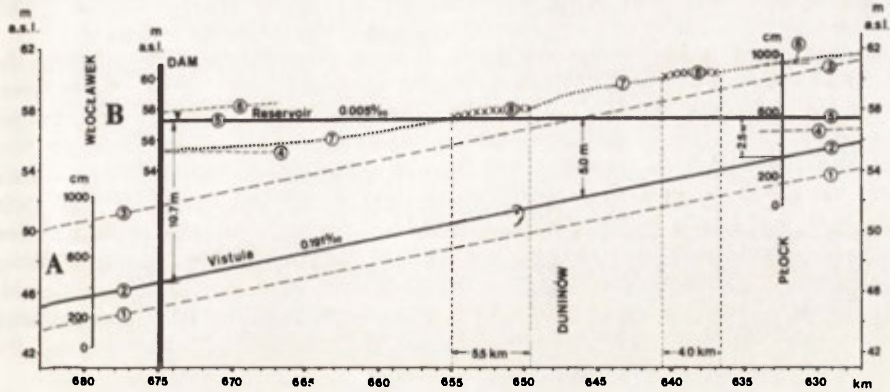

Fig. 3. Longitudinal profile of the Włocławek reservoir and characteristic water levels before and after the Vistula impoundment

A. Water levels in the river before the impoundment: 1 – the lowest, 2 – medium, 3 – the highest; B. Water levels in the reservoir: 4 – the lowest, 5 – medium (normal impoundment level), 6 – the highest, 7 – water table curve on January 10, 1982 (during the disastrous ice-jam flood), 8 – ice jams

The total capacity of the reservoir (0.387 km^3) constitutes 1.3% of the mean annual run-off in the Vistula basin in the Włocławek cross-section (29.4 km^3). The water exchange in the reservoir occurs, on the average, every 5 days and at high water flow of the order of 4500 m^3/s – it occurs within 24 hours or less (Glazik 1978).

The useful capacity of the reservoir (0.053 km^3) at the impoundment of 0.8 m constitutes 13.6% of the total capacity and less than 0.2% of the average annual run-off in the basin. The prevalence of the inflow to the reservoir over the outflow of the order of 1000 m^3/s results in filling up the useful layer within less than 20 hours. The retentional capacity of the reservoir within extreme limits of water levels in the period 1971–1982, the amplitude of which in the lower part of the reservoir amounted to 2.5 m, is by about 2.5 times higher. It does not change the flowing character of the reservoir and the data presented above bear evidence of very limited possibilities of the flood water retention.

Hydrological conditions of the reservoir depend, first of all, on the magnitude of inflow of river waters and on the power plant work. In the periods of a small inflow of waters the course and amplitude of water levels in individual parts of the reservoir are similar and depend on the power plant work. In these periods the lowest values of the water table gradient ($0.0014\,^0/_{00}$) in the reservoir and of the flow velocity are observed. During high water levels the water table in the lower part of the reservoir near the dam is relatively levelled due to high water discharges to the lower reach. Along with the increasing distance from the dam upwards the reservoir there increases the river influence on water levels of the reservoir, what manifests itself in a widening of amplitudes. Their magnitude depends on the height of flood waves. During the wave culmination process the highest values reach mean water table gradients ($0.06\,^0/_{00}$) and flow velocities (Glazik 1976).

Near the dam the amplitude of water levels in the reservoir amounted to 2.5 m in the period 1971–1982 and annual amplitudes did not exceede 5 m. The course of water levels as compared with the period before the impoundment underwent levelling, whereas the frequency of water level changes increased under the effect of the power plant work. In the upper part of the reservoir (Płock) annual amplitudes reached 2.5–3.0 m and at extreme water level fluctuations – 4.5 m.

A high flood threat occurs due to the tendency of forming ice jams in the reservoir. The ice jam formation probability is greater there than in the river before its impoundment (Baranicki 1982). The Włocławek reservoir, as a unique object of such type on the Lower Vistula, intercepts the ice and slush ice flow from the whole river sector above the dam. An obstacle in the flow way constitutes the longer duration of ice cover in the reservoir as well as the dam as such. Moreover, leading ice out of the reservoir is difficult after the ice-breaking action due to small water table gradients. In case of winds from the western sector the ice float is driven from the dam upwards the reservoir. At a considerable lowering of the impoundment level aiming at an increase of the hydraulic gradient, a threat of sedimentation of ice masses on the bottom, of narrowing of the cross-section, and even blocking the flow, can arise.

Favourable conditions for the formation of ice jams occur in the upper part of the reservoir. They include a rapid decrease of the flow velocity, small depths, great number of inundated islands, sharp bends and variable width. The formation of ice jams is favoured by an intensive debris sedimentation process (about 1.5 million m^3 a year), which resulted in a local rise of the bottom by 3.5 m (Branicki 1982).

In January 1982 in the reservoir below the town of Płock two ice jams were formed (Fig. 3). They were caused mainly by extraordinary hydrologico-meteorological conditions in the ice cover formation period. During high inflows to the reservoir (about 4000 m^3/s) caused by snowmelt, a rapid air temperature drop occurred (to −23 C). Great ice slush masses freezing under those conditions were drawn under the forming ice cover. About the scale of this phenomenon the volume of ice masses (mainly in the slush ice form) can bear evidence, which after completion of freezing processes constituted 37.1% of the reservoir capacity (Grześ and Banach 1982). It resulted in narrowing of the cross-section and in formation of ice jams at appropriate places. In the ice jam below Duninów (of 5.5 km in length) ice blocks and ice slush occupied almost 82% and in the ice jam above the locality mentioned (of 4 km in length) – 61% of the cross-section (Grześ and Banach 1982).

The water level impoundment in the reservoir caused by ice jams resulted in a disastrous flood. On January 1, 1982 the water level in the Vistula in Płock (948 cm) exceeded by 98 cm the water level recorded in 1844 (850 cm). Water flowing over the crown of embankments flooded the area of over 100 km^2 of agricultural lands. Many villages were flooded, more than ten thousand people were evacuated. A lowering of the normal impoundment level by 2 m resulted in the sedimentation of ice masses on the bottom and did not bring any improvement of the situation on flooded areas. It was the ice-breaking action, which appeared to be the most effective among the applied ice jam control methods.

3.2. HYDROLOGY OF THE RIVER BELOW THE DAM

Hydrological conditions of the river below the dam are affected to the highest degree by the magnitude and frequency of water discharges from the reservoir. They are connected with the peak and interference work of the power plant set in motion in hours of the highest energy demands. During high water levels

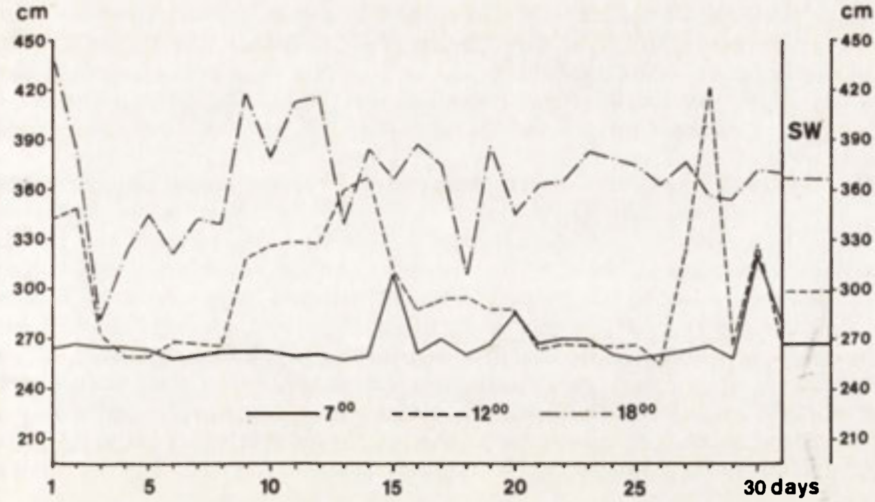

Fig. 4. Effect of work of the Włocławek dam power plant on water levels in the Vistula at 7^{00}, 12^{00} and 18^{00} h (the Włocławek water-gauge station – October 1970)

most part of waters flows through the weir in view of a low retentional capacity of the reservoir.

Unequal water discharges caused by the power plant work in the 24 hours time, result in frequent changes and wide amplitude of water levels in the river below the dam (Fig. 4). Daily water level fluctuations in the vicinity of the dam reach almost 3 m, decreasing by 0.4–0.6 m at the distance of 5 km from the dam and continuing to decrease with farther course of the river (Babiński and Glazik 1980). The power plant influence on water levels vanishes at the distance of about 200 km from the dam. In the Grudziądz region the daily water level amplitude in the river amounts still to 0.3 m (Machalewski *et al.* 1974). The navigation conditions below the dam worsened, particularly in the sector from the dam to the town of Toruń, due to a great and frequent variability of water levels, and thus of flows and river depths.

The dam influence on lowering of flood .waves in the river below the dam is insignificant in view of small retentional possibilities. That is illustrated by calculations carried out for the flood wave (June 7–20, 1962) of the volume of 4.63 km^3 and the mean flow of 4122 m^3/s. It follows from them that a full utilization of retentional possibilities of the reservoir the maximum flow in the Włocławek cross-section could be lowered from 7520 m^3 (water level of 812 cm) to 6290 m^3/s (water level of 748 cm). The wave reduction effect would thus amount to 64 cm (*Studium wykorzystania*... 1964).

It deserves to be mentioned that an insignificant smoothing of flood waves occurs at the cost of their elongation in time. This fact as well as high water level increments in the river caused by the power plant work result in a growth of the frequency and of almost 4-fold elongation of the flood plain inundation periods (Babiński and Glazik 1980). It makes the farming difficult on lower situated by-river areas. Thus, building of the dam worsened the flood situation in the Vistula valley below the dam.

During the discharge of waters from the reservoir we observe a rapid decrease of the water table gradient, flow velocity and energy of water masses. In consequence of the linear and lateral erosion, the bottom, banks and regulation structures of the channel undergo deformations. The problem of channel processes below the dam has been discussed in detail by Babiński (cf. his article in this volume).

A considerable 24-hour variability of water levels in the river and of flow velocities counteract the ice cover formation. In view of a flowing character of the reservoir, its influence on the transformation of thermal conditions of the river is probably little.

The presented river hydrology changes proved explicitly that building of the dam did not liquidate the flood threat in the Vistula valley below and above the dam, intensified the debris sedimentation process and increased the ice jam formation probability in the reservoir bowl as well as worsened the navigation conditions and intensified the course of channel processes below the dam. It seems that dredging works, both executed currently and planned, the regulation of long river sectors below and above the dam and a raise of the embankments (dykes) are of a casual character. A general improvement of the existing state can be reached only by building further dams, which would increase the possibility of the river flow regulation, enable the support of lower reaches of dams by lower situated reservoirs, reduce the debris transport to reservoirs and limit the floating of ice.

4. INFLUENCE OF THE WŁOCŁAWEK DAM ON WATER CONDITIONS ON ADJOINING AREAS

4.1. IMPOUNDMENT EFFECT ON GROUND WATERS

The reservoir adjoins the steep slopes of a moraine upland from the north and the catchment area borders run along the wide Vistula valley floor from the south. It is the most susceptible area to the impoundment effect. The valley is filled up by 40–50 m thick permeable Quaternary formations. Strongly disturbed Pliocenic and Miocenic sands occur in the substrate. The ground water table connected hydrologically with the reservoir maintains at the depth of 3 m or lower and in the valley part covered with dunes – at the depth of 4–8 m.

The Vistula impoundment effect on ground waters is not marked in the places where the roof of Pliocenic clays emerges over the reservoir surface. A direct impoundment effect on areas with permeable soils consisting in eveness of water levels in the reservoir and adjoining areas, comprised the zone of about 0.5 km in width.

The ground water table rose there by almost 2–3 m. In consequence, inundation or waterlogging of area depressions took place. The limit of an indirect reservoir effect manifesting itself in a permanent rise of ground waters running off the catchment area is determined by the hydroisohypse of 59 m a.s.l. Its value is by about 2 m higher than the reservoir impoundment level. In areas with a little gradient of the ground water table the indirect impoundment effect comprised the belt of 1.3 km in width, adjoining the reservoir.

In the depression at the lower part of the reservoir that were drainage works, which were responsible for the range and magnitude of changes of the ground water table (Fig. 5). A basic element of the drainage system is the Main Canal intercepting surface and ground waters from the hydrological catchment area as well as waters filtrating from the reservoir through the body and foundation of the lateral dam. An additional line of the drainage of filtrating waters constitute ditches running at the toe of the lateral dam. These waters are led by gravity or by means of the pumping station (Modzerowo) to the canal.

The Vistula impoundment resulted in a rise of the ground water table (by about 1.5 m) within the belt of about 0.4 km in width adjoining the reservoir.

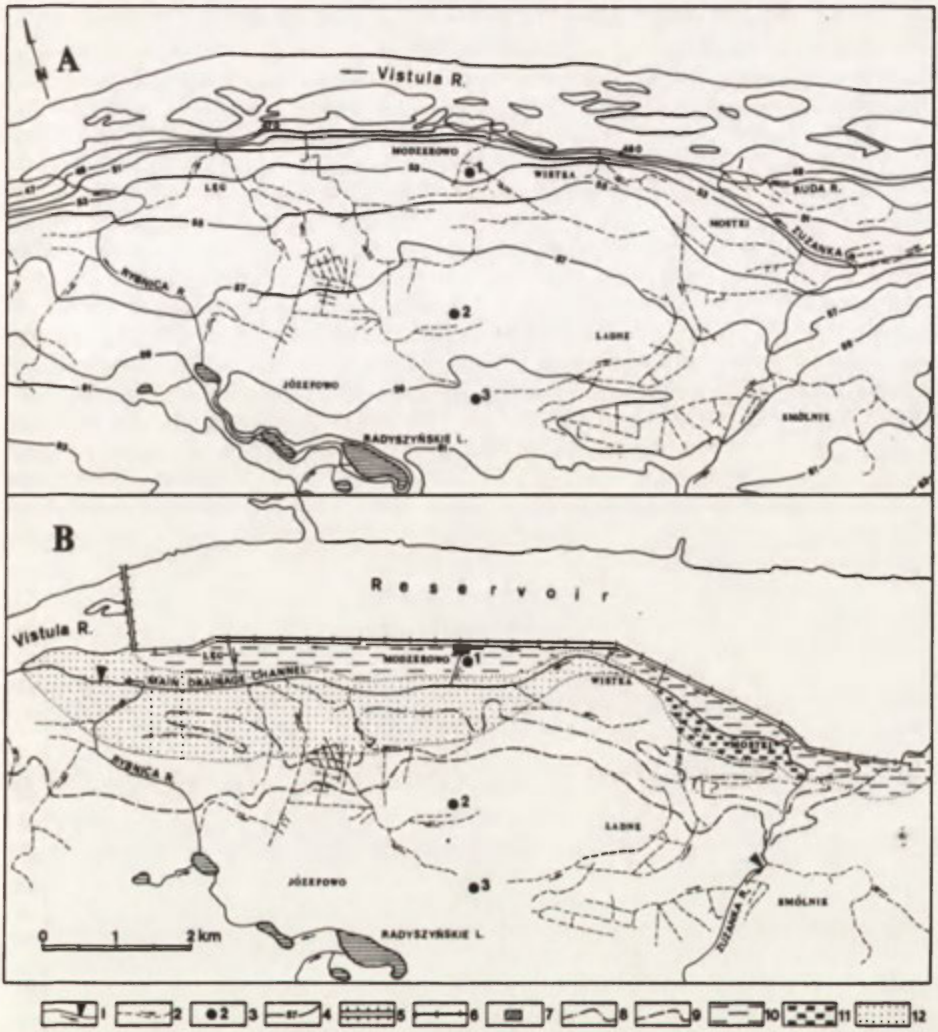

Fig. 5. Changes of surface drainage and of ground water levels in a depression area adjoining the Włocławek reservoir

A. State before the river impoundment and execution of drainage works (summer 1962); B. Changes after the impoundment (summer 1973); 1 – permanent watercourses and water-gauge stations, 2 – periodical watercourses, 3 – chosen stands of the ground water level measurements, 4 – hydroisohypses, 5 – frontal dam, 6 – lateral dam, 7 – pumping station, 8 – depression area range, 9 – hydroisohypse of the value equal to the reservoir impoundment level, 10 – areas of the risen ground water table, locally waterlogged, 11 – areas under the waterlogging threat, 12 – areas of a lowered ground water table, locally overdried

Area depressions, and particularly areas lying near the upper canal sector underwent waterlogging. Leading out waters by gravity is difficult there due to small differences in relative altitudes and to an intensive overgrowing process in the channel. More effective drainage occurred in the places where the canal runs at a little distance from the lateral dam. A deep incision of the canal in its lower sector resulted in a drop of the ground water table (by almost 2 m), which was clearly marked in the zone of about 1 km in width. Local excessive overdrying of soils affected unfavourably their water conditions. Soil wetness disappeared and dry peat deposits (by about 1.5 m in thickness) appeared locally above the ground water table. Also a drop of the water level in wells was observed and some of them ran dry.

In consequence of a rise of the ground water level in the vicinity of the lateral dam and of the draining effect of the canal a local inversion of the underground flow (from the reservoir to the canal) took place. Hydrological conditions of ground waters underwent changes. The ground water level dynamics throughout a year became more uniform in consequence of a rise of the lowest and a drop of the highest water levels. In dry periods it is filtration from the reservoir, which counteracts lowering of the ground water levels, while during snowmelts and after heavy rainfalls the water surplus is relatively quickly led out by ditches.

Most uniform water levels occur within the reach of the pumping station at Modzerowo (Fig. 6). In the well No. 1 annual water table amplitudes in the years following the river impoundment did not exceed 0.3–0.6 m. Prior to the impoundment the ground water dynamics depended on water level changes in the river, while the annual amplitudes reached 2 m. In the wells No. 2 and 3, situated outside the reach of hydrotechnical structures, the ground water dynamics did not change, while the amplitude value depended on snowmelts and rainfalls. It deserves to be mentioned that in the by-reservoir belt the relationship between water level fluctuations in the river and in wells is marked only slightly due, first of all, to low amplitude values of water levels in the reservoir.

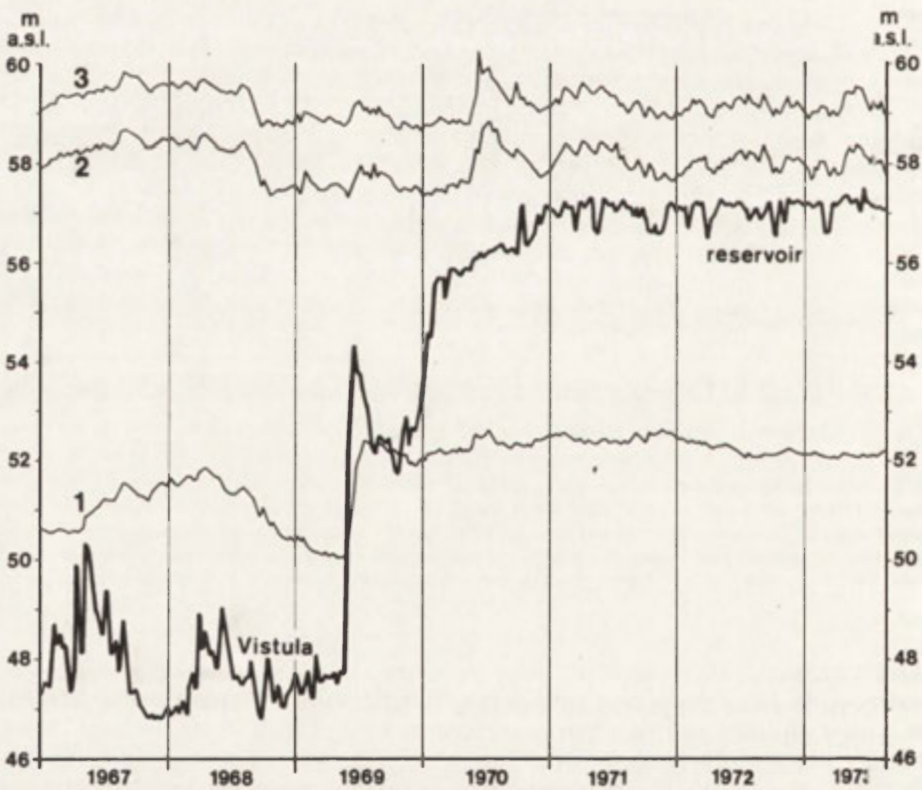

Fig. 6. Effect of work of the pumping station at Modzerowo on levelling of the ground water table in the depression area adjoining the Włocławek reservoir

Numbers at curves correspond with the ground water measurement stands as shown in Fig. 5

Along with a rise of the ground water levels, increased annual amplitudes of the water temperature in wells – by almost 11 °C. Narrowing of the aeration zone thickness led to a worsening of the water quality, observed often in the vicinity of lowland reservoirs.

4.2. WATER CIRCULATION CHANGES IN DEPRESSION AREAS

The Vistula impoundment resulted in water circulation changes in the depression area adjoining the lower part of the reservoir. This area is fed with atmospheric precipitations, surface and underground run-off from the southern part of the valley and by waters filtrating from the reservoir through the lateral dam.

To determine quantitative relations between main feeding factors, two water-gauge stations have been established (Fig. 5). One of them closed the Main Canal catchment area (117.7 km^2), in which the flow (averaging to 1.18 m^3/s) constituted the sum of water inflow from the hydrological catchment area and of filtration through the lateral dam. Another water-gauge station closed the Zuzanka river catchment area (46.8 km^2) in the place excluding the possibility of inflow of waters filtrating from the reservoir. The run-off conditions from the Zuzanka catchment area have been assumed as representative for the valley areas outside the impoundment reach (outflow coefficient 19.1%, unit run-off 3.21 $l \cdot s^{-1} \cdot km^{-2}$). These assumptions are justified by similar hydrogeological and hydrographical conditions. Unit run-off values from the Zuzanka catchment area were multiplied by the size of the Main Canal catchment area, obtaining thus the flow values in the canal due to feeding with atmospheric precipitations (averaging to 0.38 m^3/s). The difference between the flows measured and calculated on the basis of unit run-offs, constitutes the filtration value from the reservoir (averaging to 0.8 m^3/s).

The above data prove that filtration from the reservoir, is responsible for the feeding value on the depression area under study. Filtrating waters constituted, on the average, 68% of waters flowing along the Main Canal and 32% came from the hydrological catchment area. The filtration share in the total outflow decreases to 61% and increases in dry periods up to 77% (Glazik 1978). Feeding with filtration waters of the depression area is relatively uniform throughout a year. The mean filtration intensity is 0.8 m^3/s at fluctuations of mean monthly values within ± 18%. The respective differences are caused mainly by water level changes in the reservoir. In ditches running along the toe of the lateral dam, fed with filtration waters, a distinct relationship between the flow magnitude and the water level in the reservoir was observed. Following the water table rise in the reservoir the flow magnitude in ditches increases as well.

It is to stress that the inflow of filtration waters to particular sectors of the drainage network is irregular and depends on the difference between water levels in the reservoir and in the adjoining area on the one hand and the permeability of soils on the other. The greatest water inflows to ditches and to the Main Canal were found in local area depressions. Differences between the ground water levels and the water level in the reservoir are the greatest here, reaching 4–5 m (Modzerowo).

5. ANTICIPATED CHANGES OF WATER CONDITIONS IN THE LOWER VISTULA VALLEY UPON BUILDING THE CASCADE

The dams of the Lower Vistula cascade would change the longitudinal profile of the river. A decrease of the ground water table gradient and of the flow velocity would take place. The water level fluctuations in lower parts of the reservoir would be relatively uniform, depending on the power plant work. In the upper part of the reservoir, wider amplitudes of the water levels due to an irregular water discharge from higher situated dams should be expected. Water temperature in the reservoirs would be lower in spring and higher in autumn as compared with the period prior to the impoundment, whereas the ice phenomena would appear earlier and disappear later. The ice cover period would be longer. Before filling up the reservoirs it would be necessary to remove any obstacles on the ice float way, particularly mid-channel islands, what would reduce possibilities of the ice-jam flood occurrence. At strong winds from directions perpendicular to the reservoir axis the ice blocks of several meters in height could form. This process observed in the Włocławek reservoir would endanger the objects located in a close vicinity of the bank line. The wave motion would result in substitution of lateral erosion of the river by bank abrasion processes. In view of a change of hydrological conditions the stability of slopes of the moraine upland in the sector adjoining the reservoir could be disturbed. During the reservoir impoundment course the considerable water losses for bank infiltration can be expected.

In underimpounded river sectors below the dams wide daily amplitudes of water levels, caused by setting in work the power plant, could occur. These amplitudes would be narrower in case of the location of dams according to the variant II (Fig. 2) and would amount e.g.: below the Solec dam – to 2.7 m (in the variant I – 3.7 m), the Chełmno dam – to 1.8 m, the Opalenie dam – to 1.2 m (Biegała 1980). At the same time the extreme amplitudes of water levels and flows would decrease due to an increased possibility of the river outflow control. Considerable daily fluctuations of water levels and flows would counteract the ice cover formation. River sectors below the dams would undergo an intensive linear and lateral erosion. Appropriate depth for the navigation could be ensured by the regulation and dredging of channels.

Agricultural lands and buildings protected up to now by flood control dykes would be below the water table in the reservoirs. It would lead to significant changes in the surface drainage system and in the underground run-off directions. Annual amplitudes of the ground water table would undergo considerable narrowing. Filtration from the reservoirs and the ground water level rise would change the water balance structure of adjoining areas. On depression areas the amount of waters filtrating through lateral dams would be responsible for the range of feeding. The utilization structure of agricultural lands will be transformed. A decrease of the aeration zone thickness would lead to changes of the thermal conditions of ground waters and would worsen the water quality in rural wells. A rise of the ground water level would endanger the old-town structures of Toruń, Nieszawa and other ancient towns.

It is to stress that for an appropriate forecast of the river impoundment effect on environment, complex investigations in the vicinity of particular dams would be necessary. It would enable a suitable design and execution of the protection structures and thus would limit at the utmost unfavourable consequences of the river impoundment.

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STREAM RUN-OFF GENERATION IN THE POLISH CARPATHIAN MTS

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1. STUDY AREA

The investigations undertaken to learn the process of stream run-off generation were carried out on the slope of instrumented catchment of the Homerka stream (Fig. 1). The study catchment extends over an area of 19 sq. kms. It is composed of two parts: the montane higher one, and the lower foothill one. The former rises up to 1060 m a.s.l. (Photo 1). It is built of a series of sandstones with shales admixed. The soils, which include a considerable amount of skeletal particles, are overgrown with intensively exploited fir-beech forests. The denivelations between the ridges and valley bottoms are of the order of 400 m. The part of foothills rises up to 650 m a.s.l. (Photo 2). The denivelations between the ridges and valley bottoms amount to about 150–200 m. That part of the catchment is built of shale-sandstone Flysch series. The silty-clayey soils, the permeability of which decreases with the depth of the profile, are exploited agriculturally. The mosaic of arable fields is crossed by a network of cart-roads, which most often are of the character of sunken roads. Their density on the experimental slope exceeds $11\ km \cdot km^{-2}$.

The climatic conditions in the Homerka catchment vary according to the height a.s.l. (Niedźwiedź 1981). In the lower part of the catchment area, the mean annual total of precipitation amounts to about 900 mm, and in the headwater part it exceeds 1000 mm. The mean annual air temperature is 7.5°C and 5.0°C, respectively. In consequence of the variability of climatic conditions the excess of water forming the stream run-off amounts annually to about 250 mm in the lowest part of the catchment, and rises up to 750 mm in its headwater part. The most intensive rainfalls occur in the summer months: June, July and August. Once in the course of hundred summer days (or almost every year) there occurs a rainfall of a total of 50 mm per 24 hours, and once in thousand summer days (or almost every 11 years) there may occur a rainfall of a 100 mm per 24 hours (Niedźwiedź 1981). Throughout the year, the mean number of days with a rainfall ≥ 0.1 mm ranges from 160 near the mouth of the Homerka stream – to over 180 in the headwater part of the Homerka catchment. The winter season lasts from 80 to more than 120 days, respectively.

The experimental slope occupies an inter-channel area of the Homerka catchment. It is 500–700 m long and 480–600 m wide, and covers an area of 26.5 ha bordered by a natural water divide (Fig. 2). It rises to heights ranging from 458 to 608 m a.s.l. Its shape is convex-concave in the longitudinal profile, and concave in the transversal profile (Photo 3). The slope studied touches the Homerka stream through its

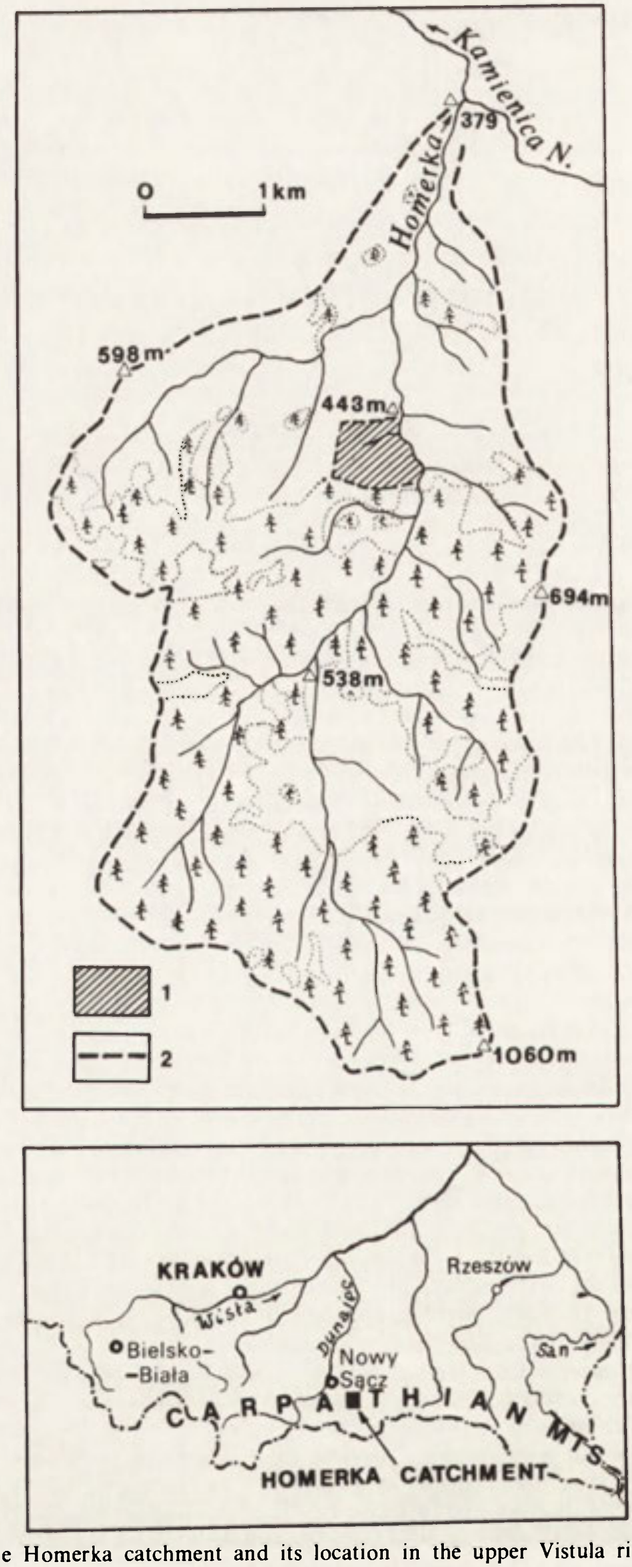

Fig. 1. The Homerka catchment and its location in the upper Vistula river basin

1 – the experimental slope. 2 – water divide

Photo 1. The montane (upper) part of the Homerka catchment

soddy valley bottom 20–30 m wide. It rises some 2–4 m above the stream water table. The slope is cultivated transversally to the drop. Between the fields there are cart-roads, which – in the course of centuries of cultivation – have been transformed into sunken roads cutting the waste covers.

The experimental slope is composed of several sub-catchments representing the chief Carpathian areas contributing to stream run-off; these are: A – the watershed

Photo 2. The foothill (lower) part of the Homerka catchment

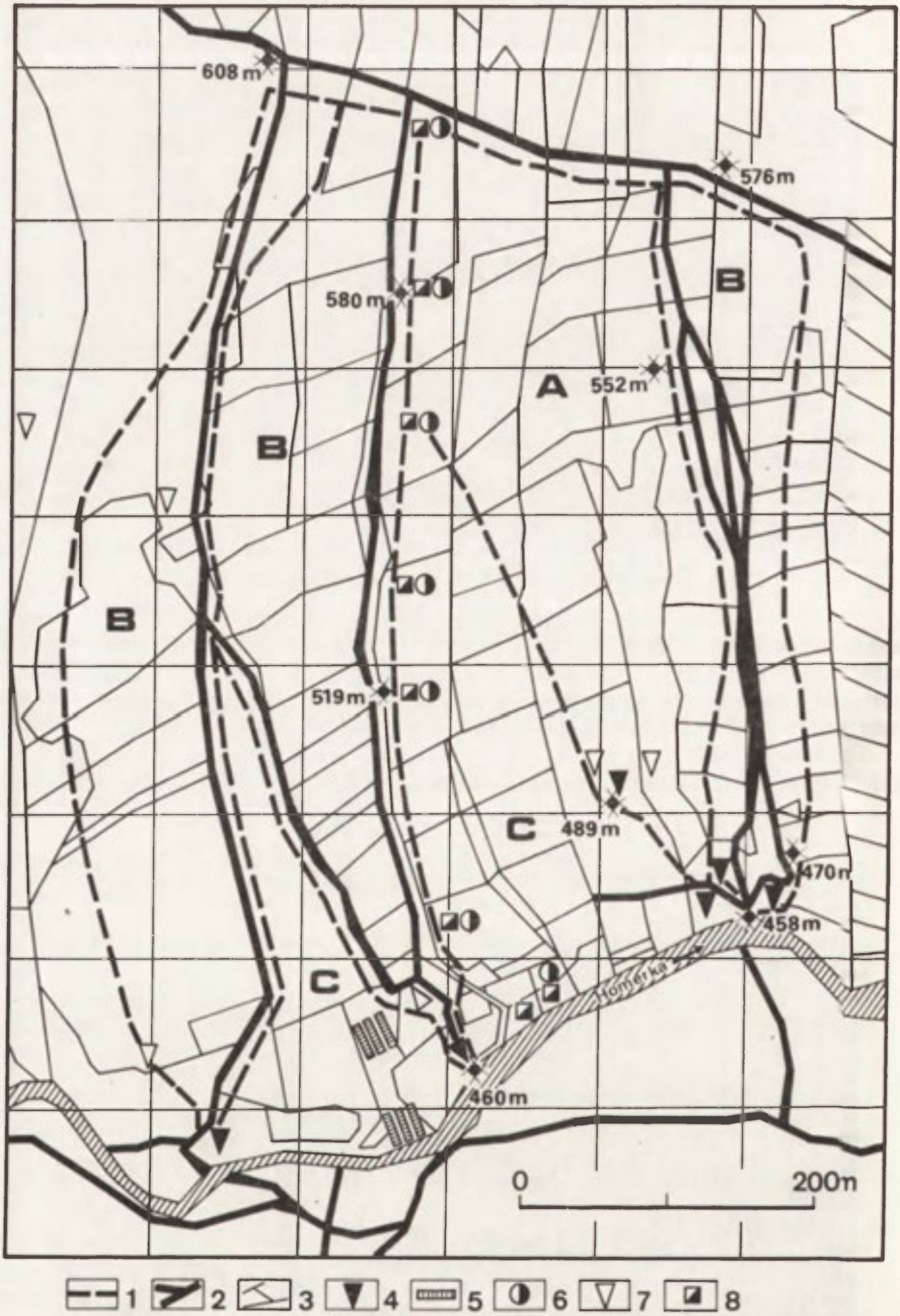

Fig. 2. The experimental slope in the Homerka catchment

A – watershed of erosional incision. B – watersheds of sunken roads. C – watersheds of inter-channel areas not drained linearly: 1 – water divides. 2 – roads. 3 – field boundaries (furrows). 4 – sharpcrested triangular weirs. 5 – spots for sheet overland flow measurements. 6 – observation wells. 7 – springs measured every day. 8 – sites for soil moisture measurements

Photo 3. The experimental slope in the Homerka catchment

of an erosional incision, B – the watershed of a sunken road, and C – the watershed of an inter-channel area (Fig. 2). The two former areas supply water from the slope to the stream channel by way of concentrated flow over the land, while the third area delivers water by way of sheet flow over the land and subsurface (Slupik 1981).

Photo 4. Sharp-crested triangular weir for measurements of concentrated overland flow

2. METHODS AND AIM OF STUDIES

Measurements were executed in five sub-catchments covering jointly 22 ha. These were: (1) an erosional incision (6.48 ha in area), (2) two sunken roads (2.93 and 5.93 ha in area), and (3) two inter-channel areas (2.27 and 4.39 ha in area). Each of these catchments was instrumented (Froehlich and Slupik 1977). At the outlets of the sunken roads and erosional incision in the stream channel the discharge of water was measured by means of sharp-crested triangular weirs (Photo 4). The frequency of measurements was adjusted to the variations in rain intensity. Sheet overland flow was caught in plastic bags (Slupik 1975) placed at the footslope and at the contact of the valley bottom with the stream channel; one bag (140 l in volume) crossing 0.8 m of contour (Photo 5). The bags were emptied after every rainfall, and during snowmelt – every day. Two measurement sites (i.e 6 bags) closed only a part of the whole slope breadth. That is why total volume of water flowing out from the whole inter-channel area was calculated according to the formula

$$d = v \cdot b : a$$

in which d = delivery of water to the stream channel from the inter-channel area, v = volume of water in bags, b – length of stream bank adjacent to the investigated slope, a = magnitude of the inter-channel area.

The extending of the ground saturated with water was observed in 7 sites distributed at the slope from the water divide to the valley bottom (Fig. 2). In these sites observation wells were installed (Photo 6) down to the depths of 50, 100, 150, and 200 cm. Water layer thickness was measured there once a day. During drought, when lack of water was stated in observation wells, soil samples were taken at the depths of 10–20, 40–50, and 90–100 cm in order to determine soil moisture by way of weighing.

The researches were carried out in the years 1976, 1977 and 1978. They were not distinguished by any weather phenomena extreme in their character but appro-

Photo 5. Plastic bags for measurements of sheet overland flow

Photo 6. Observation wells for measurements of ground water level changes

ached average ones. The aim of these investigations was to determine the role of slope in the generation of stream run-off in the Carpathian Mts by way of learning the process of the transformation of precipitation into run-off, and to determine the amount of water delivery from the slope to the stream channel. This aim was achieved by analysing and comparing the volume ($l \cdot s^{-1}$) and yield ($l \cdot s^{-1} \cdot km^{-2}$) of discharge and the frequency of occurrence (number of days) and amplitude (extreme values) of the events recorded. The author discussed separately the dry (rainless) period representing low water flow, and the wet (rainy) period representing high water flow.

3. THE PROCESS OF STREAM RUNOFF GENERATION

3.1. DRY PERIOD

The differentiation of water supply from slope to stream channel during drought corresponds to the lithology of the substratum (Froehlich and Słupik 1980a). In the sub-catchments lying in the lower part of the Homerka catchment the supply of water from the slope to the Homerka stream ranged from 0.2 to 1.3 $l.s^{-1} \cdot km^{-2}$ during a deep summer drought. At the same time, in the sub-catchment of the upper part of the Homerka catchment much higher values were recorded, i.e. 5.1–6.9 $l \cdot s^{-1} \cdot km^{-2}$. The measurements made on the same day on the experimental slope showed that the yield of springs flowing out of the slope amounted to 0.64 $l \cdot s^{-1} \cdot km^{-2}$, the supply of water to the stream channel by concentrated overland flow was 0.18 $l \cdot s^{-1} \cdot km^{-2}$, and the direct supply by sheet subsurface flow was 1.09 $l \cdot s^{-1} \cdot km^{-2}$. Thus, the experimental slope supplied to the Homerka stream the 84.5% of water from the inter-channel areas drained by sheet flow. The remaining 15.5% of water was supplied to the Homerka stream by concentrated flow from the erosional incision. The sunken roads contributed the low water discharge only during the autumn drought, when the potential of evapotranspiration

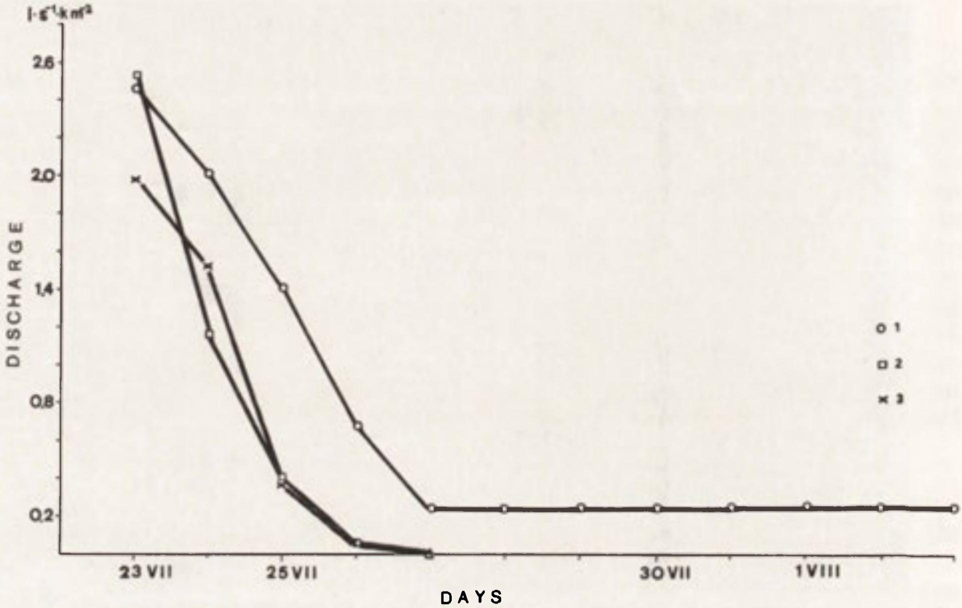

Fig. 3. Water discharge per unit area during low water flow in summer 1978. The experimental slope in the Homerka catchment

1 – erosional incision. 2. 3 – sunken roads

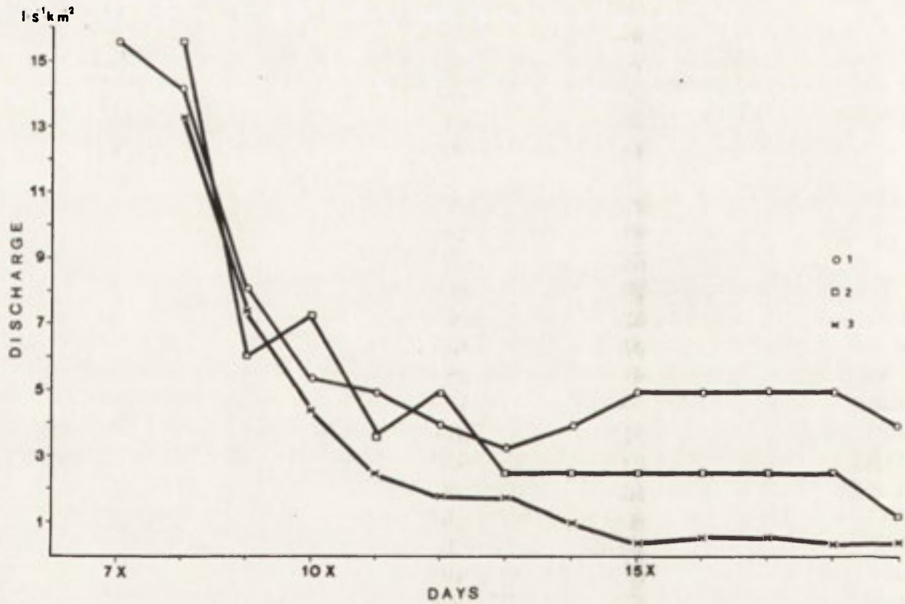

Fig. 4. Water discharge per unit area during low water flow in autumn 1978. The experimental slope in the Homerka catchment

1 – erosional incision. 2. 3 – sunken roads

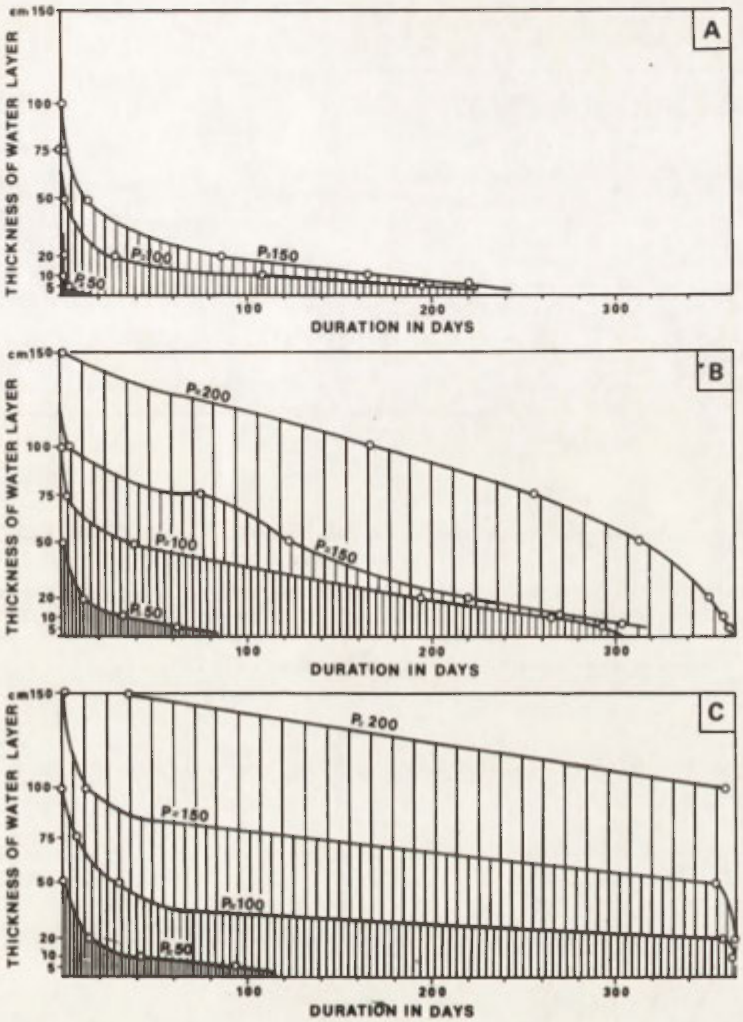

Fig. 5. Duration (number of days) and thickness of water layer in observation wells at the experimental slope in the Homerka catchment

A – observation site at the water divide. B – observation site in the middle part of the slope. C – observation site in the valley bottom. Signs P 50. P 100. P 150. P 200 denote depth of the observation wells in cm

is lesser (cf. Fig. 3 and 4). Such a close relation of the low water discharge to evaporation potential indicates a shallow circulation of water.

Besides the solid rock substratum it is the waste cover which takes a considerable part in the contribution to the stream run-off during low water flow. This is corroborated by the small discharge of the springs on the slope (0.01–$0.04\ l \cdot s^{-1}$), as well as by the high temperature of the spring waters which in summer amounts to 16°C. The direct contribution to the stream run-off by sheet subsurface flow is a consequence of the seepage of water down slope under saturation and aeration soil conditions. This is shown on the diagram representing the duration and thickness of the saturated zone (Fig. 5). As regards soil moisture, there exist the greatest differences between the ridge and the valley bottom. The intermediate stands, at

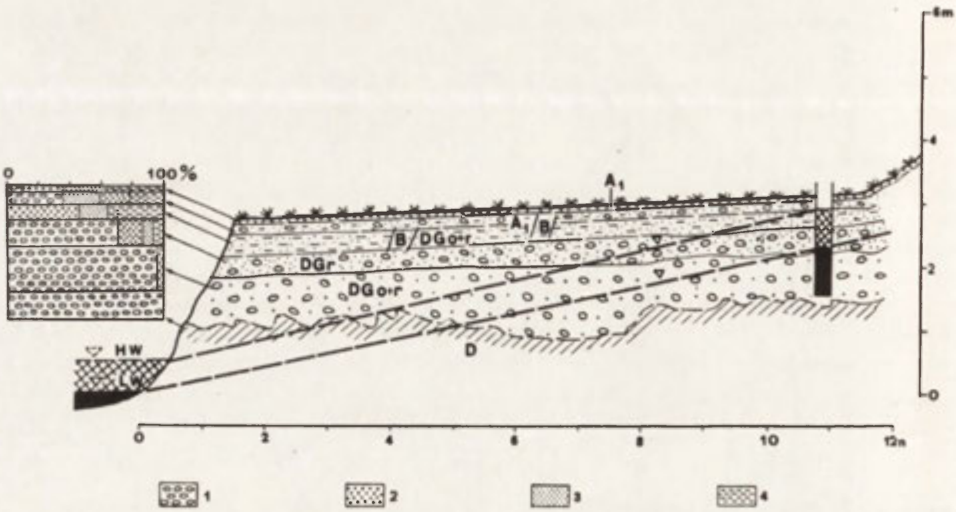

Fig. 6. Section crossing the valley bottom of the Homerka stream at the segment vhich belongs to the experimental slope

HW high water stage in the Homerka stream and corresponding ground water level. LW low water stage in the Homerka stream and corresponding ground water level: A_1, A_1/B/, /B/DG_{o+r}, DG_r, DG_{o+r}, D denotes different soil horizons. Mechanical composition: 1 skeletal particles (ϕ > 1 mm), 2 sand (1 > ϕ > 0.1 mm), 3 very fine sand (0.1 ϕ > 0.02 mm), 4 silt and clay (ϕ < 0.02 mm)

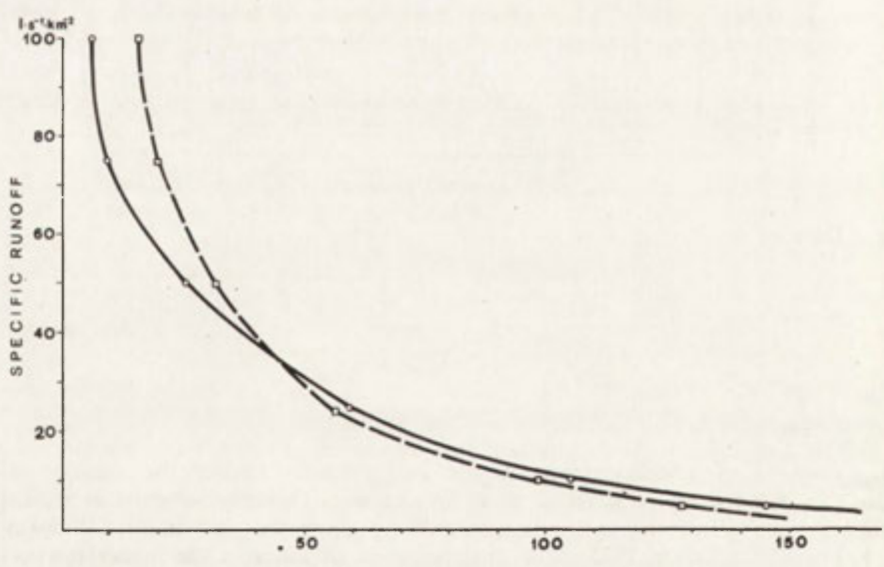

Fig. 7. Duration of flow intensity with the same values (number of days in hydrological year 1977) in the erosional incision and in the sunken road at the experimental slope in the Homerka catchment

which groundwater levels were observed, represent the transmission zone of water from the higher to the lower parts of the slope. In the soils with a deeper profile, and in the soil horizons with a higher percentage of skeletal particles the seepage of water down slope is heavier. They favour the convergence of water movement and are of the character of seepage-lines (Bunting 1961). Owing to that, at the bottoms of erosional incisions there always exist saturation conditions stimulating a perennial delivery of water to the stream. Meanwhile, sunken roads play the role of ditches draining saturated areas (bog-springs, marshes) situated on the slope far from the stream channel.

The moving of moisture down slope in the aeration and saturation zones is evidenced by the occurrence of marshes at the footslope and in the valley bottom. They lie about 2 m above the water level of the Homerka stream (Fig. 6). The valley bottom in the vicinity of the stream channel is dryer, because the alluvial covers are more permeable than the slope covers, imbibe the water flowing down, and transmit it to stream channel as sheet subsurface flow.

3.2. THE WET PERIOD

The delivery of water from the slope to the stream channel during high water discharge proceeds mainly by concentrated flow over the road surfaces and at the bottom of the erosional incision, while the inter-channel area, non-drained linearly plays a negligible role (Table 1). In the first phase of the rainfall, besides the water dropping immediately onto the stream channel, it is the bottom of erosional incision and the surface of cart-roads which form the source areas of run-off production. With a prolonging rainfall they continue to dominate in the delivery of water to the stream, because they drain the water from bog-springs, marshes and field furrows situated within the slope.

At the bottom of the erosional incision there occurs the saturated sheet flow. Initially, it is of the character of direct precipitation onto saturated areas (Dunne 1978), and while the whole bottom of the erosional incision becomes saturated, the flow acquires the form of a return flow (Dunne 1978). On sunken roads, even during rainfalls of a small yield, non-saturated flow is formed (Froehlich and Slupik 1980b). The frequency of high flows is greater than on sunken roads (Fig. 7) because the permeability and roughness of the road surface is lesser than on arable fields and meadows covered with vegetation. The frequency of low flow intensity is greater in the erosional incision in result of the occurrence of direct flow in the outlet segment of the erosional incision in the near vicinity of the Homerka stream. The run-off coefficient expressed in percent of total precipitation (Table 1) varies both spatially and temporarily. During the snowmelt period it attains a volume approaching 100% in sunken roads. This is caused by the considerable supply of water stored in snow paths (Photo 7). During rainfalls of a great efficiency the highest run-off coefficients attain 50% of the total precipitation. At such times the sunken roads change into the tributaries of the Homerka stream, and the zone of flow extends over the whole road surface, and touches by its arms the field furrows and marshes distributed over the slope.

The rainfalls of a considerable volume and intensity favour the creation of one or several horizons of perched water in the soil. This phenomenon is typical of the soils, in which the hydraulic conductivity decreases with depth (Whipkey and Kirkby 1978; Befani 1975). The disappearance of water in the higher horizon entails its appearance in the underlying horizon in a greater quantity (Fig. 8). This gives evidence for the movement of water down slope in soil during abundant rainfalls or in the period of snowmelt. The seepage down slope is a perennial process (Fig. 5), but the distance passed by the water during high water flow

TABLE 1. Comparison of streamflow from an erosional incision, cart-road and inter-channel area on the experimental slope in the Homerka catchment

Part of slope	Flow											
	Total	Intensity		Total	Intensity		Total	Intensity		Total	Intensity	
	mm	$l \cdot s^{-1} \times km^{-2}$	mm/24^h	mm	$l \cdot s^{-1} \times km^{-2}$	mm/24^h	mm	$l \cdot s^{-1} \times km^{-2}$	mm/24^h	mm	$l \cdot s^{-1} \times km^{-2}$	mm/24^h
Erosional incision	15.51	81	3.95	33.16	244	13.46	30.83	224	10.79	168.39	269	18.21
Cart-road	25.96	178	5.85	55.82	361	20.34	49.57	354	18.09	195.28	564	32.92
Inter-channel area:												
Footslope	0.07–0.19	–	0.10	0.41–1.06	–	0.20	0.31–1.22	110	–	2.49–3.69	60	0.84
Valley bottom	0.07–0.18	–	0.11	0.26–0.79	–	0.10	0.22–0.92	–	–	0.13–0.30	–	0.06
Period	4–18 July 1977			24 June to 5 July 1978			17–22 August 1978			22 Jan. to 25 March 1977		
Precipitation, total	94.1 mm			99.0 mm			98.1 mm			202.2 mm		
Maximum yield of rain	21.9 mm/24^h 14.0 mm/1^h			46.9 mm/24^h 7.5 mm/1^h			37.7 mm/24^h 22.0 mm/1^h			– –		

Photo 7. Concentrated flow in the sunken road during snow melt

is not great. That is why inter-channel areas not drained linearly supply the stream run-off with a small quantity of water during high water flow (Table 2). Sheet overland flow is distinguished by low velocity (due to the considerable roughness of the surface and the small thickness of the flowing water layer), as well as by the small frequency of occurrence. Therefore, the amount of water delivered to the stream channel from an inter-channel area drained by sheet flow is very small in comparison with concentrated flow. This is reflected both in the volume (Table 2) and in the intensity of flow (Table 3). The maximum intensity of the sheet flow approached 20 $l \cdot s^{-1} \cdot km^{-2}$ in the period of investigations. If

TABLE 2. Delivery of water from the slope to the Homerka stream in the hydrological years 1977 and 1978

Period	Whole slope 22 ha – 100%		Erosional incision 6.48 ha = 29.45%		Sunken roads 8.86 ha = 40.17%		Inter-channel areas 6.66 ha = 30.27%	
	mm	%	mm	%	mm	%	mm	%
Year 1977	251.75	100.0	101.24	40.2	153.10	59.7	0.41	0.1
Nov. 1976– April 1977	204.21	100.0	83.34	40.8	120.69	59.1	0.18	0.1
May 1977– Oct. 1977	47.74	100.0	17.90	37.5	29.61	62.0	0.23	0.5
March	55.08	100.0	21.19	38.4	33.85	61.5	0.04	0.1
July	15.40	100.0	4.98	32.3	10.35	67.2	0.07	0.5
October	0.60	100.0	0.50	83.3	0.1	16.7	0.00	0.0
May to Oct. 1978	199.31	100.0	74.12	37.2	124.43	62.4	0.76	0.4
August	36.23	100.0		32.6	24.14	66.6	0.28	0.8

TABLE 3. Maximum and minimum delivery of water (in mm) from the slope to the Homerka stream in the hydrological years 1977 and 1978

Period	Flow	Erosional incision	Sunken road	Inter-channel area
30-days	Max.	82.29	105.24	0.92
	Min.	1.04	0.24	0.00
10-days	Max.	35.36	95.41	0.69
	Min.	0.12	0.00	0.00
24 hours	Max.	18.21	32.92	0.69
	Min.	0.02	0.00	0.00

compared with the values recorded at that time it was 9 times lesser in the Homerka stream, 24 times lesser in the erosional incision, and 600 times lesser in the sunken roads (Slupik 1981).

The stream is reached by a lesser quantity of water than that recorded at the footslope. At the valley bottom, the sheet overland flow decreases because a dense grass checks the flow velocity; moreover, part of the water is absorbed by alluvial deposits which are more permeable than slope covers. That is why the interchannel areas, which are not drained linearly, take part in the storm run-off rather by supplying water from the alluvial deposits in the form of sheet subsurface flow. Sheet overland flow reaches the stream channel only from its banks and from a narrow belt of the valley bottom.

4. THE ROLE OF SLOPE IN RUN-OFF GENERATION

The role of slope in the generation of stream run-off changes in space and time (Table 2). The cart-road is of deciding importance in the generation of storm flow, and the erosional incision also plays a considerable part in the generation of the base flow. Inter-channel areas not drained linearly store the rain water during high water discharge. They deliver water to the stream with some delay, either by sheet subsurface flow or by concentrated flow over the surface of roads and erosional incisions. In this way they contribute to the stream flow during several weeks after rainfall or snowmelt.

The high water discharge in the Carpathian streams consists of the rain water falling to the surface of their channels, and of the water transmitted quickly by concentrated overland flow (Slupik 1981). According to other authors, the storm flow is composed of the precipitation falling to the channel and on its banks (Hewlett and Nutter 1970, Weyman 1974), and the water flowing from small saturated areas situated at the valley bottom (Hewlett and Hibbert 1967). The saturated zone sometimes includes the lower parts of slopes (Dunne and Black 1972, Weyman 1974) and by pipe network may reach the upper parts of the slope (Jones 1979). There is a common idea in these views that the whole storm run-off and a considerable part of the base flow derives from upper soil horizons and concentrated overland flow.

The time of stream flow response to rainfall depends on the distance of the source areas to stream channel, as well as on the quickness of water flowing

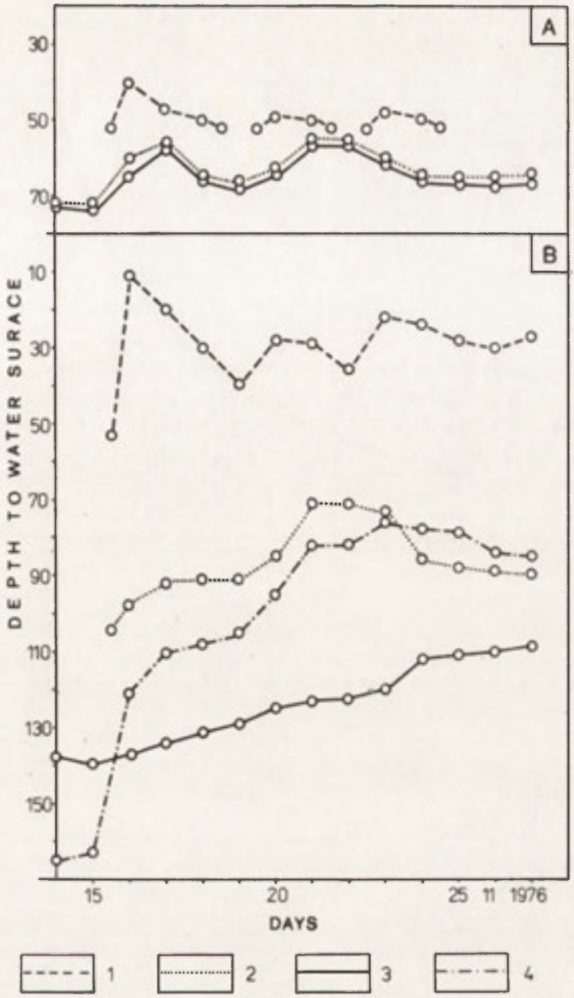

Fig. 8. Water level changes in observation wells at the experimental slope of the Homerka catchment

A – observation site in the valley bottom of the Homerka stream. B – observation site within the slope studied. Depth of the observation wells: 1 – 50 cm. 2 – 100 cm. 3 – 150 cm. 4 – 200 cm

down slope, and on the antecedent moisture – in the case of saturation flow (Fig. 9), or on the permeability – in the case of non-saturation (Horton) overland flow. Water reaches the stream channel sooner by concentrated (point A_1) than by sheet flow (point A) in spite of an equal distance from the stream channel. From points A and A_2 situated at different distances from the stream, water may reach it in equal times. A similar effect of variations in the time of water delivery from slope to stream channel may be caused by the spatial variability of antecedent moisture (Fig. 9). At points B_1 and B_2 the saturated flow may be formed sooner than at point B. For that reason there may occur a shortening of the time of the stream flow response to precipitation at an equal distance of the source areas from the stream channel (cf. points B and B_1), and equalizing of the

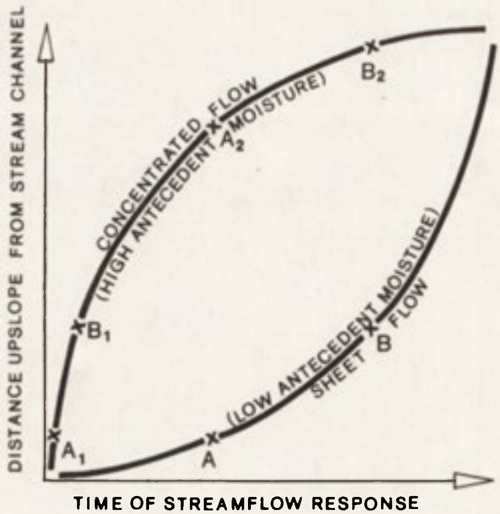

Fig. 9. Model of slope contribution in the generation of streamflow – spatial and temporal relations

importance of distance in the case of antecedent moisture (cf. points B and B_2). A similar reasoning may be applied to the non-saturation overland flow by replacing the term 'antecedent moisture' by 'infiltration capacity'.

5. CONCLUSIONS

1. The studies carried out on the experimental slope of the Homerka catchment facilitate the understanding of the spatial variability of stream run-off generation in a small catchment. The flow of water down slope begins first of all in the territories perennially saturated with water (e.g. bog-springs, bottoms of erosional incisions), and in areas of little or non-permeable surface (i.e. cart and sylvan roads, beaten tracks, built-over areas). Perennial and periodic marshes, as well as landslides are next in turn to favour the run-off.

2. The water derived from these source areas reaches the stream channel at various times: quickly – in the case of concentrated flow along cart-roads, erosional incisions, or drain-pipes, and slowly – in the case of sheet overland or subsurface flow. That is why besides roads and erosional incisions there are only the areas drained by concentrated flow which may have a considerable share in supplying high water flow, as well as other wet areas before the occurrence of precipitation which lie in the immediate vicinity of the stream channel (i.e. wet valley bottoms and footslopes in narrow valley bottoms).

3. In the Carpathian Mts there is observed a great spatial differentiation of stream flow generation. Non-permeable territories with farm buildings, little permeable surfaces of cart-roads, arable fields which rather favour water intake, and forested areas lie side by side on one and the same slope. Convex parts of the slope which are rather dry by nature, neighbour on the more humid depressions, wet landslides, marshes, and bog-springs perennially saturated with water. If to that spatial variation we add the seasonal and even diurnal differentiation of soil moisture we may easily understand that (1) the stream flow response to rainfall is highy varied both spatially and temporarily even in small catchments seemingly

identical, (2) the storm hydrograph includes all kinds of flows: the overland and subsurface, sheet and concentrated, saturated and non-saturated ones, which are delivered to the stream channel in a short time. This means that it is only a part of the catchment which forms the storm flow.

4. Such a great spatial variability of the sources contributing to stream flow make that the investigations undertaken on slopes are a necessary completion of the studies on the river run-off aiming at the acquisition of a reliable knowledge of the water cycle, the process of run-off production included. The utilization of the river run-off for description of the hydrological dynamics of the whole catchment is unsatisfactory and insufficient because the river run-off is only a result of the rainfall transformation, which takes place within the precincts of the slope.

5. The amount of water delivered from slope to stream channel is an effect of several variables: (1) permeability of the ground, (2) antecedent moisture, both permanent, resulting from the nature of the soil and type of water circulation, and temporary, resulting from the sequence of the seasons of the year and the weather conditions, (3) distance of the source areas to the stream channel in the longitudinal slope profile (from the stream banks to the water divides) and in the cross-section of the valley (from the slopes immediately adjacent to the stream channel up to the slopes divided from the channel by a broad valley bottom). In the catchment of the first order, the slope is in direct contact with the stream channel. In the small catchment (as in that of Homerka) the delivery of water from the slope occurs through the intermediate narrow valley. As the drainage basin increases, the slope becomes more distant from the stream channel and its role of a contributing area is taken over by the valley bottom. The delivery from the inter-channel areas decreases with the extension of the drainage areas on behalf of a quicker supply of water from the tributaries. Thus, the model established on the experimental slope of the Homerka catchment is repeated on a different scale.

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SOME PROBLEMS OF GEOCHEMICAL EVOLUTION OF POLISH SOILS

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INTRODUCTION

Geochemical processes lead to continuous changes in the soil medium. These changes cannot be indifferent to man, as they decide about his existence, affecting the content of nutrients in soil indispensable for the growth of plants. In addition, anthropogenic factor overlaps more and more often the processes of natural chemical changes in soil. Its action leads on the one hand to an enrichment (or supplementation) of soil in chemical compounds (fertilization) which are leached or taken out with crops, or to an impoverishment of soils on wide areas or even their complete degradation under the effect of harmful industrial emissions, on the other.

The most characteristic elements for the processes mentioned are calcium carbonates contained in soils. However, we neither dispose of an exact inventory of the occurrence of carbonates in soils, nor we know the localization of processes leading to their impoverishment all over the country. In this connection the investigations aiming at a spatial presentation of existing state in the occurrence of carbonates and of the reaction of soils as well as at determination of directions of changes of this state were carried out. The investigation enabled to make an attempt of presentation of the above changes cartographically. The maps, apart from the present picture of the occurrence of carbonates and of the soil reaction, proved its unfavourable changes. Information contained in the maps enables both to counteract efficiently and/or anticipate threats for agriculture connected with worsening state of acidification of arable soils.

MORPHOGENETIC PROCESSES IN THE SOIL SUBSTRATE

Geochemical processes occurring in nature result in formation and evolution of the soil cover. Earth surface is under an incessant action of two opposite, i.e. endo- and exogenic factors. One of manifestations of the action of exogenic factors is weathering of rocks.

Thus, soil properties depend mainly on mineral composition and origin of parent rocks. With regard to origin the three groups of rocks are distinguished, viz.: magmatic (igneous), sedimentary and metamorphic ones.

Magmatic rocks are resistant to weathering and cover only several per cent of the total area, whereas sedimentary rocks are susceptible to weathering and cover about 75% of the country territory. The most important parent rocks of soils are loose clastic rocks (gravels, sands, clays, silts and loesses), organogenic and chemical rocks.

Soil-forming processes can lead to accumulation of basic chemical elements in the parent rocks (then such types of soils, as rendzinas, typical chernozems, typical black earths and typical brown soils form), or to degradation of the initial substrate an then podzolic soils or podzols develop.

In consequence of many-century transformation chemical elements are constantly regenerated (e.g. by way of weathering), at simultaneous losses leading to their quantitative decrease (due to leaching or uptake by plants). Thus, the chemical composition of contemporary soils is a result of action of many factors.

CHEMICAL CHANGES IN SOIL

It is difficult at present to estimate, to what degree the content of elements would be connected with natural properties of parent rocks of soils and to what extent it would express the anthropogenic activity as well as to determine the rate of occurring changes.

Investigations carried out by the agricultural chemistry stations prove that the losses of macro- and microelements are connected to a high degree with the mechanical composition and the soil profile structure (and thus with substrate), and not always with the soil type. More cohesive soils (containing more clay and colloidal particles) are richer from their nature in nutrients and develop better the biologically active humus horizons than light sandy soils. Cohesive soils are also more resistant to leaching of elements by rainfall waters. It is of a great importance under conditions of our climate, where filtration constitutes an important position of the water balance. On the other hand, light soils developed from sands are poor in nutrients in connection with their mineral composition (in which silica prevails) and are susceptible to leaching of elements into the substrate and ground waters. Parallelly to losses of nutrients of basic character there are increases the acidification of sandy soils of a poor sorption complex.

Bringing into arable soils additional elements in the form of mineral fertilizers (or contaminants from atmosphere) disturbs the ionic equilibrium and initiates losses of other chemical elements. The application of physiologically acid mineral compounds, like e.g. ammonium sulphate, urea, ammonium nitrate, etc. decreases the soil pH and intensifies leaching of elements.

A considerable disturbance of the ionic equilibrium in sandy soils can be observed in the vicinity of industrial enterprises, emitting nitrogen, calcium, magnesium and exceptionally potassium compounds into atmosphere. An example of extreme disturbance of that equilibrium is the area around the Pulawy Nitrogen Plant, where toxic concentration of chemical compounds resulted in a complete disappearance of the vegetal cover (Siuta 1980).

MIGRATION OF ELEMENTS IN SOILS

The amount of leached elments under conditions of our climate (at the sum of annual precipitations of 600 mm) can be determined on the basis of results of 5-year lysimeter experiments carried out on three different soils by Ruszkowska and co-workers at Pulawy (Ruszkowska *et al.* 1970, 1979, (Ruszkowska and Sykut 1982). It has been found that the value of losses is, on the whole, proportional to the amount of water filtrated through soil. Calcium, magnesium and sulphur are leached always most intensively, whereas leaching of phosphorus is the least and that of potassium depends on the mechanical composition of soil (e.g. annual leaching of calcium ranges within 35–260 kg, of magnesium – within 27–38 kg/ha, of phosphorus – in traces and of potassium – within 3–40 kg/ha. The value of potassium losses depends mainly on the mechanical composition of soil – the lowest is in soils developed from loesses (3–5 kg/ha) and loams (5–8 kg/ha), the highest – in sandy soils (30–40 kg/ha). A lack of vegetal cover (so-called bare fallow) intensifies leaching of elements. In case of sandy soil leaching of potassium was 4-fold higher on the bare fallow (Ruszkowska and Sykut 1982).

Differences in the balance of elements found in the lysimeter experiment (Ruszkowska *et. al.* 1979), Ruszkowska and Sykut 1982) for the period 1971–1977 prove that the balance is negative for the elements investigated (Ca, N, K, Mg, S), except for phosphorus (the elements are ordered according to decreasing values of differences in the balance).

Chemical compounds flow under natural conditions down the surface of soils situated on slopes into streams and water reservoirs. They go directly into ground waters (and from there into drain waters and wells). Losses of nutrients carried away from soils and entering ground waters of areas in the vicinity of Puławy, of the catchment areas of the Bystra an Opatówka rivers, constituted the subject of investigations of Pondel and co-workers (Pondel 1965, Pondel *et al.* 1978, Pondel and Terelak 1982, Pondel and Józefaciuk 1982), whereas with losses of nutrients on the Szczecin Lowland there dealt Borowiec and co-workers (Borowiec *et al.* 1978). These authors have proved that in the ground waters analyzed Ca and Mg cations occurred in highest amounts. The content of these elements varied depending on types,' kinds and textural groups of soils. Most abundant in calcium appeared to be waters from soils developed from loams belonging to black earths and lessives soils (Pondel 1965). In waters of the Bystra and Opatówka river catchment areas the highest calcium and magnesium amounts came from soils developed from deep loesses. Much smaller amounts of the above elements were contained in waters coming from shallow loess soils on marl, loam or sand, or else, depending on the area size – from sandy soils or soils developed from strongly sandied loams (Pondel *et al.* 1978, Pondel and Terelak 1982).

Waters taken for analyses from farm wells showed the chemical composition approximating that of drain waters.

The results of investigations of Pondel and co-workers prove that the geologic structure of fragmentary catchment areas is responsible for the degree of water mineralization to which the content of calcium, magnesium and potassium salts is referred. For that reason, the mean calcium content in waters of both catchment areas maintained at the level of 100 mg/l, i.e. distinctly higher that in Vistula waters. The amount of that element in the Wieprz river flowing also through loess areas is less by a half. Mean annual amount of mineral elements in kg/ha a year, flowing from the catchment areas investigated is, according to the investigations (Borowiec *et al.* 1978, Pondel *et al.* 1978, Pondel and Józefaciuk 1982) as follows in Table 1.

The confrontation of investigation results of both authors enables to compare the amount of elements leached into ground waters coming from two far and geologically and pedologically quite different agricultural areas utilized by private (loesses on the Lublin Upland) and state sector of agriculture (soils of the Szczecin Lowland developed from boulder loams and sands). The differentiation in leaching of elements was caused both by natural and economic conditions (the mineral fertilization level in the private sector – about 200 kg, in the state sector – 750 kg/ha structure of sowings, etc.).

Investigations of Borowiec *et al.* (1978) confirm the assumption concerning decrement of chemical compounds from soils utilized by agriculture. These authors

TABLE 1. Mean amount of mineral components in kg/ha/y flowing from the catchment areas (after Borowiec (1978). Pondel (1978). Pondel. Jozefaciuk (1982))

Element (compound)	Rega and Swiniec river catchment areas	Bystra river catchment area (at outflow of 5.66 l/s/km²)	Opatowka river catchment area (at outflow of 6.63 l/s/km²)
PO_4	0.04–0.5 mg/l	0.55	0.30
N–NO_3	0.4–2.2 mg/l	2.62	1.70
N–NH_4	–	0.62	0.50
K	25.0	6.60	8.80
Ca	110–160	178.50	196.60
Mg	26.0	21.24	42.20
Na	25–38	11.96	23.40
SO_4	–	47.66	66.70
Cl	36–56	26.42	50.80

have found that from particular catchment areas utilized intensively by agriculture by 1.6 fold higher calcium amounts are carried away in a year (214 kg/ha) as compared with soils of catchment areas of an average utilization intensity (144 kg/ha). Particularly high decrements occur in arable lands (from fields after shelling and those after potato harvest), where tillage leads to an intensive mobilization of elements. Lesser losses of elements occur on grasslands (and stubbles) and the least on poor forest sites (dry or fresh pine forests).

According to German authors data (*Faustzahlen fur*... 1974), mean yields of crops take the nutrient amounts from soils, which are cited in Table 2.

According to the same source, leaching of macroelements from soil (in kg/ha/y) amounts to: N – 10–100, P_2O_5 – 0–10, K_2O – 10–70, CaO – 100–600, MgO – 10–120, Na_2O – 10–120 g. SO_4 – 200–360, leaching of microelements (in g): B – 150–250, Mn – 150–1100. Cu – 15–50.

The value of losses due to leaching depends on the sum of precipitations, mechanical composition and biological activity of soils, fertilization level and vegetal cover. Mean annual calcium losses (in conversion to CaO) due to leaching are, according to particular authors, as follows: Lityński – 140–250, Kurylowicz – 50–200, Sadowski – 350–400 (for the Opole voivodship), Vetter (for the GDR) – 60–600. Annual calcium losses (due to leaching and uptake by plants) amount after Boguszewski (1980) to 250 kg from hectare.

Elements are returned to soil by the way of mineral fertilization and liming, taking into consideration available nutrients content of soil determined by the agricultural chemistry stations. Mean rates of mineral fertilizers in this country in 1980 (*Rocz-*

TABLE 2. Uptake of nutrients by different plants in kg/ha (after *Faustzahlen für*... 1974)

Crops (yield)	N	P_2O_5	K_2O	CaO	MgO
Cereals (3 t) grain and straw	60–90	21–45	60–90	18–30	6–15
Potatoes with haulms (20 t)	90–110	30–40	150–180	30–80	16–30
Sugar beets (30 t)	120–165	45–60	150–225	30–60	30–60
Meadow hay (5 t)	75–100	25–50	100–150	40–60	30–40
Alfalfa hay (5 t)	100–150	25–50	75–125	125–150	10–20

nik Statystyczny... 1981) maintained at the level of about 200 kg NPK (N – 70, P – 50, K – 80) and of liming – of 159 kg/ha (in conversion to CaO). Differences in use of mineral fertilizers and lime per 1 ha of agricultural lands are high, in particular:

Use in kg/ha:	NPK	CaO
state sector	323	243
collective farms	280	144
farms of farmer circles	280	323
private farms	152	135

Also, the high regional differences occur in use of mineral fertilizers an lime between particular voivodships, e.g.:

Voivodship Use in kg/ha:	NPK	CaO
Ostrołęka	119	90
Siedlce	121	46
Zielona Góra	260	404
Szczecin	201	225
Poznań	290	205

In the 10 voivodships below 150 kg and in the 13 voivodships above 220 kg/ha NPK; in the 15 voivodships below 100 kg and in the same number of voivodships above 200 kg/ha CaO are applied.

Only in 8 districts are the lime inputs sufficient for neutralization of sulphuric acid in soils, which forms at burning of coal. It has been found that in 1980 about 2.5 million tons S (or 5.0 million tons SO_2) went to atmosphere. Lower SO_2 amounts quotes Boguszewski (1980) for 1970s. Thus, about 80 kg S falls per one statistical hectare. For neutralization of that amount, 249.6 kg/ha $CaCO_3$ are needed. Additionally there come calcium decrements due to leaching and uptake by plants.

PROCESSES OF DECARBONATIZATION AND ACIDIFICATION OF SOILS

An element characterizing geochemical transformations in soil and playing a very important role in these transformations is calcium, including its compounds, i.e. carbonates (of calcium and magnesium). Therefore, the author should like to draw attention to the processes leading to impoverishment of soils in carbonates and to acidification of soils.

The source of bases in unfertilized soil constitutes almost exclusively weathering of alumosilicates being in its composition and carbonates (of calcium and magnesium). On some areas, like e.g. the Cuiavian Upland (Cieśla 1961) and the Suwałki Lakeland, carbonates can form from carbonate rocks carried by glaciers. Less probable is the presumption of translocation of carbonates with pit waters upwards from lower situated mezozoic parent material, as the layer of Tertiary clay would hinder filtration of waters. The clay layer lying even deeply in the parent material can counteract leaching of carbonates from soil.

Carbonates are hardly soluble, readily soluble only as acid carbonates forming in consequence of the reaction of carbonic acid with calcium and magnesium carbonates. Solubility of carbonates increases with an increase of the amount of CO_2 (secreted by plant roots and microorganisms) in the soil air. The CO_2 concentration in the soil air depends on temperature. At higher temperatures, when the "soil respiration" becomes intensive and the whole amount of produced CO_2 goes into atmosphere, carbonates remain to be hardly soluble. Low temperatures in soil result in an increased CO_2 solubility in water and in limited penetration of CO_2

into atmosphere: it remains in soil forming with carbonates the water soluble acid carbonates. Losses of carbonates due to leaching are thus proportional drectly to the amount of flowing water and inversely related to temperature. They are modified by such factors, as relief and vegetal cover. Acid carbonates dissolved in water flow over the soil surface down the slope or are leached downwards (at a horizontal surface).

Some plant species can reduce the calcium losses due to leaching while retaining a part of the filtrating waters (e.g. grassland, alder forest), enrich upper soil layers in calcium due to its translocation in upward direction from the substrate (e.g. alfalfa, clover, melilot), or deepen the losses of carbonates (e.g. coniferous forest).

An important role in processes of the Ca, Mg, K and Mn translocation plays the natural vegetal cover. Thompson and Troeh (1978) have proved that in the translocation of the above elements from the rhizosphere to the superficial zone the root system of plants is involved. The more elements will be taken up by plants, the less amount of them will be leached from the soil profile. By that lower acidification (in similar natural systems) and higher reaction of meadow than forest soils can be explained. Namely, grasses show a very high requirement for nutrients of basic character. While decaying, they leave behind many bases. On the other hand, the vegetation of coniferous forests stimulates leaching processes leading to losses of carbonates. Its requirement in alkaline compounds is much lower. Moreover, the forest litter decomposition by fungi releases organic acids, which accelerate leaching of elements by precipitation waters. It has been proved that deciduous forests show a higher requirement for nutrients of basic character than coniferous forests. Intensification of the leaching process grows along the following line: meadow vegetation → deciduous forest → coniferous forest (dry pine forest).

According to Borowiec *et al.* (1978) the communities of weeds in the Western Pomerania region constitute a good index of the differentiation of site condtions (particularly thermal ones). While comparing the percentage of acid communities (in relation to remaining ones) on particular lakeland areas, he found a progressive acidification growth of soils from the west (mean annual temperature of 8°C) tovards eastern direction (mean annual temperature of 6.5°C). The percentage of acid vegetation communities in the lakelands under study is as follows: Mecklemburg – 32%, Myślibórz – 45%, Wałcz – 80%, Drawsko – 78%, Kaszuby region – 100%.

Papers of Reimann and co-workers (Reimann and Wójcik 1959, Reimann and Cieśla 1961) concerning changes of soil properties on several areas after their 15–17-year utilization have proved that leaching of basic elements in soils deveoped from sandy loams not always depends on their type. Only in case of nearby occurrence of soils lessivés and brown soils leaching of carbonates runs more intensively in soils lessivés.

The changes after long-term utilization of some objects manifested themselves in widening of the area of acid soils, whereas after such utilization of other ones – in widening of alkaline areas (at the cost of soils of neutral reaction)

While looking over results of the investigations of several objects, the general conclusion can be drawn that the changes would depend on natural condtions of the given object (kind and textural groups of soils, relief, precipitation sum etc.) and on the intendity of measures carried out by man.

Lieberoth (1969) states that in loess soils of Saxony differences in deph of occurrence of carbonates can be observed in profile depending on their tillage time. In young loess soils taken for cultivation 60–70 years ago carbonates occur at the depth of 70 cm, in old soils utilized for 100 years – at the depth of 120 cm.

According to Meyer *et al.* (1962) it is also an important way of soil utilization which could affect the leaching depth of carbonates. He compared the results of examinations of two identical profiles of leached brown soils (mineralogical composition, situation, profile structure, geological origin, thickness). Both profiles developed for the period of over 10000 years under the same climatic conditions below the natural forest cover. The profile of the the first soil represented forest soil. that of the second – soil being since the Middle Ages in the arable utilization. Apart from small differences in the humus, water and colloidal clay content (in the eluvial horizon), very great differences occurred in the decarbonatization depth. In the first profile they amounted to 180 cm, in the second – to 135 cm.

According to Mückenhausen (1978), the soil decarbonatization depth can be affected also by warming up soil depending on the slope exposition activating biological life. E.g., on the slope of northeastern exposition leached brown soil (*Parabraunerde*) was decarbonatized to the depth of 65 cm and on the same slope, but of the southwestern exposition – it was decarbonatized to the depth of 90 cm.

In model experiments carried out by Terelak-Motowicka (1978), calcium losses depending on the liming and mineral fertilization level were determined. At infiltration of 580 cm, leaching of calcium from unlimed loamy soil amounted to 110 kg per hectare. Calcium losses in the same soil, but intensively limed, reached 550 kg/ha, those in the soil without liming and at PK fertilization amounting to 400 kg/ha whereas in intensively limed and PK-fertilized soils they reached 933 kg/ha.

It follows from the model experiments that the mineral fertilization results in a very considerable increase of calcium losses due to leaching and consequently in a strong acidification of soils, counteracted only by calcium compounds contained in soil. The content of carbonates depends (as it was already mentioned) on origin and type of soil as well as on its mineral and mechanical composition.

SPATIAL OCCURRENCE OF CARBONATES AND OF SOIL REACTION

In order to explain how far the content of carbonates would depend on the textural groups of soils, the collection of 48000 analyses (soil data bank) was used by the author (Kern and Pietraś 1980). Samples for the analyses were taken by soil surveyors from characteristic soil profiles and analyzed by agricultural chemistry stations in the period 1965–1970 (during preparation of soil agricultural map of Poland). Thus, they could be regarded as representative for soil conditions of the whole country.

Results of the analyses were ordered according to groups of the mechanical composition of soil samples. In each group the number of soil samples containing calcium carbonates (> 0.1% $CaCO_3$) was determined.

The percentage of soil samples containing carbonates in the textural groups is presented in Fig. 1. For every mechanical fraction (sand, silt, loam and clay) multiple regression coefficients expressing relationship between the content of the given fraction and the $CaCO_3$ content were calculated. These relationships are presented in Fig. 2. It follows from the course of straight lines that, along with increasing percentage of sand in soils of the collection investigated, decreases the $CaCO_3$ content. The silt fraction percentage does not affect the content of carbonates. On the other hand, a considerable effect on the amount of carbonates exerts the percentage of clay fraction (< 0.01 mm), and particularly of colloidal fraction (< 0.001 mm).

The collection of mentioned 48000 analyses was made use of for determining differences both quantitative and connected with the occurrence depth of carbonates in the profile, depending on age of soil. For this purpose, soil units more frequently occurring on the territory of two glaciations (Vistulian and Middle Polish), in which

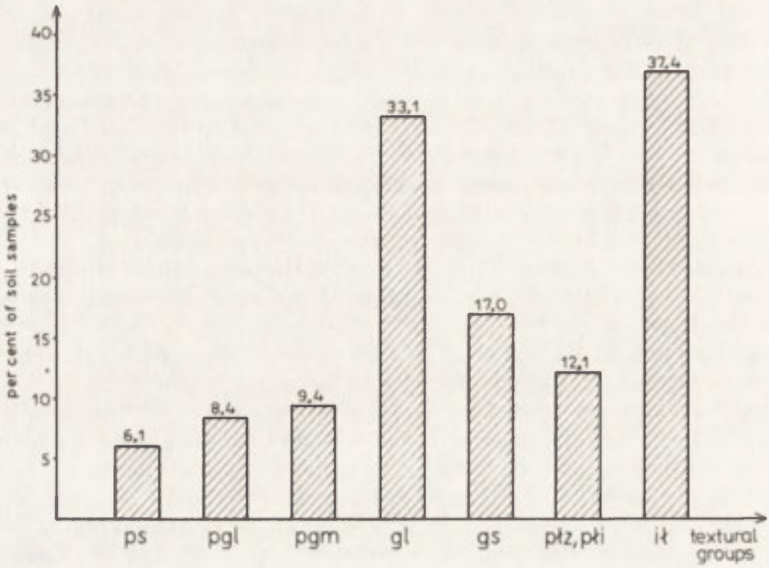

Fig. 1. Per cent of soil samples containing carbonates in textural groups

ps – coarse sand. pgl – light loamy sand. pgm – medium sand. gl – sandy loam. gs – medium heavy loam. płz. płi – silt. ił – clay

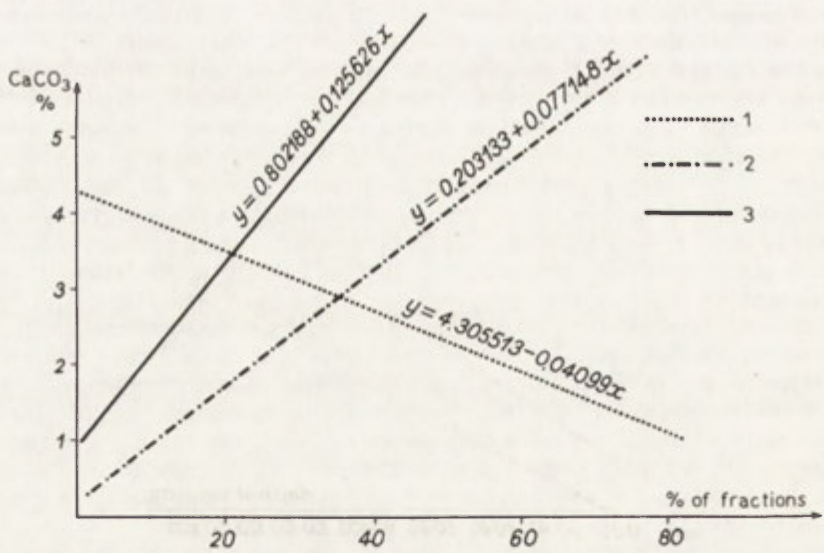

Fig. 2. $CaCO_3$ content in soil profiles depending on the percentage of sand. silt and clay fractions

1 – sandy. 2 – silty. 3 – clayey fraction

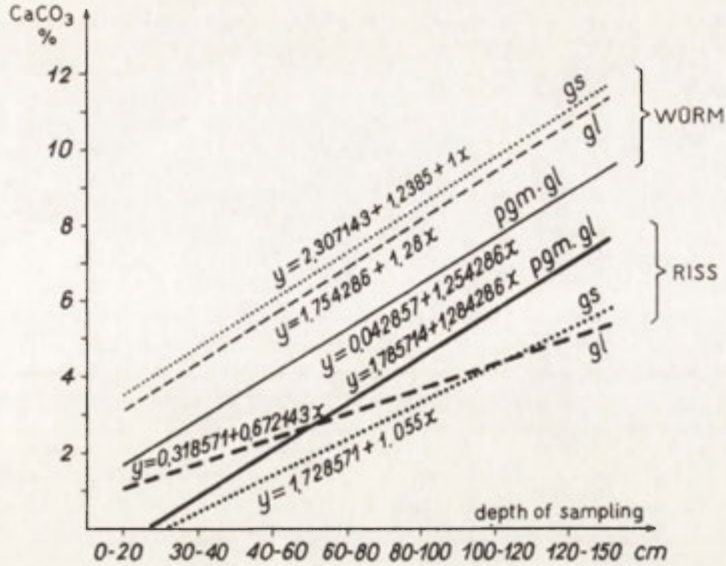

Fig. 3. $CaCO_3$ distribution in soil profiles developed from loams belonging to Würm and Riss glaciations

the presence of carbonates was found, were distinguished. They were soils developed from sandy loam and medium loam.

The sorted out subcollection of these soils comprised 6694 results of analyses (i.e. about 1673 soil profiles). It was divided into two groups of soils according to their localization within the reach of:

I – Vistulian glaciation (Würm),

II – Middle Polish glaciation (Riss).

The calculated linear regression equations illustrate relationships between the $CaCO_3$ content and depth of its occurrence in profiles of four identical soils of the Vistulian glaciation (Fig. 3 and 3a) and their counterparts of the Middle

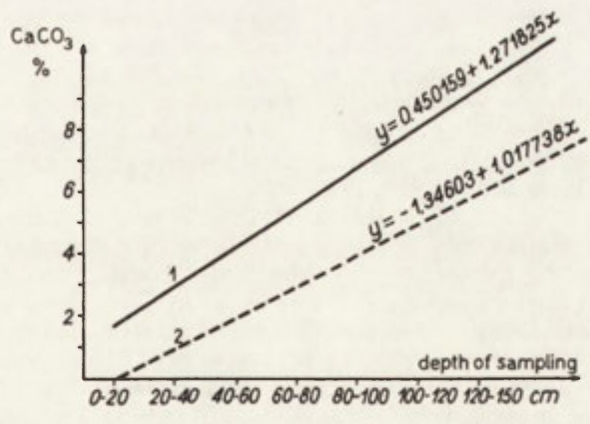

Fig. 3a. $CaCO_3$ distribution in soil profiles developed from sandy loams and medium loams belonging to Würm and Riss glaciations

1 – Würm, 2 – Riss

TABLE 3. Content of carbonates in soils developed from boulder loams of the Vistulian and Middle Polish glaciations

No.	Soil unit	Per cent of samples with $CaCO_3$	Mean $CaCO_3$ content		Semi-intervals of confidence
			Vistulian glaciation	Middle Polish glaciation	
1.	medium sand on loam	15.4	5.06	3.35	3.33
2.	sandy loam	30.3	6.87	3.00	2.74
3.	sandy loam on medium heavy loam	29.4	6.94	2.28	2.17
4.	medium heavy loam	52.5	7.26	2.49	2.18
	Mean for soil units compared	26.6	5.57	2.93	1.11

Polish glaciation. The statistical analysis of results confirmed the significance of differences in the amount of occurring $CaCO_3$ in four couples of identical soil units situated on the territory of the glaciations mentioned. The results of analysis are presented in Table 3.

To obtain a spatial pattern of the soil reaction and the content of carbonates in particular soil profile horizons, the following maps were worked out:

1) occurrence of carbonates in the soil profiles (Fig. 4),
2) occurrence of horizons of neutral reaction (pH_{KCL} 6.5–7.2, Fig. 5),
3) occurrence of horizons of acid reaction ($pH_{KCL} < 5.5$, Fig. 6).

In drafting the maps available results of soil analyses for characteristic and pattern profiles, carried out for the soil cartography purposes in he period 1965–1980 by the agricultural chemistry stations in Poland, were used. The maps contain informations concerning the soil reaction and the content of carbonates in relation to four profile depth intervals: 0–25, 25–50, 50–100 and 100–150 cm.

A characteristic feature of the maps is a distinct regularity in the occurrence of calcium carbonates in the soil profiles and in the horizons of acid reaction. It has been proved that carbonates occur, as a rule, in middle or lower part of the profile. They occur only exceptionally from top, i.e. in the whole profile, in rendzinas, proper black earths (Cieśla 1961) and proper brown soils. The horizons of acid reaction occur mainly in upper and middle part of the profiles. Exception constitute in that case acid brown soils developed from acid parent rocks (e.g. loams of acid reaction in the whole profile). The horizons of neutral reaction occur as well in upper profile horizons (e.g. in anthropogenic soils) as in middle (within the transition between horizons of acid and alkaline reaction) and in lower horizons (in case of regulating effect of ground waters or in the vicinity of deposits rich with carbonates).

The analysis of contents of the map of occurrence of carbonates (Fig. 4) proves that wide areas of the carbonate containing soils are connected with the geological origin and the petrographic and mechanical composition of parent rocks, relief, water conditions and vegetal cover. Soils developed from carbonate rocks (marls, limestones and lacustrine chalk) and from marly loams and carbonate loesses assigned to rendzinas, pararendzinas, proper brown soils, proper black earths and proper chernozems occur on these areas (*Systematyka gleb*... 1974). The widest areas are covered by soils developed from marly loams in the Lakeland Belt and on the Polish Lowland and by soils developed from carbonate loesses, particularly in the eastern part of the Upland Belt, and from calcareous rocks. Carbonate sandy soils occur sporadically and in considerably scattered arrangement.

Acid horizons (Fig. 5) occur mainly in the soil profiles developed from sands and strongly and deeply sandied loams (or sandy loams of acid character) occurring in the Polish Lowland, acid soils in the Coastal Belt and flysh formations in mountains and submontane regions. The areas of acid soils correspond mainly with outwash plains (uniform loose sands) and marginal zones (sands underlain by sandy loam or silt and strongly sandied loams).

The horizons of neutral reaction occur mainly in alluvial soils of the Vistula, Odra and Warta and other river valleys as well as in soils, where flowing ground waters adjust the reaction, in cultivated soils lessives, where man controls the reaction of soil by means of liming, as well as in leached brown soils and degraded black earths, where marly loams or calcium-rich loesses occur often in parent rocks. Localization of soils with horizons of neutral reaction (Fig. 6) is thus connected either with the vicinity of carbonate parent rocks or with the influence of neutralizing factors: anthropogenic (from top) and water factor (from below).

SUMMARY

On the basis of the comparison of contents of the enclosed maps of reaction and occurrence of carbonates in the soil profile as well as of investigations and observations of the author, the general conclusion can be drawn that geochemical processes in the soil medium assumed the line unfavourable for agriculture. It can be confirmed by the following statements:

– on about 70% of the area of agricultural lands of the country acid reaction in upper (and middle) horizons of the soil profile predominates; the total area of soils of neutral and alkaline reaction in mentioned horizons amounts to about 15%, the remaining 15% of soil areas in upper horizons has slightly acid reaction,

– acid soils are liable to further growth of the degree and depth of acidification; it is connected with the occurrence of aluminium in these soils (pH below 5.0), toxic for plants, disturbance of the natural structure of soil, reduction of its biological activity (and consequently of its fertility and yielding capacity) as well as with exclusion from cultivation of some crops sensitive to the acid reaction (like e.g. sugar beets, barley, alfalfa),

– carbonates in upper soil profile layers on wide areas are translocated to middle and lower layers, where these compounds occur most often,

– soils devoid of calcium carbonates are liable to the development of processes of leaching of some macro- and micro-elements necessary for the plant growth (e.g. potassium, boron) or for their retrogradation (e.g. phosphoric acid, molybdenum),

– soils developed from loams, situated on the territory of the Middle Polish glaciation, are more strongly impoverished in carbonates and acidified deeper than the same soils situated within the reach of the Vistulian glaciation,

– about 91% of soils developed from sands (from coarse sands to medium ones) were devoid of carbonates and deeply acidified; only some sandy soils situated in outflow troughs show alkaline and those situated in contemporary flood terraces – neutral reaction.

Thus, the perspective of geochemical transformations of elements in soils cannot be optimistic against the background of the above facts. It is to reckon that, along with the intensification of farming, further losses of basic elements leading to a growth of the degree and depth of acidification of soils could occur. Increased losses of carbonates could occur on the areas submitted to the action of emissions from industrial enterprises producing high amounts of sulphuric and nitric oxides; alkalization of the environment could be observed in the vicinity of dust-emitting

enterprises (e.g. cement mills). Dusts contain, beside calcium and some microelements, also toxic lead, cadmium and fluorine compounds.

It is foreseen that by 1990 the sulphur amounts coming from burning of coal, falling down every year over the Poland's territory, will amount to 7 million tons. With growing motorization an increase of the contamination of soils along communication lines will take place. Alarming is also the fact of occurrence of the so-called acid rainfalls in atmosphere of the Westeuropean countries, the pH of which for the year 2000 is estimated for 3.15. These factors will deepen acidification of soils and contamination of the natural environment. Accumulation of elements and toxic compounds or dusts can lead in some cases to exclusion of arable soils out of cultivation (or to consumptive disqualification of crop yields). In the total balance of losses a decisive role play the total area higher deficiencies or harmful excess of elements, where an evident degradation leading to a drop of fertility and yielding capacity of soils and consequently to a decrease of the quantity and quality of yields, will take place. The fact cannot be left unnoticed, either, that degradation and contamination of the environment, beside the threat of a drop in the quantity and quality of yields, endangers directly human health.

Anticipation of the consequences of equilibrium disturbances in geochemical transformations in soils (due to intentional or unintentional introduction by man of chemical compounds into circulation) enables to work out regional plans of counteracting chemical degradation of the soil medium. In these plans, first of all, the need of control of the reaction of acid soils should be taken into account, at a full consideration of both needs and urgency of liming.

The author hopes that for working out regional plans of counteracting chemical degradation of Polish soils, the cartographic materials (soil-agricultural maps with supplements) prepared by the Institute of Soil Science and Cultivation of Plants for villages, communes and voivodships will be used to a full extent.

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POLISH STUDIES IN PHYSICAL GEOGRAPHY IN MONGOLIA 1974–1980

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The territory of the Mongolian People's Republic is characterized by a great differentiation of the natural environment. Further both social and economic development of this country needs a detailed recognition of its natural resources in order to exploit them rationally. The wide-spread territory of Mongolia and the relatively narrow cadre of research workers are the factors delaying the process of the recognition of those recources. It resolves Mongolian scientific institutions to cooperate with scientists from other countries.

The idea of studies in physical geography in Mongolia was born in Poland early in the sixties (Klimek *et al.* 1976a, b). However, it took ten years before the formal grounds enabling their realization came into existence. Those were agreements on joint research in physical geography carried out in 1974 and 1976 between the Institute of Geography and Spatial Organization, Polish Academy of Sciences and the Institute of Geography and Geocryology, Mongolian Academy of Sciences. On these grounds there were organized two Mongolian-Polish Physical Geography Expeditions: The KHANGAI in 1974–1975 and the TRANSMONGOLIA in 1976–1980. Both expeditions were organized by the Institute of Geography and Spatial Organization Polish Academy of Sciences – Department of Physical Geography in Kraków and were headed by Professor Kazimierz Klimek. About 70 research workers participated in both expeditions. Apart from the Institute of Geography and Spatial Organization, Polish Academy of Sciences, they represented the following institutions: the Nature and Natural Resources Protection Research Center, Polish Academy of Sciences (Kraków), Jagiellonian University (Kraków), University of Mining and Metallurgy (Kraków), University of Agriculture (Kraków), High Pedagogic School (Kraków), Adam Mickiewicz University (Poznań), Mikołaj Kopernik University (Toruń), Maria Curie-Sklodowska University (Lublin), Warsaw University (Warszawa), Forest Research Institute (Warszawa).

Results of studies of those expeditions are successively published. This paper is a review of those studies as to the end of 1982.

VARIABILITY OF THE NATURAL ENVIRONMENT OF MONGOLIA AS A BASIS FOR THE COMPLEX PHYSICAL GEOGRAPHY STUDIES

The territory of Mongolia is situated within two great physico-geographical regions: the mountains of Southern Siberia (Altai, Sayan, Perikhubsugul Mts) and the Plains of Central Asia (Gobi, Basin of Great Lakes). Distinct geological-oro-

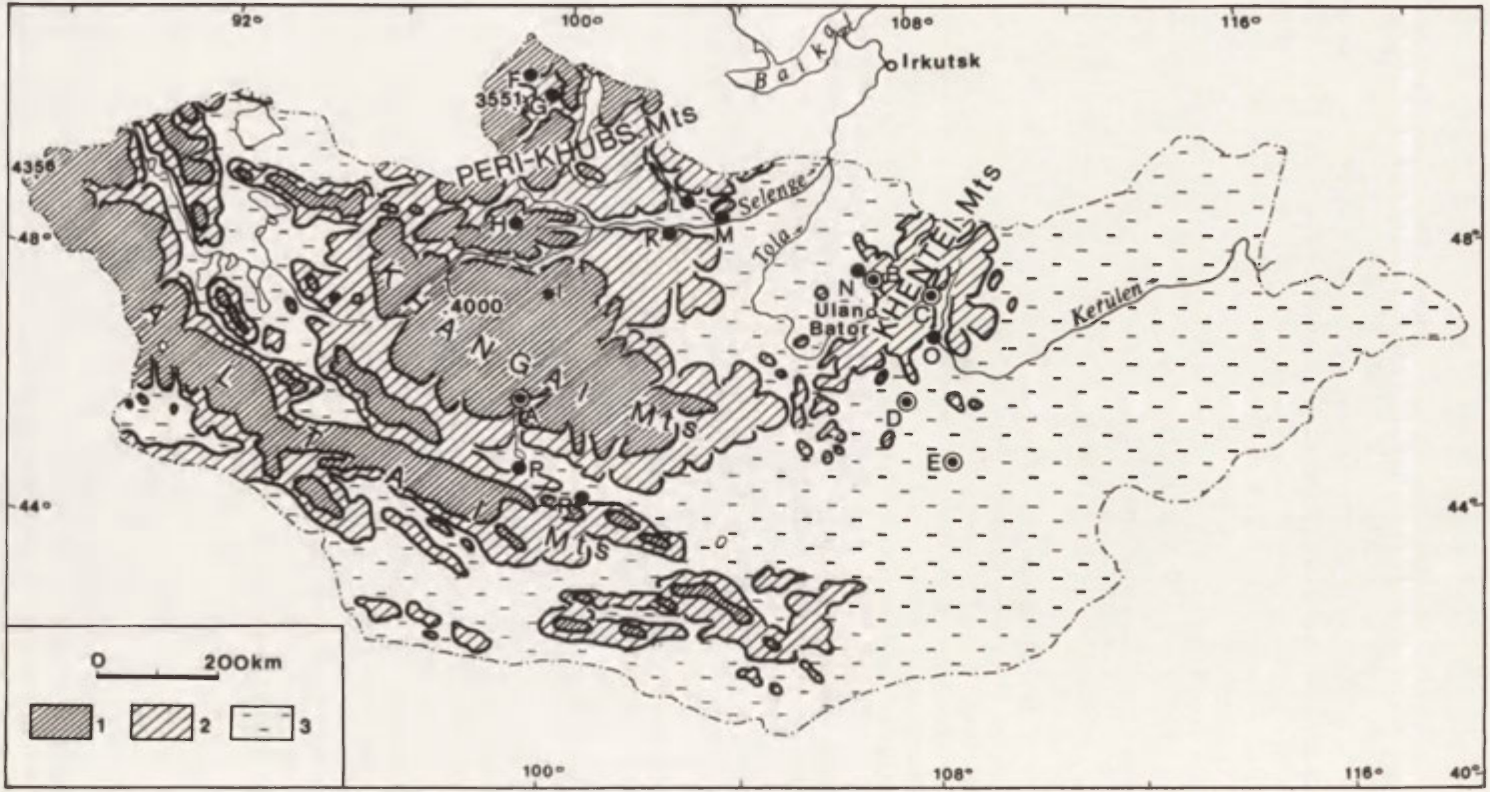

Fig. 1 Study-areas of the Mongolian-Polish Physico-Geographical Expedition against a background of the main relief features of Mongolia

1 – mountains rising above 2000 m a.s.l., 2 – low-mountains or mountain forelands rising to 2000 m a.s.l., 3 – low-mountains of Northern Mongolia or undulating plains of Western Mongolia rising to 1500 m a.s.l. Study areas of research groups: A – KHANGAI, B – KHENTEI I, C – KHENTEI II, D – GURVAN TURUU, E – GOBI; additional study areas of the TRANSECT group: F – Siskhid-gol, G – Darkhat Basin, H – Sangin-Dalai-nuur, I – Terkhin-Tsagan-nuur, K – Selenga river valley, L – Egiin-gol valley, M – Bayan Gol, N – Khara-gol valley, O – Kerulen valley, P – Boon Tsagan-nuur, R – Orok-nuur

graphic differences occuring between those two areas are additionally marked by the climatic-hydrological variability and the differentiation of plant cover resulting from the great parallel wideness of the country.

The high mountain ranges of Northern and Western Mongolia (the Khangai up to 4000 m, the Perikhubsugul up to 3200 m, the Khentei up to 2800 m and the Altai up to 4600 m a.s.l.) (Fig. 1) and separating them intramountain basins are on geological scale the young elements of the relief formed during Tertiary--Quaternary as a result of cutting and an unequal uplift of an old planation surface. Remnants of that surface are clearly visible in the relief of the summit areas of the Khangai and Khentei Mts now.

The hilly or undulating plains of Southern and Eastern Mongolia situated at altitudes of 1000–1500 m a.s.l. contrast with the mountain areas of Northern and Western Mongolia. They form an old planation surface unaffected by young tectonic movements.

The presence of high mountain barriers to the north and west of the country makes difficult inflowing of moist air masses from those directions. It is an additional reason of the strong continentality of Mongolia resulting from its situation in the center of the vast continent (Starkel 1980). Low precipitation (from 100 mm in the south to slightly above 400 mm in the north), wide amplitude of daily and yearly air temperatures together with strong spring winds connected with changes in the global atmosphere circulation are the main climatic features of that area. In the northern part of Mongolia, in vast intramountain basins, mean air temperatures fall below $-30°C$ (minimal ones $-49°C$) in January and in July they are higher than 20°C (maximal ones $+35°C$) in many areas. In winter the lack of snow cover favours strong cooling of the ground surface what results in the occurrence of permafrost in the northern part of Mongolia. Its southernmost limit reaches as far to the south as to 46°36' of latitude.

Northern Mongolia, which is characterized by higher precipitation, slight evaporation, and rivers which are partly supplied in water by melting ground and surface ice, has the drainage system pretty well developed. From that area waters flow to the Arctic Ocean through the drainage systems of the Selenga River, the Baikal Lake and the Jenisey River. The rivers of Eastern Mongolia flow permanently or periodically through the Amur River system to the Pacific Ocean.

Southern Mongolia lies in the endereic area of Central Asia. Considering low precipitation and high evaporation in summer periods, the permanent drainage system is very rare there. However, in the endereic basins there occur fairly numerous episodic or intermittent salt lakes.

The lithologico-orographic and climatic differentiation of the territory of Mongolia results in a great differentiation of soils. There occur the mountain tundra and taiga soils, many types of the steppe chestnut soils, and the burozems desert soils in the Gobi area. In succession such a zonal arrangement of soils and climate results in a very clear zonation of plant cover (Fig. 2). In the summit areas of the Perikhubsugul, Khentei and Khangai Mts there occurs vegetation characteristic of the high mountain tundra and in lower parts – the stone pine-larch mountain taiga. A wide zone is occupied by the mountain forest-steppe. That is hilly area or low mountains where the north-facing slopes are covered by larch forests and the south-facing ones – by steppes. The plain and mountain steppes, the semi-desert (dry steppes) and desert areas have also a wide range (Fig. 2).

Such a strong variability of the natural environment within one country creates possibilities to carry out similar studies in different climatic-plant zones. It is rare opportunity to compare results of investigations, specially in the field of climatology, hydrology, pedology, botany, ecology etc. The differentiation of the natural environment of Mongolia when taking into account the poor knowledge of it,

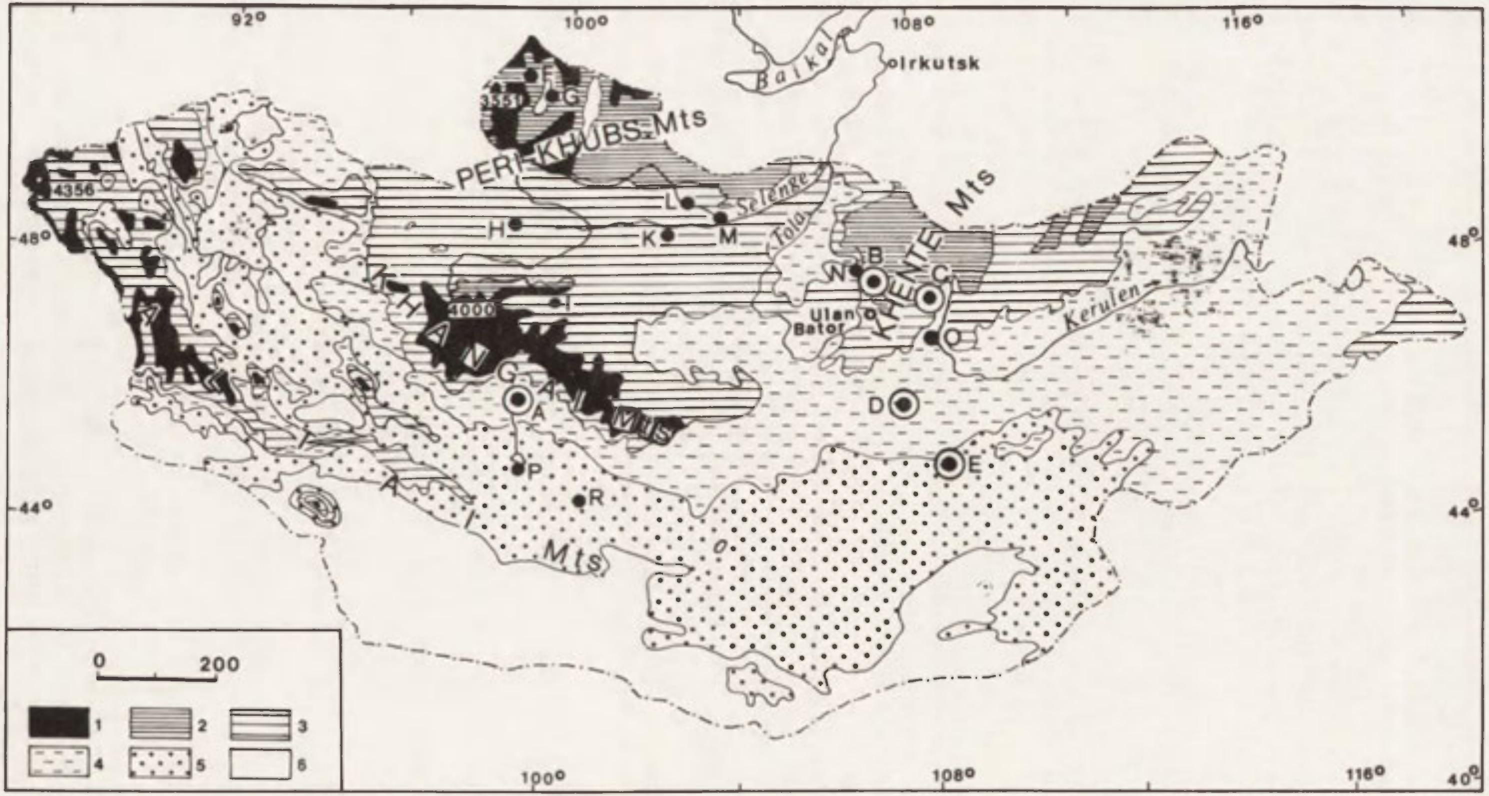

Fig. 2 Study areas of the Mongolian-Polish Physico-Geographical Expedition against a background of the main climatic-plant zones

1 mountain tundra. 2 – mountain taiga. 3 – mountain steppe and forest-steppe. 4 – dry steppe. 5 – semi-desert. 6 – desert.
Study areas of research groups A-R see Fig. 1

created the chance and necessity of multidisciplinary studies. Those studies aimed among others at learning the structure of the natural environment and functions of its elements within the different natural zones of Mongolia.

AREA, ORGANIZATION AND OBJECTS OF STUDIES

The wideness of the territory of Mongolia together with the great differentiation of neighbouring areas demanded the studies to be carried on in areas representing each particular zone. Hence, investigations covered all climatic-plant zones: the mountain tundra, the mountain taiga, the forest steppe, the mountain steppe, the dry steppe and the semi-desert (Fig. 1 and 2). Special attention was paid to the steppe zones, both mountain and plain ones because their natural resources are the most exploited mainly by pasturing.

In the selected parts of those zones, in summer periods, the detailed investigations were carried out in the study areas not exceeding 1000 km^2 supplemented with permanent climatic and hydrologic observations. The representative study areas were as a rule situated in the center of a given climatic-plant zone but in mountains they cover two or more climatic-plant zones (Fig. 2). The set of studies was rather wide. In each of the selected areas there were carried out geological--geomorphological meso- and microclimatic, hydrological and pedological research, together with studies on the intensity and type of present-day geomorphic processes. In four study-areas the botanic investigations were additionally performed and in one area – ecological studies. For the selected small areas (for instance the Sant valley in the Khangai Mts. environments of Gurvan Turuu) the geodetic-topographic maps were accomplished at the scale of 1 : 10000 or 1 : 5000 (Zapolski 1975).

Apart from the multidisciplinary studies mentioned above the supplementary investigations were also carried out in the field of geomorphology, hydrology and pedology in other parts of Mongolia (Fig. 1 and 2). As a rule those investigations dealt with selected questions and were carried out in small areas by teams consisting of 2–3 persons during shorter periods of time.

Studies as a whole were coordinated by Professor K. Klimek who also organized the expeditions. Each particular research-group, consisting of 6–12 Polish scientists and 1–3 Mongolian ones, worked in the chosen representative areas in the course of one or several summer periods.

The KHANGAI-group headed by Professor K. Klimek worked on the south-facing slope of the Khangai Mts in the drainage basin of the Tsagan-Turutuin-gol in the summer periods 1974–1975. Supplementary geomorphologic and hydrologic investigations were made in April 1976. The following zones were taken into account: the high mountain tundra, the forest-steppe, the mountain steppe, and the dry steppe zone in the foreland of the mountains (Fig. 1 and 2).

The KHENTEI I-group headed by Assoc. Professor Tadeusz Ziętara worked on the west-facing slope of the Khentei Mts in the drainage basin of the Sugnugurin-gol in 1977. Supplementary geomorphologic and hydrologic studies were carried out in June-August 1978. The following zones were investigated: the high-mountain tundra, the typical mountain taiga, the mountain steppe and the dry steppe in the Batsumber basin (Klimek et al. 1980; Fig. 1 and 2).

The KHENTEI II-group headed by Assoc. Professor Kazimierz Pękala worked on the south-facing slope of the Khentei Mts in the drainage basin of the Dunda-Bajdalagijn-gol and the adjacent Kerulen valley in the summer period 1978. Investigations were prosecuted in the lower part of the mountain taiga zone, the forest-steppe zone, the mountain steppe zone and the dry-steppe zone in the Kerulen valley (Fig. 1 and 2).

The GURVAN TURUU group led by Professor K. Klimek representing simultaneously the staff of the permanent station worked within the central part of the wide belt of the Mid-Khalkasian dry steppes in 1975–1980. Considering the long period of the activity of that station the scope studies realized by the group was very wide (Fig. 1 and 2).

The GOBI group headed by Professor Karol Rotnicki performed their research within the undulating-plain part of the Gobi near the northern limit of the semi-desert in 1977–1978 (Fig. 1 and 2).

In 1976–1979 the TRANSECT group headed by Professor K. Klimek carried on the additional studies in the field of geomorphology, hydrology and pedology in other areas of Mongolia (Fig. 1 and 2). Those were: the Darkhat Basin in 1979, the upper course of the Siskshid-gol (Yenisey) in 1979, the shore of the lakes: the Sangin-Dalai-nuur in 1979, the Terkhin-Tsagan-nuur in 1979, the Boon-Tsagan-nuur in 1979, the Orok-nuur in 1979, the middle and the upper course of the Egiin-gol valley in 1976–1979, the middle course of the Selenga river in 1977–1978, the Khara-gol valley in 1977–1978, the upper course of the Kerulen river in 1978.

MAIN ACHIEVEMENTS OF THE EXPEDITIONS

The pronounced majority of participants of the expeditions have performed independent studies the results of which have been prepared for publication or already published. Many problems are still in elaboration. The materials collected during those investigations constitute the basis of some important dissertations for D. Sc. and Dr hab. degree being now prepared.

The published material of the expeditions includes above 100 items. It is an important contribution to the understanding of the general or regional problems of many branches of. sciences.

There were two basic goals in the geological and geomorphological studies. On the one hand they aimed at recognizing the paleogeographic conditions of the relief evolution of Mongolia, especially in the Quaternary, on the other hand – at determining the type and intensity of the present-day morphogenetic processes in the different climatic-plant zones.

Paleogeographic studies referring to Russian and Soviet investigations have made a great contribution to the knowledge of the extent and character of the last mountain glaciation in the Khangai and Khentei Mts (Klimek and Sugar 1975, Klimek 1977, 1980a, b. c,) and that of the role of the Quaternary climatic changes in modelling summit areas, slopes and mountain valleys (Klimek 1980d, e; Kowalkowski *et al.* 1977, Kotarba 1980a, Starkel and Kowalkowski 1980, Starkel 1975, Starkel *et al.* 1975, Ziętara 1980a, b). In the foreland of the Khangai Mts in dry at present basins there were recognized deposits of Pleistocene lakes supplied in water by glaciers melting in mountains (Klimek and Sugar 1975, Klimek and Rotnicki 1977, Rotnicki 1977). The mode of transformation of those deposits by Holocene eolian and cryogenic processes was also investigated (Babiński and Pękala 1975/76, Rotnicki and Babiński 1977, Rotnicki and Lomborinchen 1977, Starkel 1980).

Studies on the present-day morphogenetic processes contributed significantly to our understanding of weathering processes, specially the frost-weathering and solifluction processes transforming summit areas and slopes of higher parts of mountains (Dżułyński and Pękala 1980, Kotarba 1980b; Kowalkowski 1977b, Pękala 1975, 1980, Pękala and Ziętara 1977, 1980a, b, c, Ziętara 1981). A contribution was also made to the knowledge of processes transforming river channels and river valleys (Andrzejewski 1980; Froehlich and Sugar 1975; Froehlich *et al.* 1977; Froehlich and Słupik 1977a, b, Klimek 1975, Pękala and Ziętara 1980b; Świeca 1979). Moreover,

Photo 1. Darkhat Basin. The tectonic depression bordered to the east on the Khoridulin-Sardig Mts rising above 3000 m a.s.l. (Photo K. Klimek)

granulometry an morphoscopy of quartz grains weathering in different climatic conditions were studied (Dżułyński and Kotarba 1979, Kowalkowski 1975, Malarz and Pękala 1980, Lomborinchen *et al.* 1975/76; Kowalkowski *et. al.* 1980).

In the field or climatology a significant contribution was made to the understanding of the following questions: meso- and microclimatic relations and a balance of soil radiation within the dry steppes of Central Mongolia (Kowanetz and Olecki 1980, Hess *et. al.* 1980, Bublewski *et al.* 1981), a zonal variability in climatic conditions on the south-facing slopes of the Khangai Mts (Brzeźniak 1977, 1980, Brzeźniak and Niedźwiedź 1980), and a daily variability in climatic elements of

Photo 2. Khubsugul Lake. The deepest lake in Mongolia (238 m) filling the large tectonic depression (Photo K. Klimek)

Photo 3. Northern slope of the Khangai Mts. The Chulutuin-gol canyon cutting in basalt rocks (Photo K. Klimek)

a summer period in mountain valleys of the Khangai and Khentei Mts (Airmid and Niedźwiedź 1975, Brzeźniak 1980, Brzeźniak and Malarz 1980, Niedźwiedź *et al.* 1975).

In the field of hydrology some more important achievements are the folowing ones: the learning of an overland flow phenomenon, infiltration of preciptation waters and mineralization of surface and ground waters within the mountain seppes and the dry plain steppes (Slupik 1975, Michalczyk 1979, Chełmicki and Tserev 1980, Wicik 1981), the understanding of a summer hydrological regime of small

Photo 4. Southern slope of the Khangai Mts. The Tsagan-Turutuin-gol in the Bayan-Nuurin-khotgor tectonic depression (Photo K. Klimek)

Photo 5. Western foreland of the Khentei Mts under snow cover; a very rare phenomenon (Photo K. Klimek)

mountain rivers according to the mode of their supply in water (Froehlich et al. 1975, Dauksza and Soja 1977, Michalczyk *et al.* 1979, 1980, Soja 1980, Glazik 1980, Woźniczka 1980) and possibilities of natural irrigation of the selected valleys in the Khangai foreland (Froehlich and Slupik 1975).

A contribution was made to the recognition of a phenomenon of icing (Froehlich and Slupik 1977b, 1978, 1982 Pękala and Ziętara 1980d) and that of occurrence and degradation of permafrost in a summer period (Babiński 1977, 1980, Babiński and Grześ 1975, Babiński and Pękala 1975/76).

A great contribution was also made to the understanding of typology and the

Photo 6. Middle-Khalkhasian Plain. An example of undulating steppe plains in Central Mongolia (Photo B. Nowaczyk)

Photo 7. Lake Valley. Sand dunes parallel to the river valley scarp at the northern border of the Gobi (Photo K. Klimek)

Zonal and vertical arrangement of Soils according to local geologic and orographic conditions and vertical or zonal changes in climatic-plant relations (Dorzigotov and Kowalkowski 1981, Kowalkowski 1977a. b. c. 1978. 1980a. b. c. 1981. 1982; Kowalkowski and Borzyszkowski 1980, Kowalkowski and Lomborinchen 1975, Kowalkowski and Mycielska-Dowgiallo 1980, Kowalkowski and Pacyna 1977, Kowalkowski *et al.* 1980 a. c. 1981; Skiba 1980a. b. Pomian 1979).

Geobotanical studies carried on in the Khangai and Khentei Mts and in the steppes of Central Mongolia (Kowalkowski and Pacyna 1977, Pacyna 1980a, b; Święs 1979) made possible the detailed recognition of the vertical arrangement of

Photo 8. Gobi Altai Mts rising up to 4000 m a.s.l. Typical desert vegetation (nitnria) in the foreground (Photo K. Klimek)

plant cover according to local habitat changes conditioned mainly by water-climatic relations as well as human impact in forest (Lach 1980).

Ecological studies performed only in the steppes of Central Mongolia resulted in the collection of interesting material concerning the habitat of small mammals, their metabolism and role in the circulation of organic matter (Górecki and Weiner 1981, Górecki *et al.* 1982, Weiner and Górecki 1981, 1982, Weiner 1981, (Weiner *et. al.* 1982a, b, Zieliński 1982).

The above review shows that Polish studies of physical geography of Mongolia covered a broad range, and the set of problems they dealt with was also wide. For many Polish scientists who had previously done their research only in Poland the expeditions created possibilities to carry out studies in different natural conditions. Together with Mongolian and Soviet scientists they have made a significant contribution to the understanding of the nature of that part of Asia.

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WATER CIRCULATION IN THE STEPPE ZONE OF MONGOLIA

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The upland steppes of Mongolia cover over 25 per cent of the total area of that country. Due to the abundance of grassland it is an important economic region. On account of a considerable deficiency of precipitation in relation to the potential evaporation, estimated at about 760 mm/year (*Mirovoy*... 1974), the knowledge of water circulation and evaluation of conditions of the formation of water resources are of great practical significance.

There is a lack of thorough studies on water circulation in the region of the Mongolian steppes. Earlier hydrological investigations of water conditions of steppe, carried out by Russians (Kuznetsov 1964, 1968, 1973, Kuznetsov and Murzaev 1963, Marinov 1956, Marinov and Popov 1963, and others), had a general character. The results of the most recent investigations carried out in the steppe and forest-steppe zones are to be found in publications by the Mongolian-Polish Geographic Expeditions: "Khangai 1974–1975" and "Transmongolia 1976–1978" (Froehlich *et al.* 1975, Słupik 1975, 1980, Chełmicki and Tserev 1980, Chelmicki 1982, Glazik 1980, Michalczyk *et al.* 1980, Soja 1980).

LOCALIZATION OF THE STUDY AREA

The studies of water circulation here discussed were carried out in three summer seasons of 1976, 1977 and 1978 in the vicinity of the Mongolian-Polish Physical-Geographic Scientific Station "Gurvan Turuu" localized in the western part of the Middle-Khalkhasian Plateau (Murzaev 1957). The study area lies in the middle part of the upland steppe zone, in the northern part of the undrained continental basin of Central Asia and within the zone of sporadic occurrence of permafrost (Fig. 1).

CHARACTERISTIC OF THE STUDY AREA

Hydrological investigations cover an area of about 400 km^2. The altitude ranges from 1260 m to 1617 m a.s.l. The landscape is characterized by low ridges of relative altitude up to 200 m, divided by valleys and undrained depressions.

The following structural-morphologic units (Fig. 2B) have been distinguished (Dzulyński 1977, 1978):

– Eastern Plateau, composed mainly of granite, culminating at the Bayan Ovo Peak (1617 m a.s.l.);

– Zone of metamorphic rocks (granitogneisses, metamorphic schists and marbles);

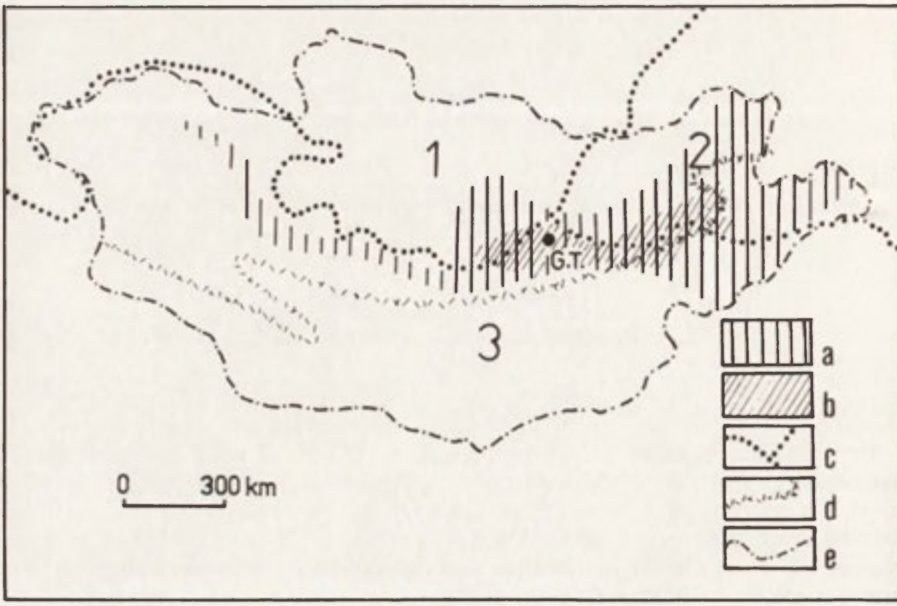

Fig. 1. Localization of the "Gurvan Turuu" Scientific Station (G. T.)

a – extent of the upland steppe zone (after Yunatov 1950). b – Middle-Khalkhasian Plateau (after Murzaev 195'). c – continental watershed on Mongolian territory (1 – drainage area of the Arctic Ocean. 2 – drainage area of the Pacific Ocean. 3 – undrained basin of Central Asia). d – southern limit of the permafrost (after Gravis 1974). e – state boundary of Mongolia

– Fault delineated depression, composed mainly of basalts occurring in the form of lava flows. The basalts form systems of fault blocks inclined toward the axis of depression. The central part of this depression is filled with various sedinents (Cretaceous sandstones and shales, Neogene limestones, marls and gypsum, Quaternary sands and gravels).

The climate of the Middle-Khalkhasian Plateau is strongly continental. The annual mean temperature is 2.7°C, mean temperature of January is −23.5°C and of July is 15.5°C. The mean annual precipitation is about 250 mm, out of which 200 mm fall in June, July and August (*Klimaticheski*... 1971).

In the vicinity of Gurvan Turuu the chestnut soils prevail. The thickness of the soils decreases towards summit areas of the elevations and increases towards depressions. The chestnut soil of the steppe is overgrown with Artemisia, Stipa and Caragana as the dominating species. The bottom of undrained depressions is covered with silty material overgrown with halophytes.

The characteristic features of the investigated region may be regarded as representative for the whole area of Mongolian steppes. Due to specific climatic conditions, the steppe of Mongolia finds no analogues in other steppe areas of the world.

WATER PHENOMENA

Surface water. Distribution of the surface water phenomena in the vicinity of Gurvan Turuu is shown in Fig. 2. The study area is characterized by a complete lack of perennial streams. Only one seasonal stream occurs in the tectonic depression. The mean discharge of the stream in summer months is about 10 l/s. The steam

Fig. 2. Hydrographic map of the vicinity of Gurvan Turuu (A) with the schematic geological sketch (B)

1 – seasonal stream. 2 – episodic streams. 3 – routes of flow of episodic water. 4 – perennial lakes. 5 – seasonal lakes. 6 – episodic lakes. 7 – seasonal springs. 8 – shallow sinked wells (the wells under observation are marked with numbers as in Fig. 5). 9 – deep drilled wells. 10 – areas of wet grounds. a – Eastern Plateau. b – metamorphic rocks area. c – basalt fault scarps. d – central part of the tectonic depression

is supplied mainly by underground water. In some places water disappears completly in alluvial deposits and then reappears again. The stream ends in the salt pans of the Baga Omboi Nuur Lake (about 20 km to the south of the study area).

The course of episodic streams, marked out on the map, coincides with that of distinct channels showing evidences of water flow (e.g. deposited rock material and fresh erosive undercuts). Episodic streams flow only after heavy rain-storms, which occur probably only once in every few years.

The routes of flow of episodic waters coincide with the course of V-shaped valleys, collecting water from the overland flow. However, these valleys seldom if ever, show recognizable traces of water erosion.

Salty seasonal lakes are most characteristic among the hydrographic elements of landscape. They occupy the bottoms of undrained depressions filled with silty sediments. Only one perennial fresh-water lake (Hoir Nuur) – made up of two ponds – occurs in the investigated area. This lake is supplied by a large spring and drained through underground conduits.

The seasonal lakes are numerous (Fig. 2). Salinity of these lakes ranges from 3 to over 200 g/l. The lakes are filled with water every year, after the first heavy summer rainfall.

The episodic lakes of the study area are filled with water, probably, once in several years, after exceptionally heavy rainstorms.

Groundwater. Groundwater occurrs in granites, basalts, alluvial sands and gravels. Particulary large resources of groundwater are found in sponge-like basalts. Free water table occurrs within the marginal fault scarps of the tectonic depression, whereas in the central part of the depression there are subartesian waters. Groundwater resources in the Quaternary alluvial sediments are also very abundant. They do not form a single aquifer but numerous separate, small aquifers, which occur within valleys and undrained depressions.

In granites water occurs in fissures only; granite aquifer is not abundant in water.

According to Marinov and Popov (1963) the artesian or subartesian waters occur in Cretaceous sandstones and conglomerates, Neogean limestones and marls lying on basalts within the central part of tectonic depression.

Springs are of seasonal character and in general gave a low discharges (ca 0.1–1.0 l/s). They are supplied with water mainly from the Quaternary alluvial deposits filling the bottom of valleys.

WATER CIRCULATION

Water circulation in the undrained areas consists of the following components: precipitation, infiltration, overland flow and evaporation.

The precipitation data are from the Climatological Station at Gurvan Turuu.

Measurements of infiltration were made with Burger cylinder infiltrometer at 32 measurement sites, localized within the range of representative transect (Fig. 2) including the main morpho-structural units of the study area. The boundaries of the areas characterized by similar values of permeability, have been delineated basing on geomorphological map made by Kotarba (1978) and the map of soils made by Kowalkowski *et al.* (1979). The intensity and dynamics of infiltration was estimated by analysing changes of soil moisture and groundwater level.

The overland flow was estimated on the basis of the results obtained on two experimental plots, localized on typical basalt and granite slopes, covered with several tens of centimetres of waste. The plots, 80 m^2 each, were bounded from above and on either side by plastic foil inserted into the ground. Water from the overland flow accumulated in gutters, set up at the foot of the plots, and then carried off into containers.

Evaporation rates from water surface were based on diurnal observations of the water losses in the seasonal lake during the rainless periods. The absence of water percolation into the silty bottom of the lake was confirmed by infiltration measurements. The supply of water into the lake by four seasonal springs was also taken into account in the evaluation of evaporation.

Evapotranspiration was evaluated on the basis of the losses of soil-water in the 40-centimetre-thick layer of chestnut soil during rainless periods.

Precipitation. The continental climate of the Mongolian steppes is characterized by high concentration of precipitation in the summer season. Over 80 per cent of the total annual precipitation fall during three summer months. The first major rainfall occurs usually in late June and early July. This is followed by intensification of water circulation, manifested in activation of the springs and filling lake basins with water. An earlier occurrence of first rainfall may stimulate an earlier occurrence of some water phenomena.

Another characteristic feature of climate is great variation of annual precipitation totals from year to year (Table 1) and considerable differentiation of the spatial distribution of precipitation. In the vicinity of Gurvan Turuu rainfalls of a limited spatial range are frequently observed. They are usually limited to few kilometres as confirmed by differences in the filling lake basins with water.

TABLE 1. Monthly totals of precipitation at Gurvan Turuu during seasonal investigations in 1976, 1977 and 1978, compared with mean values of the long period precipitation data (in mm)

Month / Year	May	June	July	Aug.	Sept.
1976	•	29.0	75.2	19.8	•
1977	20.4	15.7	112.0	46.1	13.2
1978	53.8	80.4	25.4	13.1	•
The average annual precipitation for the period 1956–1963	7	39	106	57	24

Diurnal totals of precipitation are usually low (cf. Fig. 6). Days with precipitation totals not exceeding 10 mm. make up over 85 per cent of the total number of days with precipitation. During the studies comprising 12 summer months altogether, only two days with precipitation exceeding 30 mm and a single day with precipitation exceeding 40 mm were recorded.

Generally, the intensity of rainfalls is low; in the range of 0.01–0.1 mm/min. Passing showers of a few millimetres, occur often. Rainstorms of a very high intensity occur sporadically. The highest intensity of rainfall recorded at Gurvan Turuu in the period of 1976–1978 was 1.7 mm/min.

Infiltration. The process of infiltration of rain-water depends first of all on perme-

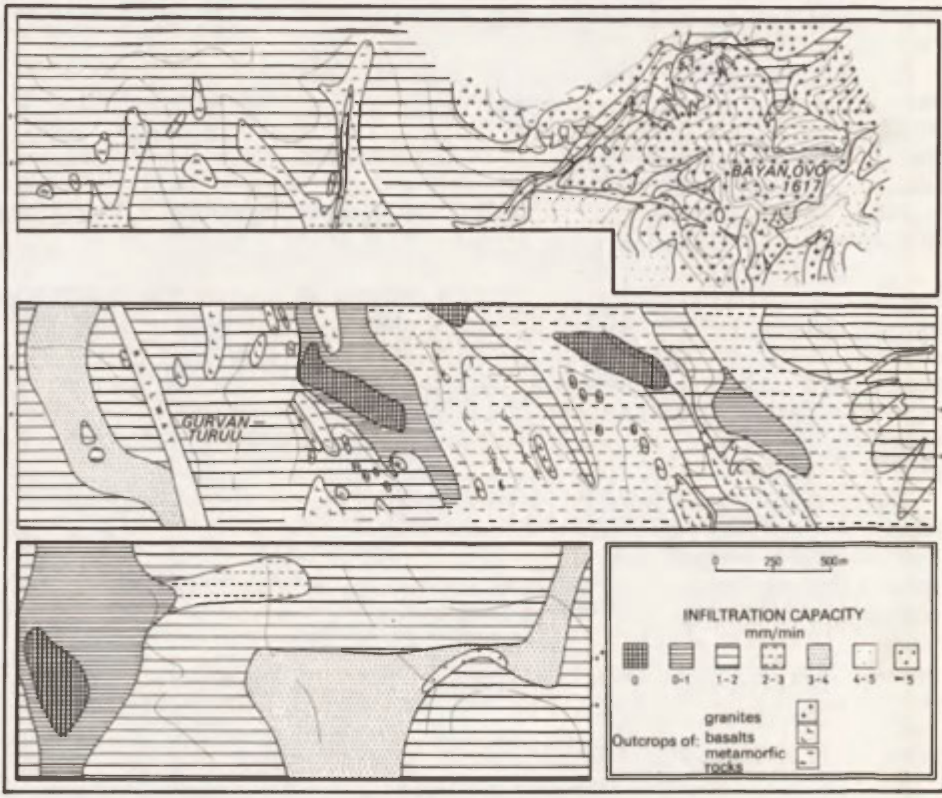

Fig. 3. Infiltration capacity of the superficial formations within the range of representative transect

ability of the superficial formations. Permeability of superficial formations is expressed by infiltration capacity (mm/min).

Infiltration capacity of steppe soils varies considerably from 0 to over 5 mm/min (Fig. 3). The lowest capacity is observed in silty sediments filling the bottoms of undrained depressions. After saturation with water, these sediments are practically impermeable; insignificant infiltration of water may occur only along polygonal cryogenic and thermal fissures. In areas occupied by silts there are, therefore, favourable conditions for the formation of lakes.

Soils with infiltration capacity of 1 to 3 mm/min are predominant. They occur mainly on the waste-covered slopes. Within the basalt areas a decrease of permeability of soils in the direction of depressions is observed. That is a result of fine granularity of the waste. A reverse situation is observed in metamorphic and granitic rocks. Here, the valley sediments show higher permeability than the waste covered on summit areas. This is due to the fact, that in the valleys, a coarse-grained waste – resulting from granular disintegration of crystalline rocks – is deposited. Infiltration capacity of the sediments deposited in the episodic stream bed at the foot of Bayan Ovo reaches 10 mm/min.

In areas of outcrops of basalts, metamorphic rocks and granites, conditions of water infiltration are differentiated. The basalts are able to absorb some quantities of water, especially in places where of the upper parts cavernous lava flows are exposed. Where the lower and less cavernous parts of lava flows are exposed, there is insignificant infiltration of water.

Observation of natural process of rain-water infiltration is possible by examination of soil moisture in profile-section (Fig. 4). The course of soil-water storage in a 40-centimetre-thick layer of chestnut soil, show that, in spite of good permeability of soil (1.8 mm/min), the percolation through the whole profile occurs only after very heavy rainfalls of about 40 mm. After low yield rainfalls, soil water returns to the surface before reaching the bed rock. This is a result of high soil capillarity and of intense evaporation. The groundwater alimentation by way of rain-water infiltration is therefore possible chiefly in places, where the waste cover is thin: it is in the summit areas. In places of thick sediments, the groundwater alimentation by rain-water infiltration is of a little significance. This is confirmed by observations of the position of groundwater level in wells (Fig. 5). It was found, that relationship between precipitation and the groundwater level is not distinct. When the daily total of precipitation is at least 20 mm, a marked rise of the groundwater table occurs. In the periods without heavy rainfalls, lowering of the groundwater table occurs.

The role of permafrost in determining the level of groundwater is insignificant, due to the small extent of frozen grounds. The effect of permafrost was observed only in one of the four wells examined. It was manifested in the tendency towards lowering of the water table, which is connected with springtime thawing of the active layer (Fig. 5).

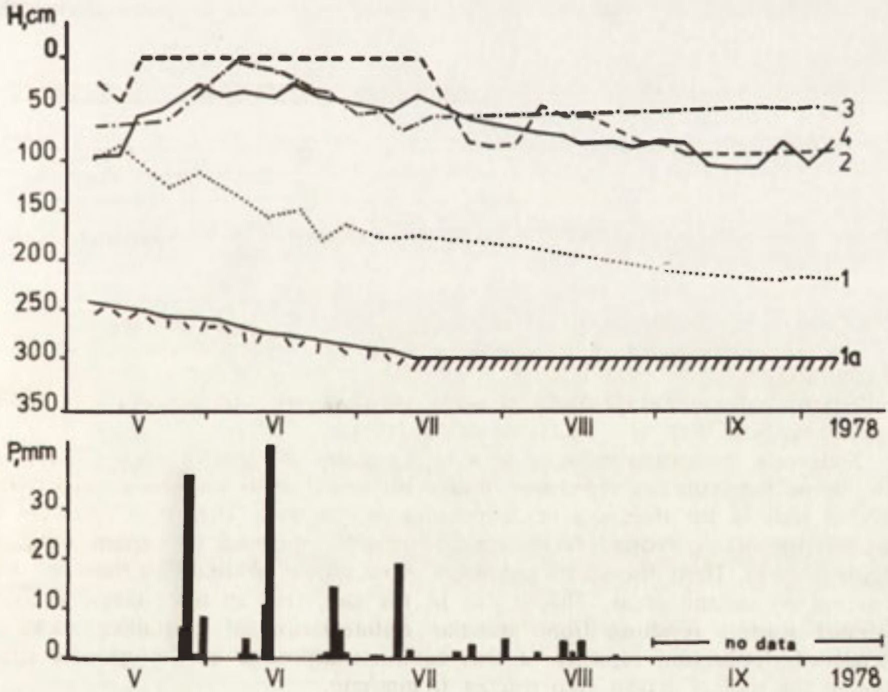

Fig. 5. Groundwater level in shallow alluvial wells (H) in relation to precipitation (P) in the vicinity of Gurvan Turuu during seasonal investigations of 1978

1 8 – numbering of the wells as in Fig. 2, 1a – bottom level of the well no. 1 varying in result of melting of the active layer of permafrost

Overland flow. The overland flow depends mainly on the intensity of precipitation and permeability of the ground. The comparison of these two parametres indicates, that there is a very small probability of the occurrence of overland flow in the greater part of the study area. During the three seasons of the investigations, a single case of overland flow on a large scale was recorded (13 June 1978). A considerable rise of the seasonal stream discharge, activation of episodic streams and flow of water in the V-shaped valleys were observed simultaneously. It was due to a very heavy rainfall (Table 2). Such rainfalls occur probably once upon several years. The remaining precipitations, which occured at Gurvan Turuu in the years of 1976–1978, did not create the overland flow on a large scale. The data given in Table 2 refer to the typical slopes covered with well-permeable waste. Different conditions of the overland flow are found within the range of the bottoms of undrained depressions, because these areas are covered with impermeable silts. This makes possible the occurrence of the overland flow after each rainfall of at least a few millimetres. Therefore, in the periods of summer rainfalls there are good conditions for the creation of seasonal lakes in undrained depressions. The changes of water level of seasonal lake in relation to precipitation are illustrated in Fig. 6.

The precipitation of a few millimetres do not cause the filling up of the lake basin with water. When the seasonal lake is already filled and the neighbouring silts are saturated with water, the precipitation of a few millimetres is enough to produce a slight rise of the level of water.

Evaporation from water surface. The mean diurnal evaporation from the water table of seasonal lake, evaluated on the basis of the losses of water during the

TABLE 2. Overland flow on experimental plots during seasonal investigations of 1976, 1977 and 1978

Date	Plot on basalt slope				Plot on granite slope	
	precipitation			overland flow	precipitation total	overland flow
	total	mean	max.			
	mm	mm/min	mm/min	mm	mm	mm
1976						
3/4 July	24.5	•	•	0.025		•
22 July	13.7	•	•	0.062	14.0	0.082
23/24 July	24.8	•	•	0.040	41.0	0.277
1977						
30 June	4.9	0.065	0.5	0.018	5.5	0.000
6/7 July	24.8	0.015	0.2	0.015	17.0	0.000
21 July	12.2	0.072	0.6	0.067	19.3	0.047
22/23 July	37.5	0.023	0.1	0.102	41.3	0.033
1/2 August	17.3	0.038	0.2	0.000	18.6	0.010
1978						
13 June	37.0	0.037	1.5	12.3	•	•
9 July	17.5	1.700	1.7	flow from melting hail	•	•

Annex to the article by W. Chełmicki

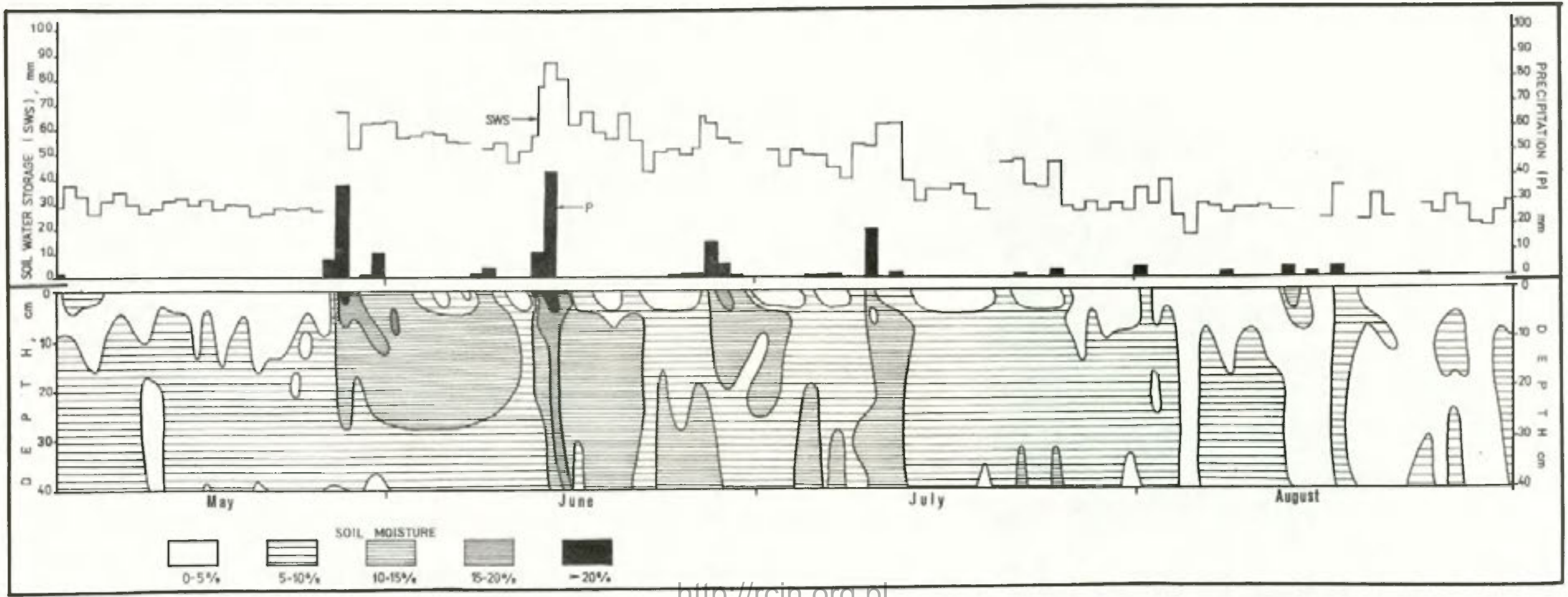

Fig. 4. Soil moisture and soil-water storage in the 40-centimetre-thick layer of chestnut soil in relation to precipitation in the period of May 5th–August 31st, 1978

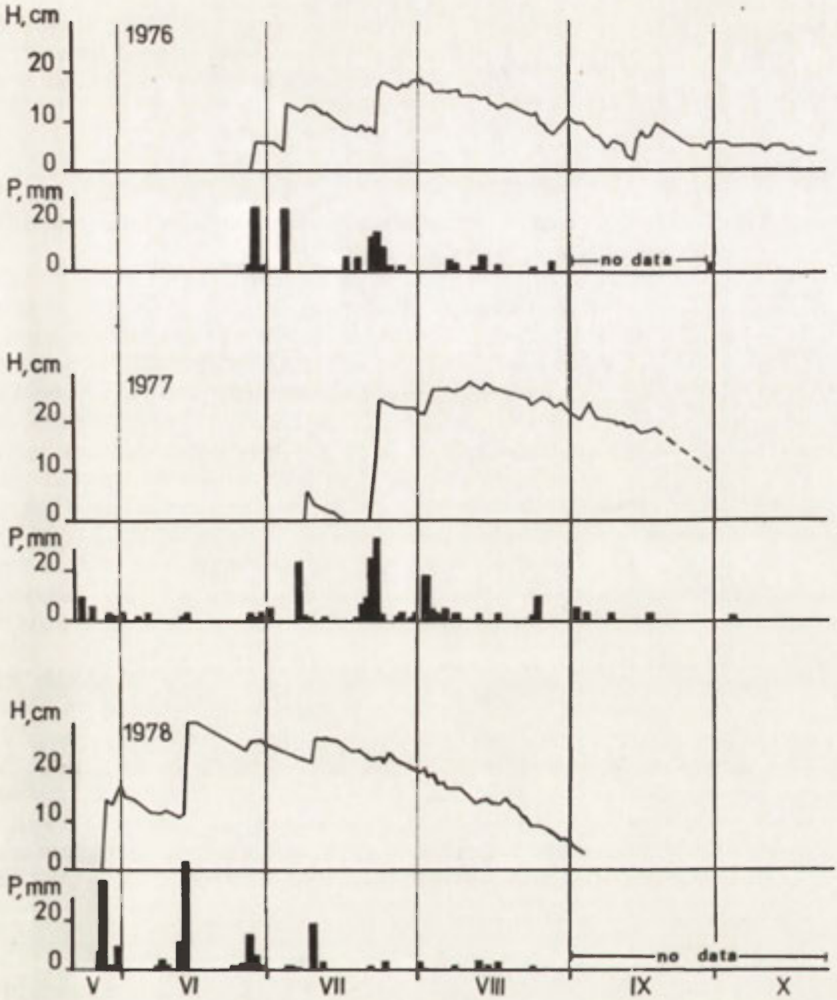

Fig. 6. Water level of the seasonal lake (H) in relation to precipitation (P) during seasonal investigations of 1976, 1977 and 1978

rainless periods, amounts in summer months to about 4.5 mm. The maximum diurnal evaporation may sporadically exceed 15 mm. Since the thickness of the water layer in most of steppe lakes does not exceed 25–30 cm, the disappearance of lake water, caused by evaporation in rainless periods, takes place in about 50–60 days. Due to a large diurnal sums of evaporation, the low-discharge springs do not play significant role in the shaping of the water table of lake.

Evapotranspiration. Evapotranspiration, evaluated on the basis of the losses of soil water in the 40-centimetre-thick layer of chestnut soil (cf. Fig. 5), varies much more than evaporation from the water surface of seasonal lakes. The values of evapotranspiration are controlled by the quantities of water stored in the soil. The average daily losses of soil-water range from 3 to 7 mm. In the periods of high soil-water storage, the daily losses of soil-water are higher than in the periods of low storage, and average up to 23 mm.

Fluctuations of soil-water storage may also be caused by water supply from other sources, not connected with precipitations. Favourable conditions for water condensation in the soil may arise in the early summertime, when the ground is cool.

CONCLUSIONS

Results of the studies lead to the following evaluation of the role of the particular components of water circulation in steppe areas:

– Precipitation is the main factor controlling the dynamics of water circulation and the development of water phenomena in summer months. In the wintertime the role of precipitation in the formation of hydrological conditions is insignificant. Rainfalls occurring in the Mongolian steppe zone are characterized, in general, by low intensity, which results in the predominance of infiltration over the overland flow.

– Infiltration, owing to moderate intensity of rainfalls and very good permeability of chestnut soils, makes possible absorbtion of the nearly total amount of rainwater by the superficial waste material. This does not include the areas of impermeable silts, where conditions for the creation of episodic and seasonal lakes are favourable.

– Overland flow do not play an important role in the creation of hydrological conditions of steppe. Overland flow – except in the areas of silty sediments – occurs only sporadically. The annual total amount of the overland flow may result from one single violent flow.

– Evaporation is the dominant hydrological process in the Mongolian steppe zone during the summer. Potential evaporation exceeds considerably the amount of precipitation. In thc periods when the ground is dry, the main cause of the losses of water is evaporation from the water table of lakes. In the periods, when the ground is wet, the role of evaporation from lakes is relatively small, due to the fact that the total area covered by lakes is very small in comparison with that of the land. An intense evapotranspiration cause, in spite of good permeability of the soils, a marked shortening of the underground phase of water circulation.

Acknowledgements

I wish to express my grateful thanks to Prof. K. Klimek – the chief of the expeditions to Mongolia, and to Prof. I. Dynowska, for their help in realization of the hydrological investigations. I am indebted to O. Tserev from the Mongolian Academy of Sciences, for his assistance in the field work and to Dr A. Kotarba, Dr A. Kowalkowski and Mr L. Kowanetz for help in making available data from the field of geomorphology, soil science and climatology. I am also greatly indebted to Prof. S. Dżulyński for his critical reading of the manuscript.

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GLACIAL SEDIMENTARY FORMS OF THE PRESENT-DAY GLACIATION IN SPITSBERGEN

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INTRODUCTION

It is nearly for 150 years that glacial forms have been studied. The term moraine was defined for the first time by Agassiz in 1837 and Charpentier in 1841 (Pawłowski 1938, Drygalski and Machatschek 1942, Woldstedt 1954). Through the 19th century all the principal types of moraines were recognized, chiefly in the Alpine regions. However, terms that even referred to the same type of a moranic form abounded in literature. For that reason, at the suggestion of Eduard Richter, then the president of the International Glacier Commission, a scientific conference was held at Gletsch in Switzerland from 20th to 25th August, 1899 to propose a classification of moraines (Böhm 1901; Pawłowski 1938; Gripp 1938; Drygalski and Machatschek 1942). Nineteen scientists, including such distinguished workers as Drygalski (Berlin), Finsterwalder (Munich), Heim (Zürich) Lugeon (Lausanne), Penck (Vienna), Richter (Graz) and Baron Toll (Petersburg), attended the conference. After trips to the Rhone and Unteraar glaciers, the classification of moraines was drawn up during seven debating sessions at the conference. Parts of the Conference Proceedings were published by Richter. The classification developed by the conference participants is described in detail in the work of Böhm (1901), which also offers a detailed review of literature on moraines till 1900. The conference participants put different types of Alpine moraines into two main groups: moving moraines and deposited moraines (at rest). A simplified scheme of this classification is as follows:

I. Moving moraines
   1. Surface moraines
      (a) lateral moraines
      (b) median moraines
   2. Internal moraines
   3. Basal moraines

II. Deposited moraines (at rest)
   1. Dumped moraines
      (a) longitudinal moraines
      (b) border moraines
   2. Ground moraines
      (a) ground moraines
      (b) drumlins

The above classification was exhaustively and sharply criticized by Böhm. In brief, his criticism raises the following points:

1. It is unnecessary and unjustifiable to separate the essential concept of ground moraine into basal moraine (moving) and ground moraine (at rest).

2. Deposited moraines comprise only dumped moraines and ground moraines. Thus, following this classification system, all that is not a dumped moraine is a ground moraine; such an approach would be misleading.

3. In many cases it is difficult to determine which morainic material is at rest and which is moving. For this reason, the above classification scheme distinguishes between different types of moraines in a false manner.

Böhm (1901, pp. 266–267) developed his own classification comprising as many as 23 types of moraines. Too many detail and a lot of inconsistencies in his classification system made its adoption in science inadvisable. A still more comprehensive classification of moraines was provided in 1904 by Oyen (Charlesworth 1957, p. 404). It was not adopted in science, either, because of the introduction of new nomenclature and unnecessary differentiation of morainic subtypes. In spite of Böhm's criticisms of the classification drawn up at the conference of 1899, it was just this classification that received common attention and was quoted in many textbooks (Drygalski and Machatschek 1942; Charlesworth 1957; Lencewicz 1954).

During discussions at the Geographical Congress that was held in Amsterdam in 1938, Gripp and Pawłowski presented a general classification of end moraines. On that occasion Pawłowski put emphasis on the fact that the moraine classification of 1899 had no genetic implications as it allowed only for locations of particular moraines and was not quite consistent even in this respect.

In spite of countless critical remarks, however, up till now there has been no classification that would be entirely satisfactory for the present-day state of knowledge of moraines. A complete classification of moraines, like that of 1899, should be a result of joint efforts of a number of workers who have known a variety of glacial relief terrains by direct field observation. Such a comprehensive classification should describe morainic forms produced by the Pleistocene glaciations, as well as those due to modern glaciations. A number of ephemeral morainic forms, e.g. some portions of medial moraines, ice-cored moraines, shear-plane moraines, etc., occur in the marginal zones related to present-day glaciations. In consequence of their modifications, i.e. the melting of relic ice, ablation moraine will result; its surface morphology will be characterized at the most by the presence of hummocks. Therefore, definitions of classificatory criteria for categorizing morainic forms in Spitsbergen are based on the assumption that the classification will include only existing forms of the surface morphology but not forms that will develop in future as a result of modifications along glacier margins. Thus, the classification takes no account of the so-called internal moraine as it is only morainic material entrapped in the glacier. A criterion of dynamics is also left out here since geomorphological observations alone make it difficult to decide whether, for instance, a given portion of a medial moraine is still taking part in glacier movement or whether it has already become stagnant. It is easier to classify morainic forms from the glaciated areas of the Pleistocene Epoch because they retain their original features and undergo only slight modifications.

Moraines in Spitsbergen are classified here into the following categories: 1. Lateral moraines, 2. Medial moraines, 3. Ground moraines, 4. Ablation moraines, 5. Ice-cored moraines, 6. End moraines: (a) depositional moraines, (b) push moraines. The first four types of moraines are dealt with in this article.

LATERAL MORAINES

Lateral moraines in Spitsbergen form the edges of nearly all valley glaciers alongside glacier tongues. They are made up of rock debris that moves down

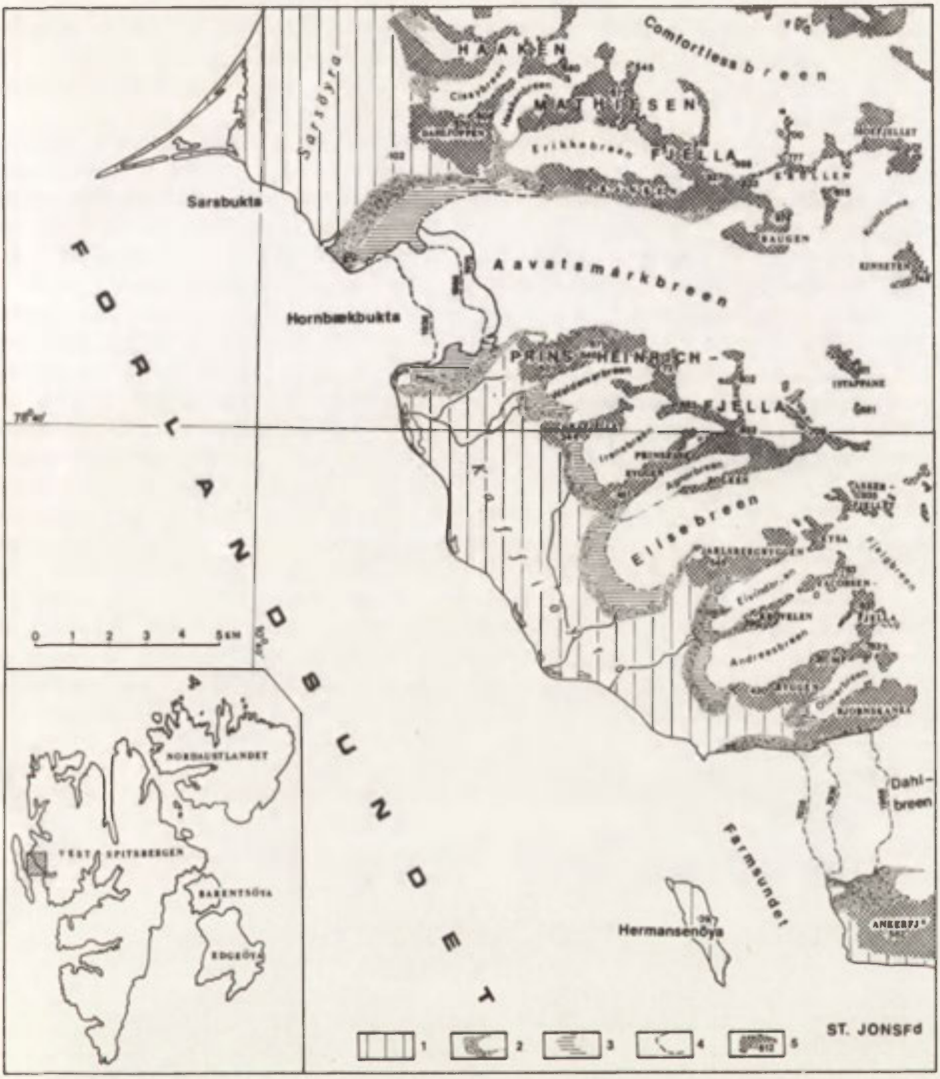


Fig. 1. The glacial forms in the marginal glacier zone of Oscar II Land-Spitsbergen

1 – areas of isostatically raised moraine terraces. 2 – end and lateral moraines and ice-moraine ridges. 3 – ground and ablation moraine. 4 – ranges reached by glaciers. 5 – mountain massifs

mountain slopes into a depression between the slope and a glacier side or directly onto the surface of a glacier. Material flows downslope under the influence of gravity as the result of a snow avalanche, surface run-off on slopes or sudden rock falls.

The dimensions of lateral moraines depend on many factors, namely glacier movement rate, the angle of a mountain slope and geologic structure of mountain massifs around a glacier. Gentle mountain slopes do not promote the formation of lateral moraines for weathered material produced on slopes is very slowly removed and protects the slopes against further weathering. As a general rule, large lateral moraines are built at the base of a steep rock wall (Fig. 1).

In consequence of ablation at a glacier surface, lateral moraines stand above the surface as ridges. It the ridges have been built between the slope and the glacier, they are composed of morainic material only (Fig. 2 and 3). In case debris accumulates on the glacier, ice-cored moraines will form due to the process of ablation. The glacier margins covered with a thick blanket of debris are not subjected to ablation and as a result, stand above the glacier surface as ice-cored moraines. The thickness of a morainic mantle on the surfaces of ice-cored moraines ranges from several centimetres to a few metres. As opposed to forms of lateral moraines composed only of morainic material, ice-cored moraines are of more frequent occurrence. The material that makes up lateral moraines ranges in size from very fine particles to huge boulders. The largest boulders several metres in diameter have been reported by the author from a lateral moraine along the side of a small glacier named the Lestris Glacier in North Spitsbergen. The material that makes up lateral moraines is unsorted and nonstratified. Coarse debris particles

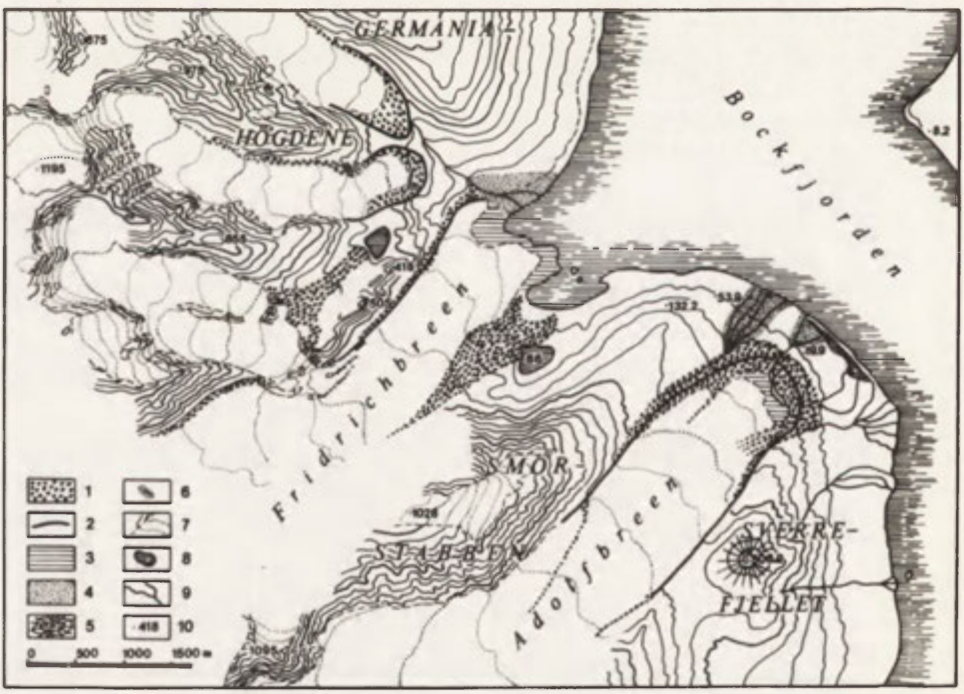


Fig. 3. Map of marginal zone of Fridrichbreen and Adolfbreen

1 zone of ice-cored moraine. 2 crests of morainic ridges. 3 zone of ablation and ground moraine. 4 out-washes. 5 volcanic cone. 6 esker. 7 contour lines. 8 lakes. 9 rivers. 10 altitude points

Fig. 2. Medial moraine on Werenskiold glacier (Photo by J. Szupryczyński. July 1960)

Fig. 4. Ground moraine – "fluted moraine" on the Werenskiold glacier foreland (Photo by J. Szupryczyński, August 1972)

Fig. 5. Clay walls in forefield of Monaco glacier, North Spitsbergen (Photo by J. Szupryczyński, 1963)

Fig. 6. Interior structure of clay wall on Lerner island, North Spitsbergen (Photo by J. Szupryczyński, July 1963)

Fig. 7. Fragment of interior structure of clay wall (Photo by J. Szupryczyński, July 1963)

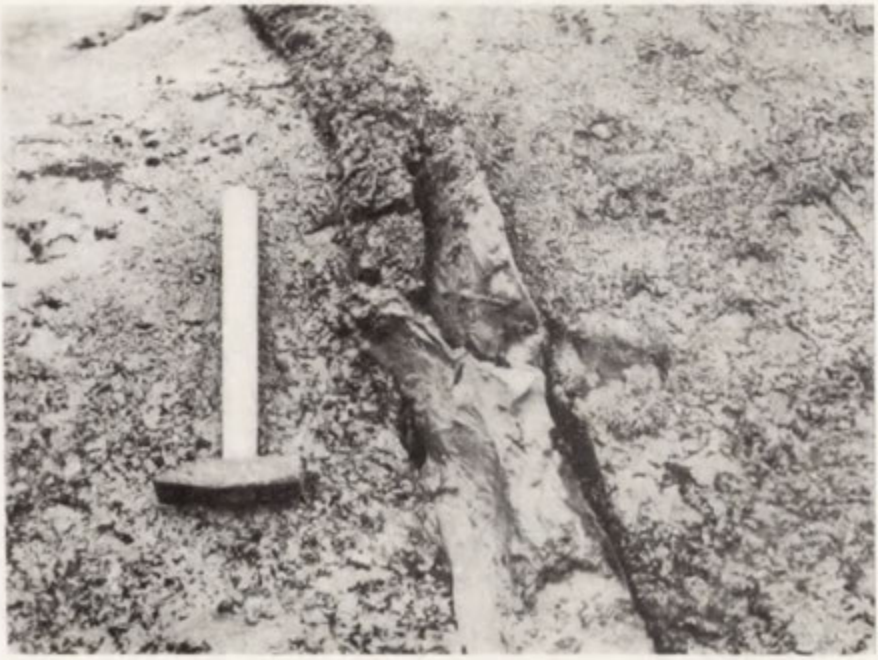


Fig. 11. Outflow of the moraine on the glacier surface along the shear plane. Börre glacier – North Spitsbergen (Photo by J. Szupryczyński, July 1963)

Fig. 8. Ground moraine in the marginal part on the Werenskiold glacier (Photo by J. Szupryczyński, August 1972)

Fig. 9. Fragment of ground moraine on the Werenskiold glacier (Photo by J. Szupryczyński, August 1972)

Fig. 12. Outcrops of rocks substratum (20 m terrace), covered by ablation moraine of Werenskiold glacier (Photo by J. Szupryczyński, July 1960)

have sharpness around their edges. Lateral morainic ridges have no vegetation cover along their entire length. Sometimes there are clusters of saxifrage plants and mosses on their slopes.

The heights and size of lateral moraines increase downglacier. It is just at the glacier snout that they attain the greatest heights. This is explained by the highest intensity of the process of ablation on glacier snouts. In South Spitsbergen lateral morainic ridges reach 40–50 m in height (Szupryczyński 1963a, 1965a). A lateral ice-cored moraine with the relative height of 90 m has been found along the north-facing side of the Dahl Glacier (Fig. 1) in central Spitsbergen (Klimaszewski 1960). Thus, the height of a lateral morainic ridge indicates such magnitude of ablation that occurred over a period from the maximum glacier advance till the moment measurement was made of the height. Pillewizer (1939) reported that in 1938 a lateral morainic ridge built along the side of the Gas Glacier had been 40 m high at its snout and admitted that during the years from 1899, i.e. the date of the last measurement made by de Geer, to 1938 the rate of ablation had been 1.1 m per year. From 1938 to 1959 the height of the lateral morainic ridge increased to about 50 m (Szupryczyński 1963). Thus, during that period of time the rate of ablation diminished, resulting in 0.48 m a year only. For the afore-mentioned reasons, the heights of lateral morainic ridges are variable with reference to the surface levels of different glaciers.

The longest lateral moraines, up to 20 km, are formed on the edge of the Nathorst Glacier while lateral moraines along the margins of the Paul, Holmström, Strong and Ors glaciers attain lengths of 13–15 km. The broadest belt of lateral morainic ridges, up to 2.5 km, has been reported from the Paul and Nathorst glaciers. Sometimes a broad belt of lateral moraines contains several parallel-trending ridges separated by meltwater valleys (Klimaszewski 1960, Szupryczyński 1963). Slopes of a lateral moraine are very steep and the angle of slope of moraine sides usually exceeds 30 degrees. Lateral ice-cored moraines at the glacier snout are liable to abrupt changes as morainic material moves along descending flow lines and relic ice becomes exposed. Upon melting of relic ice numerous hollows form in moraines, and ice-cored moraines disintegrate slowly.

As has been reported so far, relative heights of lateral moraines in Spitsbergen do not exceed 100 m. For the purpose of comparison mention must be made of the fact that the '1850 moraines' of the Alps attain heights of 100 m while lateral moraines in Greenland are up to 200 m high (Charlesworth, p. 405). Rock boulders in a lateral moraine along to margin of the Inylchek Glacier in the Tien Shan are 100 m in diameter and many thousand cubic metres in volume (Drygalski and Machatschek 1942).

MEDIAL MORAINES

Medial moraines form on the surface of a valley glacier. The longest medial moraine, up to 18 km, is reported from the Strong Glacier. Medial moraines attain lengths of up to 15 km on the Veteranen and Torell glaciers and up to 8 km on the Nathorst Glacier. The simplest type of a medial moraine that is built due to the coalescence of two lateral moraines at the confluence of two glaciers prevails throughout Spitsbergen. This type of a medial moraine was already recognized in 1787 by Kuhn. Afterwards, Agassiz's and Charpentier's observations confirmed such a mode of medial moraine formation (Charlesworth 1957). Finally, Godeffoy developed a simple formula implying that a number of medial moraines corresponded to a number of confluent glaciers. From subsequent observations, inferences were made as to the invalidity of that statement. Moraines also stream from nunataks or rock spurs extending from the glacier sides, or appear in places where englacial moraines emerge (Charlesworth 1957, Klimaszewski 1963).

If two lateral moraines join to form a medial moraine, petrographic components of particular lateral moraines do not get mixed but remain concentrated in bands close to one another. A varied inventory of rocks and rock colour frequently permit differentiation between constituents of particular lateral moraines as far as the glacier snout. An example of such stratification of a medial moraine was reported by Gripp and Todtmann (1926) from the Green Bay Glacier where there were as many as 14 different bands.

In the upper portions of a glacier, a medial moraine appears exclusively as a strip of a surface moraine. In a down-glacier direction a medial moraine is forming gradually as a ridge that attains a maximum relative height at the glacier snout. In 1925 medial morainic ridges built at the snout of the Green Bay Glacier in central Spitsbergen reached the heights of up to 25 m (Gripp and Todtmann 1926). According to Lipert's measurement of 1959, a medial morainic ridge at the snout of the Werenskiold Glacier was about 30 m high (the Werenskilbreen 1:5000, 1961). A morainic mantle on the ridge barely ranges from 0.5 to 2.0 m in thickness (Szupryczyński 1963). The breadth of a medial morainic belt also increases downglacier; for instance, a medial morainic strip on the Werenskiold Glacier is barely 1 m broad in the upper portions of the glacier tongue, whereas its breadth ranges up to 200 m at the glacier snout (Szupryczyński 1963, p. 68).

If a medial moraine is the result of the coalescence of lateral moraines, a distinct seam of an englacial moraine that frequently penetrates to the glacier base lies beneath a surface morainic strip on the glacier. In 1910 Drygalski reported many examples of moraines of this type from glaciers terminating in cliffs in the sea, for example, from the 14 Juli Glacier in the Krossfjorden and from glaciers terminating in the Raudfjorden. In case a medial morainic strip starts extending from the projecting nunatak or rock spur, morainic material remains on the surface and does not move to englacial positions (Drygalski and Machatschek 1942). An example of such a moraine type is one of medial moraines on the Green Bay Glacier (Gripp and Todtmann 1926).

On Spitsbergen glaciers there are also medial moraines, the whole or parts of which are composed of subglacial material that usually reaches the glacier surfaces only at their snouts. Such a medial moraine is present on the surface of the Gås Glacier in Sörkappland (Szupryczyński 1963, p. 68). It is made up of fine-grained material, namely morainic mud that is brought up onto the glacier surface along shear planes. Its length is a few hundred metres, while its width is only several metres. Morainic mud flowing on the glacier surface spreads over its foreland as ablation moraine.

Besides sharp-edged Permian-Carboniferous quartzite and limestone blocks, Gripp and Todtmann (1926) found much abraded Lower-Carboniferous sandstone boulders in one of medial moraines on the Green Bay Glacier. Sandstone was undoubtedly of subglacial origin and was released from the glacier base as it was absent from the areas adjoining the glacier. Thus, the above medial moraine contained not only supraglacial material but subglacial debris as well. The presence of such material within medial moraines was for the first time reported by de Seue in 1870 from the Jostedal Glacier of Norway. Afterwards, similar inferences were drawn from the observation of Alpine glaciers by Simony (1871), Finsterwalder (1897) and Penck (1882) and glaciers around Nanga Parbat in the Himalayas by Finsterwalder (1937) (Charlesworth 1957).

In 1870 already, de Seue inferred from the observation of the Jostedal Glacier in Norway that, in case lateral glaciers combined, the arrangement of their layers became upturned and a medial moraine was exposed by ablation. Such a moraine is formed due to the transition of ground moraine into englacial moraine that next, reaches the surface in the form of a medial moraine. This type of medial moraines is composed exclusively of subglacial debris. It was also reported by Heim and Finsterwalder from several Alpine glaciers (Drygalski and Machatschek 1942). In his description of one small glacier in the Raudfjorden in North Spitsbergen, Drygalski (1911, Fig. 22) provided information on such internal structure of a glacier with upturned shear planes.

Little observation was made of structure and relief details of a medial moraine in Spitsbergen. Medial morainic ridges rising above the glacier surface at its snout undergo intense modification by ablation. Tiny erosion grooves frequently are formed on medial moraine slopes due to erosion by ablation water. The melting of glacier ice leads to the formation of numerous hollows in a medial morainic ridge. Its slopes are eroded by ablation water flowing over the glacier surface. In consequence of relic ice melting and the destructive action of meltwater, a ground morainic ridge that lies in the glacier foreland disintegrates gradually and becomes ablation moraine cover.

GROUND MORAINE

Ground moraine is extremely rarely encountered in Spitsbergen and occupies there a small area. Garwood and Gregory (1898) reported that in many cases ground moraine was laid down beneath Spitsbergen glaciers at their snouts. The plane of contact between the glacier ice and the ground moraine was never clearly marked and ground moraine material was hard frozen. Drygalski (1911, p. 3) found ground moraine of a little thickness below the cliff of the Mayer Glacier (Mayerbreen) in the Krossfjorden. Yet, he made no mention of material consistency. Gripp's observations (1929) of the Spitsbergen region confirmed earlier inferences drawn by Garwood and Gregory as to the consistency of ground moraine material. Gripp reported from places of easy access that ground moraine deposit was in a frozen condition beneath glaciers. This fact deserves mention since Drygalski's observation of the Greenland region and other workers' observations of Alpine glaciers indicate that ground moraine occurs beneath the ice as plastic morainic till, i.e. morainic mud (Drygalski and Machatschek 1942, p. 132). In most cases the basal portions of a glacier are rich in morainie material accumulating inside the ice in distinct layers that run parallel to the glacier base (Woldstedt 1954, p. 29, Fig. 9; Klimaszewski 1963, p. 379, Photo 58). Thus, plastic or frozen ground moraine material underlies ice. A thickness of this layer does not usually exceed 2 m. The plane of contact between morainic material incorporated in the ice and material underlying the ice is difficult to observe. In Spitsbergen the author frequently made observation of the basal portions of the glacier that lay directly on the bedrock and were greatly enriched in morainic material. Thus, like Gripp, he did not find plastic ground moraine beneath the glacier. However, some indirect observations indicate that plastic morainic mass is also sometimes encountered beneath glaciers of Spitsbergen. If there are variations in the degree of consistency of ground moraine material, differences surely occur in the process of its displacement.

Schytt (1959) investigated ground moraine with a fluted surface on the Isfells Glacier in Kebnekajse, northern Sweden, in a tunnel deep inside the glacier snout. This morainic type forms due to the flow of plastic morainic mass beneath a glacier. The ground moraine that develops when the glacier recedes, is characterized by specific morphologic expression; it is like a ploughed field with distinct ridges and furrows. The ridges run parallel to one another and are perpendicular to the glacier snout. As has been proved by observations made in the tunnel, they extend beneath the glacier. This type of ground moraine was also reported by Todtmann (1957, 1960) from the foreland of the Bruar Glacier in the north-eastern part of Vatnajokull, Iceland.

A similar type of ground moraine has been reported by the author from Spitsbergen (Szupryczyński 1963, 1965b), next to the margin of the retreating Werenskiold Glacier (Fig. 4). In 1960 there were ridges 0.30 m high and 1–1.5 m broad that ran parallel to one another and were separated by grooves ranging up to 1 m in breadth. The ridges were composed of morainic till with countless pebbles, the orientation of which was parallel to the morphological axis of the ridge. The orientation of even large boulders laing along the axes of ridges tended to be similar. The thickness of ground moraine did not exceed 0.50 m. The moraine was characterized by high meltwater content at the glacier snout and was in a plastic state of morainic mud, yet with ridges and grooves being clearly marked. Unfortunately, there was no possibility of excavating a tunnel into the glacier snout. At that time there were no subglacial tunnels in the glacier snout; they would have permitted observation of the basal portions of the glacier. The specific topographic expression of the ground moraine and pebble segregation indicate that the morainic material must have flowed in a plastic state beneath the glacier. However, note should be made of the fact that this type of ground moraine is only encountered in a small area in front of the southern-most extremity of the glacier snout.

Recently "fluted ground moraine" was also found in the foreland of the Elise Glacier (Fig. 1) in North-West Spitsbergen (Olszewski 1977) and in the foreland of the Vitkovsky Glacier in South Spitsbergen (Andrzejewski and Stankowski 1981).

The process of ablation leads to the melting out of a specific set of till ridges (*Lehmmauern, Türme*) in the forelands of some Spitsbergen glaciers. Such forms were reported by Gripp (1929) from the margins of the Nathorst and Sefström glaciers and *in statu nascendi* from the Holmstrom Glacier. In his study, Gripp (1929, Table 22, Photo 1 and Table 33, Photo 1) presents interesting photos of these forms and discusses their origin but provides no related morphometric data. It can be inferred from the photos that these peculiar forms in the foreland of the Nathorst Glacier range up to several metres in height and breadth and are composed of morainic till. Following Gripp's suggestions, they form in basal crevasses of the glacier as plastic ground moraine material falls into the crevasses. From his observations it follows that basal crevasses are not related to crevasses on the glacier surface. In further discussion of this problem, Gripp comes to the conclusion that observations he has made do not permit him to state whether the material is squeezed into basal crevasses during glacier movement or whether the squeezing of plastic morainic mass takes place only in dead ice under the pressure exerted by the weight of the ice. Disintegration of these forms by precipitation and wind action contributes to the formation of the topography of undulating and hummocky ground moraine (Gripp 1929, Table 25, Photo 1 and Table 27, Photos 2–4).

Ridges of till from the foreland of Kongsvegen of Spitsbergen were for the first time described by Loven in 1837 already. An extensive passage describing these forms and the drawing are presented in Torell and Nordenskiöld's book (1869, pp. 289–290). The figure shows narrow, sharp-crested ridges of till. Loven (Gripp 1929) also described such forms from the north side of the Negri Backlund Glacier. Photographs of till ridges in the foreland of the Nathorst Glacier were taken by Zawadzki (Zagrajski and Zawadzki 1935, p. 95; Różycki 1936, p. 80) and Biernawski (Klimaszewski 1963, p. 292), the members of the first Polish expedition to Spitsbergen in 1934. Różycki (1936, p. 80) names these forms "muddy balls" and quotes their Norwegian name *Leirhauwa.*

In 1963 the author reported the presence of a high concentration of till ridges in the foreland of the Monaco Glacier in North Spitsbergen. These forms mark a position of the maximum transgression of the present-day glaciation or only one of retreat phases. There was only a possibility of making observations of the east side of the fjord. Till ridges occur there as extensions of the lateral moraine and are also found in Lerner Islands. They consist of clay-rich morainic till containing a comparatively large number of pebbles or even large boulders. Till ridges attain maximum relative heights of up to 10 m and their breadth does not exceed 3 m in places. Crests of these forms are frequently only a few tens of centimetres broad. Crest lines are either straight or irregular (Fig. 5). The angle of slope usually exceeds 45 degrees and very frequently approaches 90 degrees (Fig. 5 and 6); this is due to the petrographic composition of clay-rich till. Within the till there are distinct flakes that are placed nearly vertically in many cases (Fig. 7). The long axes of small pebbles, for the most part, lie along an upward orientation, whereas for large boulders a variable orientation is observed (Fig. 6). Internal structure of these forms appears to confirm Gripp's suggestion about their origin. They must have formed due to the squeezing of ground moraine material into basal crevasses. Such forms depended on a thickness of ground moraine for their formation; the thickness must have been rather substantial. Some broader till ridges contain relic ice. Some crevasses must have been so close to one another that the intervening glacier ice became covered with morainic material by ablation. Observations of the foreland of the Monaco Glacier suggest that forms lying next to the glacier are newly created and sharp in outline.

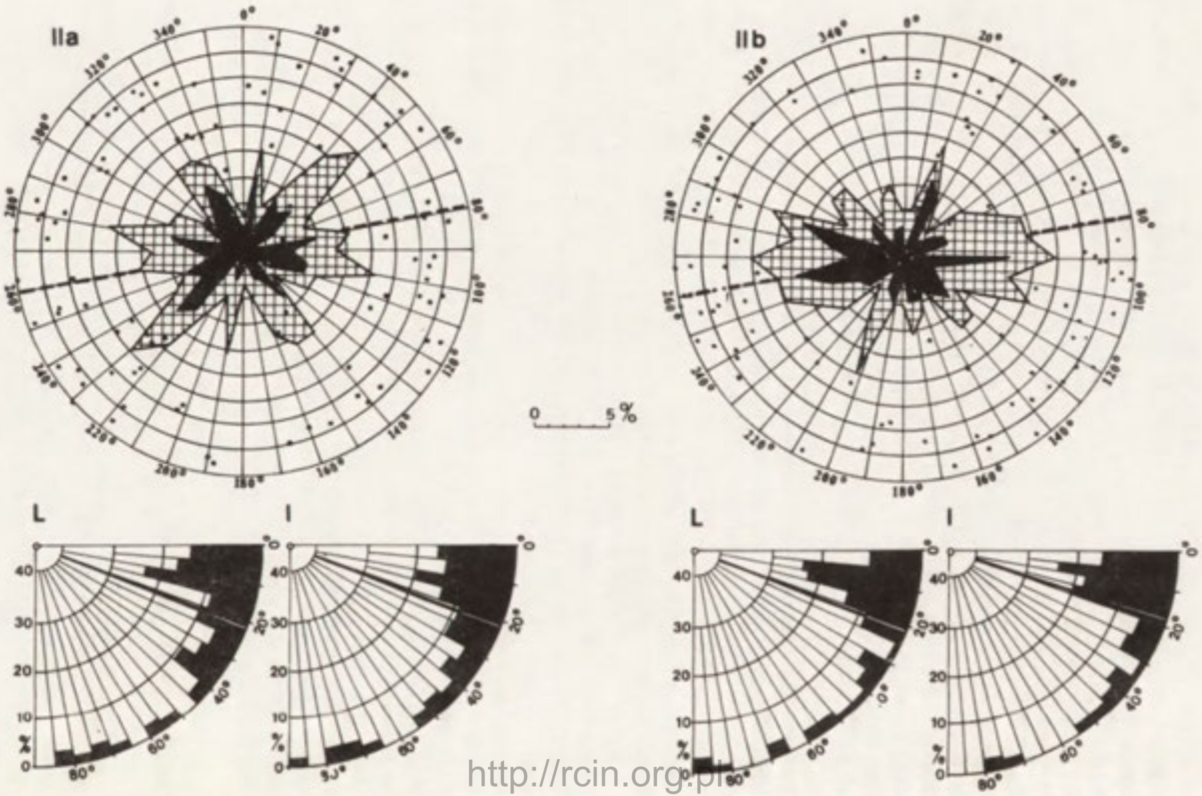
Recently, detailed investigation of texture and structure of ground moraine sediments was carried out in Spitsbergen (Boulton 1967, 1968, 1970, Olszewski and Szupryczyński 1975, 1980, Karczewski and Wiśniewski 1976). It provided a great deal of new data permitting inferences about the origin of ground moraine. Ground moraine sediments are examined in detail in a crevasse on the Werenskiold Glacier (Fig. 8 and 9). The ground moraine attained a thickness of 0.7–0.8 m. The azimuthal measurement and the inclination of the long axes of pebbles in the ice (Fig. 10, diagrams IIa and IIb) show that the orientation of the long axes tends to parallel glacier movement. The two remaining diagrams (Fig. 10, IIIa and IIIb) show the orientation of pebbles at the contact between the upper portions of morainic sediment and the basal portions of ice. The above diagrams confirm an established principle of the compatibility of the orientation of the long axes of pebbles with the direction of glacier movement since the Werenskiold Glacier moves from the east westwards.

ABLATION MORAINES

Klimaszewski (1960, p. 65 and p. 69) was the first worker to pay attention to the significance of ablation moraines for the surface morphology of Spitsbergen glacier margins. As a general rule, glacier snouts remain covered with a blanket of surface moraine. Morainic material incorporated in the ice becomes a surface moraine due to two processes (Jahn 1952/53).

(1) the process of ablation which leads to the release of debris from the melting glacier ice,

(2) the advance of active ice over little active or dead ice; in consequence, morainic material is brought up along shear planes onto the glacier surface as morainic mud (Fig. 11).


IIa
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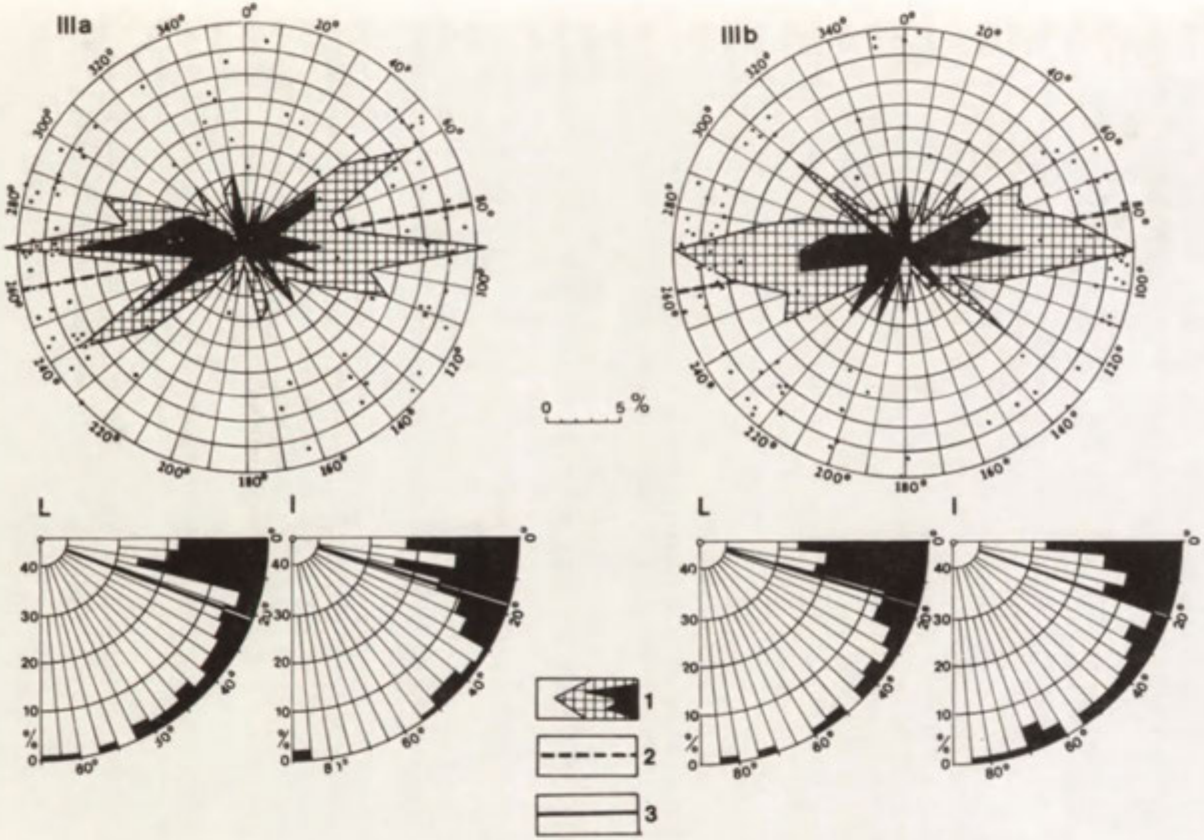

Fig. 10. The structure of rock particles – the orientation of longer axes and the per cent share of tilts of the basal transport of the glacier in the dead glacial cover (IIa, IIb) and in the top of the subglacial deposits, at their contact with the regelation ice (IIIa, IIIb)

1 – diagrams of per cent quantity of the rock particular orientation directions in symmetrical (squares) and asymmetrical (black) aspects, 2 – orientation of the "fluted moraine" ridges. 3 – the mean per cent inclination of the longer (L) and medium (l) axes of pebbles in the particular sites (IIa-IIIb). Worked out by J. Szupryczynski and A. Olszewski

The latter was recognized in 1950 by Ward, a member of the American expedition making field observations in Baffin Island (Jahn 1952/53). The author observed numerous examples of the transport of morainic material along shear planes onto the surfaces of Spitsbergen glaciers.

During the polar summer when the process of ablation proceeds to operate intensively, a surface moraine overlying the glacier snout is intensely washed and soaked in ablation water. For this reason, it assumes a consistency pertinent to morainic mud that flows downglacier on the surface of its snout into the glacier foreland (Klimaszewski 1963, Photo 64). A strip of morainic mud with a breadth of several metres and a thickness ranging up to 2.0 m forms in front of the glacier snout. Not infrequently does the mud become displaced many times, whether depending on the angle of slope of the surface where it is deposited or due to a new mudflow from the glacier surface. Multiple dislocations of morainic material result in intense modification, i.e. diagenesis, especially in structure and texture. Klimaszewski (1960, 1963) names this type of moraines the altered ablation moraines. Internal structure of a consolidated ablation moraine of this type displays a high degree of fluidity. However, if morainic mud becomes displaced within a comparatively short distance, the ablation moraine has no banded but only chaotic internal structure (Fig. 12). In such case a certain bipartition can frequently be observed, namely the basal portions of the ablation moraine contain large boulders because of the immersion of boulders in morainic mud, whereas finer morainic material is present in the upper portions of the ablation moraine. Numerous profiles of this type of ablation moraine were studied by Klimaszewski in the glacier forelands of Spitsbergen.

The glacier snout blanketed with a surface moraine frequently becomes a large patch of dead-ice. Numerous dead-ice patches were observed throughout the entire Spitsbergen region (Klimaszewski 1960, Szupryczyński 1963, Jewtuchowicz 1966). As the dead ice melts out gradually, an ablation moraine with a chaotic structure results. Dead-ice patches usually melt out at their outer margins. This causes the release of surface moraine debris and englacial material under the force of gravity. As a general rule, the resultant ablation moraine is superimposed upon the ground moraine that lies under the dead-ice patch. This type of ground moraine has already been recognized earlier and classic schemes illustrating its formation are presented in Flint's textbook (1957).

The ablation moraine sometimes occurs as boulders strewn across the solid bedrock. Such an ablation moraine was often reported from North Spitsbergen (Szupryczyński 1966). Areal deglaciation that now takes place in Spitsbergen favours the formation of ablation moraines. As contrasted with ground moraines, they are of major significance in the relief of the marginal zone. An explanation for this is provided by the fact that there is a possibility of a great supply of weathered material from mountain slopes in mountainous regions of the Alpine glaciation. The ablation moraine is surely present in areas of former Pleistocene glaciations in Europe as well, but continental glaciations, i.e. ice sheets, are more favourable to the formation of ground moraines rather than ablation moraines since weathered material required for the development of surface morainic mantles is lacking.

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ECOLOGICAL MONITORING AS A METHOD OF LAND EVALUATION

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INTRODUCTION

The growing need to intensify food production as well as to limit the increasing environment pollution makes it necessary to have programs for controlling the state and functioning of the biosphere. Initially this need was recognized mainly by highly-industrialized, densely populated developed countries. Nowadays, however, it seems that the way and rate at which developing countries devastate their natural environment are even more dangerous; a high natual increase of human population typical of these countries creates an increasing demand for food, which is not satisfied. Since their agricultural standards are usually low and cause the degradation of soils, and since there are no real possibilities to raise those standards quickly, it can be assumed that in those countries the future of biological resources is highly threatened. Perspectives even for these countries that have rich deposits of valuable raw materials are not very encouraging; it seems unquestionable that quite soon food, that is the organic matter produced by the living biosphere, will be the most valued merchandise in the world. It is imperative, therefore, that methods of control and protection of the biosphere against its increasing devastation should be worked out. The idea of environmental monitoring programs seems to be an answer to these present day needs.

The presented paper is concerned with the programs (systems) of ecological monitoring.

Let us adopt the following definitions of the terms: Monitoring is the collection of information 1) for a large number of points at the same time, 2) repeatedly in longer time periods, and 3) by means of the same,. commonly available methods. Ecological monitoring collects the information on the state and functioning of the biosphere or its parts. Thus, ecosystem monitoring is a continuous long-term program of collection of information on specific ecological systems (ecosystems) and their changes; the number of these systems has to be established according to the actual diversity of a given region and according to the present state of ecological knowledge concerned with identification of ecosystem types. Monitoring data may be used to detect changes in the state of an object under study or in the rate of a process. These signals are interpreted on the basis of the whole existing knowledge of the event involved; conversely, as a result of the signals obtained from monitoring we can undertake more detailed, deeper studies in a given direction. It should be assumed that in monitoring programs information has to be collected by means of relatively simple techniques, as the institutions participating in the program will differ in their staff and equipment facilities. Countries that are in most need of ecological information will often have great difficulty in carrying out a complex monitoring program.

The ecological objects that can be 'monitored' are various. Here are a few examples.

UNEP Programme Activity Centre, the Global Environment Monitoring System (GEMS) carry out the program of monitoring of living resources in Kenyan pastures and national parks; particular attention is paid to dry lands and deserts. Observations are gathered at three levels: on land – by mobile groups and field stations; from the air – by means of light aircrafts during regular reconnaissance flights; and from outer space – by color sensitive scanners in orbiting satellites such as LANDSAT. The authors whose data have already been published (Croze *et al.* 1978, Gwynne and Croze 1975) suggest that the first survey during which photographs are taken from an aircraft should be carried out at the height of about 100 m in either 5×5, or 10×10 km squares. Well trained observers can register then the following information: topography, drainage, vegetation type and cover, greenness, grass height, intensity of grazing and number of animals (large mammals) by species. Attempts have also been made to work out techniques enabling the collection of more information, especially as regards cattle registered from the aircraft; Sinclair (1969) for instance, tried to evaluate the age and recruitment of buffallo herds; Croze (1972) used measurements of elephant back-length from vertical serial photographs to determine the age structure of elephant populations. The photographs taken and information gathered by an aircraft flying at a low height are completed during research carried out in selected experimental areas on land. Respective specialists are then concerned with soil, its fertility and water regime, with plant productivity and chemistry of all components. Gwynne and Croze (1975) believe, however, that the productivity of pastures is better evaluated on the basis of photographs taken by a satellite and they suggest to use mainly LANDSAT scanners characterized by a high frequency (every 18 days). Let us analyse the results of this type of monitoring in administrative district of Kenya's Maasailand, south and west of Nairobi. The district of Kaijado covers an area of 21000 sq. km. The surveys were aimed at providing information as regards the distribution and density of the wild and domestic herbivore populations. These data form the basis for various management strategies. The biomass of animals recorded in the investigated area was evaluated and a synthetic map of units requiring various forms of management was prepared for Kaijado (Fig. 1). The author maintains that the cost of preparation of these maps and figures was relatively low. It is difficult to verify this statement in different conditions, yet, undoubtedly the described method of monitoring is quick, does not require many specialists and can cover large areas. Evidently this is a necessary stage and possibly the best method to be applied in countries entering the phase of intensive development.

A different type of monitoring activity can be presented from the North of Europe. The proceedings of Scandinavian symposium "The use of ecological variables in environmental monitoring" (1979) include examples of ecological monitoring programes in Scandinavia. One of these are the studies of Norvegian lakes. Øakland and Øakland (1978) investigated over 1000 Norvegian lakes and described 10 environmental parameters characterizing the living conditions of their bottom fauna (Fig. 2). The geographical distribution of lake bottom fauna presented on the maps is a point of departure for a continuous monitoring of changes which – as the authors assume – will occur as an effect of environmental pollution. As the extinction of animal species is known in the contaminated areas and, at the same time, it is known that bottoms of lakes accumulate pollutants, the changes of bottom fauna can be considered as an indicator of the pollution intensity.

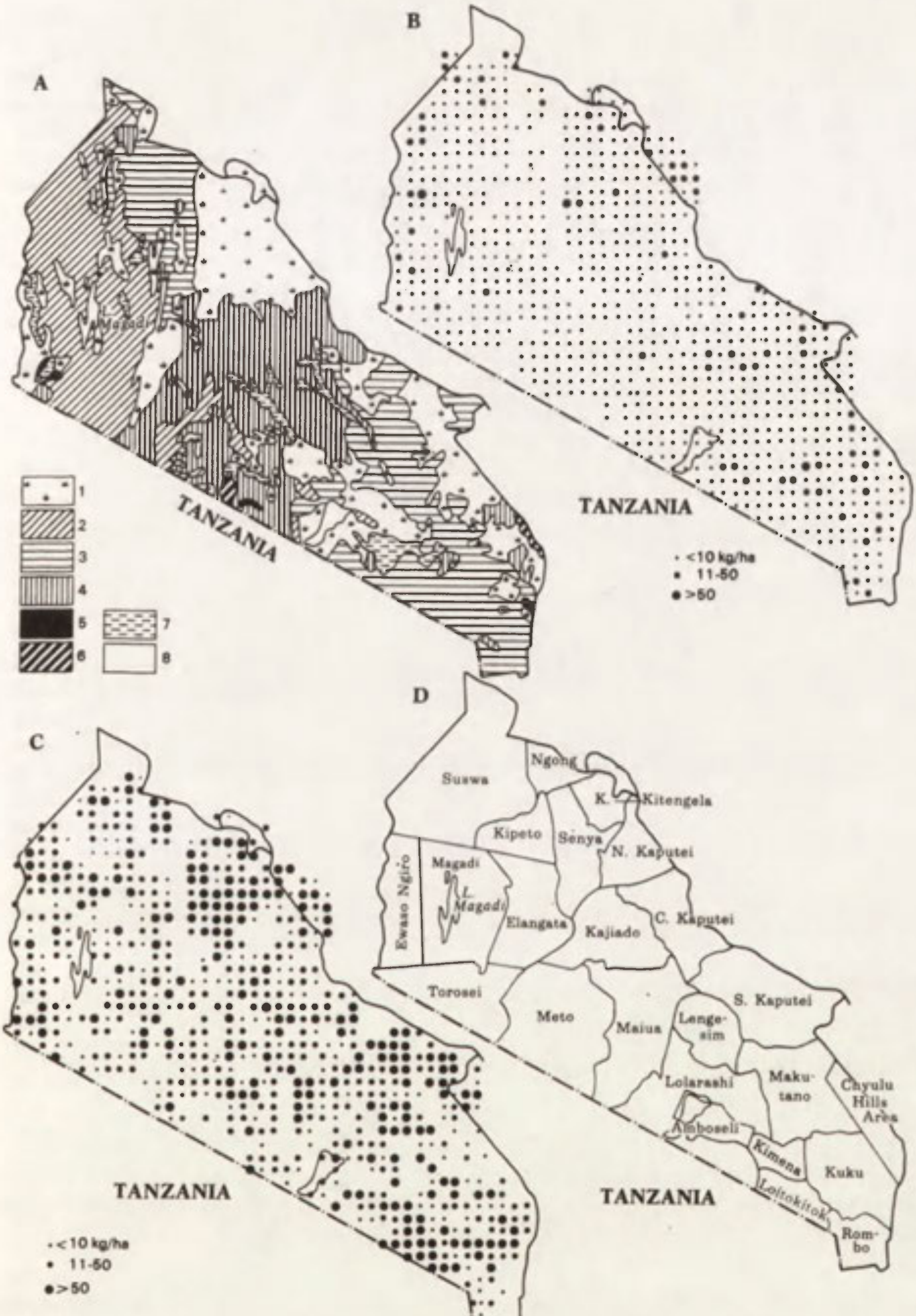

Fig. 1. Kajiado District. Maps based on aerial photographs

A – Vegetation type map: 1 – grasslands, 2 – wooded and bush grassland, 3 – bushland, 4 – woddland and bushland, 5 – woodland, 6 – forest, 7 – swamp, 8 – soda and seasonal lakes B – Average biomass occupancy of 'resident' wild herbivores between October 1975 and October 1976 C – Average biomass occupancy of cattle between October 1975 and October 1976 D – Wildlife Management Units in Kajiado District of Kenya (after Croze *et al.* 1978)

Fig. 2. Map of Norway indicating distribution of 1500 fresh-water localities where environmental parameters were registered and bottom fauna investigated. Most of these localities were lakes (after Økland and Økland 1979)

Two systems for the division of Norway into smaller units are used to illustrate the distribution of environmental parameters and bottom fauna: 1) 50 km squares developed for use in the European Invertebrate Survey, and 2) faunistic regions which mainly use municipal borders. The project relates environmental conditions with characteristics of the bottom fauna. The ecological tolerance of bottom animals was quantified with particular reference to 10 environmental parameters: 1) elevation above sea level, 2) geology, 3) terrestrial vegetation in the watershed, 4) macrovegetation in shallow water along the shore, 5) substratum, 6) wave exposure, 7) water temperature, 8) pH, 9) total hardness (calcium+ magnesium), and 10) water colour and turbidity. The relation between environmental and ecological parameters is analysed from four points of view: 1) single factor analysis, 2) bivariate analysis, 3) three-variate analysis, and 4) multivariate analysis using stepwise regression. These analyses will make it possible to identify the environmental parameters which are connected by causal dependences with lake fauna. A very dense network of lakes under observation covering practically all Norway and a precise description of the lakes at the start of the study will make it possible to carry out continuous observations of the state of Norwegian lakes.

MONITORING OF ECOSYSTEMS IN POLAND, A PROGRAM FOR CONTROL OF AIR POLLUTED PINE FORESTS

To build up a broad scale program of ecological monitoring it is necessary to review the background knowledge on natural environment. In Poland, similarly as in other European countries, we have the descriptions and the maps of soils, of potential vegetation and of land use. Especially good and detailed maps are available from Forestry Services; each forested area is evaluated on these maps according to the type, age and condition. There are also the first, continuously improved maps of air pollutants floating over the country's surface; an example of a map of this kind is showed on Fig. 3. This map is based on the mathematical models describing the dispersion of sulphur oxides emitted to the atmosphere from fossil fuel combustion using the current state of knowledge on meteorological, physical, and chemical processes involved. A computation step of 20 or 10 km was used in calculations; the authors utilize the prognosis for the development of fossil fuel combustion in Poland based on gross energy consumption from the 1970s. Some fragments of this prognosis may not be valid because of changes in the economic situation of the country, but the general picture of the dispersion of sulphur pollution will certainly remain unchanged. At the same time the pollution is evaluated by terrestrial investigations of some sensitive bioindicators. For the whole country we can already present the published results on the content of pollutants in mosses growing in Polish national parks (Grodzińska 1978, 1980; Fig. 4). Mosses are commonly used as bioindicators of air pollution; they accumulate far more heavy metals than do higher plants. In 12 national parks two moss species were used as bioindicators of nine heavy metals (Cd, Co, Cr, Ni, Cu, Pb, Zn, Mn, Fe) and four other metals (Mg, Na, K, Ca). Figure 4 shows the levels of contamination in the parks in different parts of Poland. The investigations of roe deer antlers show similar but not so complete picture of air pollution (Sawicka-Kapusta 1979). Roe deer antlers appear to be sensitive indicators of industrial pollution of the forest ecosystems: they comprise the pollution accumulated in 130 days of their growth and they may be available every year in great quantity. The chemical composition of antlers reflects the composition of diet of roe deer from December to March, when they eat mainly the browse and green parts of ground vegetation, and when the fall-out of pollutants is rather intensive (the lack of leaves). Roe deer antlers can also be used for reconstruction of the history of pollution in the region (Fig. 5). The comparison of all above described pollution maps and indices show the same picture: the highest pollution in south-west of the country, the lowest in the north-east.

Two programs recording directly the influence of pollutants on pine forests are presently under way: the first one is carried out by the scientific staff of the Botanical Garden, Polish Academy of Sciences, the second one by the Ministry

Fig. 3. Map of the predicted air pollution with sulphur oxides in Poland in 1990

The isolines represent mean annual concentration of SO_2 in $\mu g \cdot m^{-3}$. The SO_2 emission from the fossil fuel combustion from point and area sources located in Poland. Czechoslovakia and East Germany is included (after Juda *et al.*, unpublished. Warsaw Polytechnic)

of Forestry. The Botanical Garden project concentrates on the evaluation of sulphur and fluoride compounds in the needles of the Scots pine (Molski *et al.* 1981). Chemical analyses of 2-year old pine needles are done from the samples made up of 30 trees 20-years old. Poland is divided into squares with a side length of 25 km each, and the samples are taken at 5 different points of each square. The second program held by the forestry service stations is concentrated on the polluted parts of the country where the pine forest devastation is visible. Damages caused by industrial emissions are estimated for selected species of coniferous trees such as pine, spruce and fir. Trees are cut down on sampling plots and changes are recorded such as needle shortening (a symptom of SO_2 pollution) or excessive elongation (a symptom of nitrogen pollution), changes in needle coloration, crown shape, height and thickness of tree etc. Such a description of sample trees allows the classification of a given site to an appropriate zone of emergency. Three zones of emergency have been distinguished according to the degree of forest devastation. From the comparison of changes recorded on trees with air polution

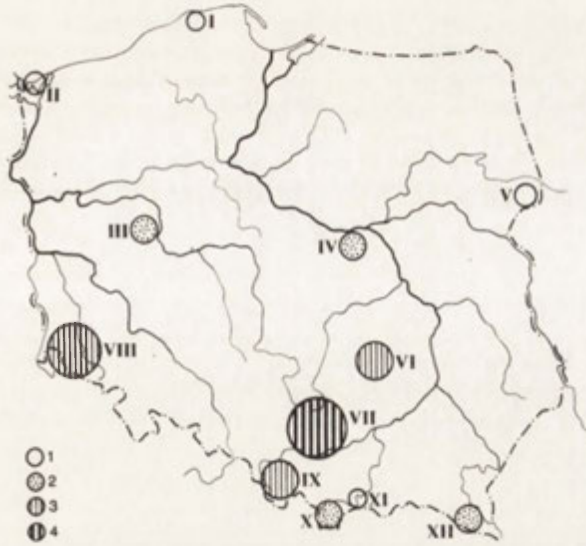

Fig. 4. Heavy metals in mosses in Polish National Parks

I – Słowiński. II – Wolin. III – Wielkopolski IV – Kampinos V – Białowieża. VI – Świętokrzyski. VII – Ojców. VIII – Karkonosze. IX – Babia Góra. X – Tatra. XI – Pieniny. XII – Bieszczady

Two species of moss were used: *Hylocomium splendens* and *Pleurozium schreberi*, common in the whole country. The values of pollution index represent the sum of standardized contents of metals

1 – relatively clean. 2 – moderately polluted parks. 3 – heavily. and 4 – very heavily polluted parks. Circle diameter is proportional to the index of pollution (after Grodzińska 1980)

maps it has been found that the first zone of emergency corresponds to 20 mg $SO_2 \cdot m^{-3}$ of the air. the second zone ranges from 50 to 100 mg $SO_2 \cdot m^{-3}$. and the third one is above 100 mg $SO_2 \cdot m^{-3}$. The analysis of the predictive map suggests that in 1990 the coniferous forests of Poland may be threatened with SO_2 pollution on 50% of the country's area.

The program 'Monitoring of ecosystems' prepared in the Institute of Geography and Spatial Organization, Polish Academy of Sciences, is based on the assumption that the deformations in the functioning of ecosystems are the basic ecological danger which can be identified quickly and easily. The present knowledge of ecosystems is sufficient to construct a broad utilitarian program of the control of their functioning. In the last years the number of publications in ecology of ecosystems has considerably increased; in the ecological literature there are available large sets of detailed information on ecosystems of different types (Breymeyer 1971. French 1979. Farnworth and Golley 1974. Golley and Medina 1975. Kajak 1974. Kovalev 1974. 1976. Medwecka-Kornaś *et al.* 1974. Zlotin 1970). as well as first descriptive and functional models (Breymeyer and Kajak 1976. Innis 1979. Noy-Meir 1974. Reichle *et al.* 1973) and some attempts of preliminary synthesis (Andrews *et al.* 1974. Bazilevich *et al.* 1971. Breymeyer 1978. Breymeyer and Van Dyne 1980. Coupland 1979. Lieth and Whittaker 1975. Numata 1979. Roswall and Heal 1975. Goodall and Perry 1981. Holdgate and Woodman 1977. Wiegert *et al.* 1970). The conditions favouring or deforming the functioning and existence of ecosystems are analysed in these publications. Two processes. production and decomposition of organic matter are basic for the existence of ecosystems. The elimination or slowing down of these processes must lead to the destruction of every 'natural' ecosystem. Of course. there are also such ecological systems where. for example. the process of decomposition of organic matter and supply of nutrients to plants is substituted by continuous intensive fertilization. These ecosystems are not self-sustained, they require constant, often very expensive, human intervention. Obviously, this type of intervention cannot be applied to large areas and for a longer time period; therefore, the natural ability of ecosystems to self-supply and maintenance must be monitored and protected.

The ecosystems of pine forests were proposed to be monitored first. Pine forests are the most common forests in Poland. They cover relatively large areas

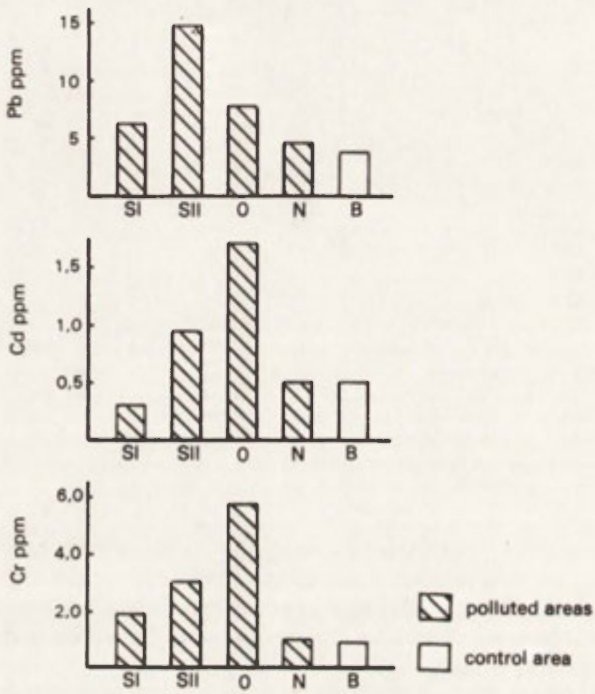

Fig. 5. Concentration of lead, cadmium and chromium (ppm, dry weight) in roe deer antlers from the forest regions

S I Silesian forests in the years 1938 1950. S II Silesian forests in 1951 1973. O Ojców National Park. N Niepolomice forest. B Bialowieża National Park. Silesian and Niepolomice forests and Ojców National Park are located in south-west of the country Bialowieża National Park in the north-east (after Sawicka-Kapusta 1979)

throughout the whole country; according to Trampler (1982) pine forests cover 69% of the whole forested area in Poland and their biomass accounts for about 70% of the total wood biomass. As it is well known, pine forests are sensitive to air pollution: for that reason they perish in many places and have to be replaced by more resistant deciduous forests. Pollution with sulphur oxides and heavy metals is particularly devastating to pine forests. The first data illustrating the influence of pollution on production and decomposition of organic matter in forests can be found in ecological literature. For example, Grodziński and Yorks (1981) present long-term data illustrating timber production in a mixed forest of southern Poland. These data reveal that the production has largely decreased since the construction of a steel mill that pollutes the atmosphere. Similar information is provided about Scandinavian forests. Smith (1981) gives data suggesting that the rate of organic matter decomposition can be slowed down as an effect of the emission of pollution. Tyler's (1972) ideas are quoted, namely: "decompostion

Fig. 6. The net of basic control areas in the program 'Monitoring of ecosystems'

of forest litter and remobilization of nutrients will be slower or less complete as heavy metals ions bind with colloidal organic matter and increase resistance to decomposition or exert a toxic effect directly on decomposing microbes or enzymes they produce". Our own investigations have shown that pine forest litter serves as a catching net of air-born pollutants. As an example, the unpublished data by Grabinska from the area polluted by the industry producing fertilizers can be cited. The contents of N and S in per cent and of heavy metals in ppm are as follows:

	Zn	Fe	Cu	Mn	N	S
litter	228	3500	16.9	380	2.43	0.32
upper soil layer	8.2	1460	1.1	16	0.05	0.01

The procedure recommended for the realization of the 'Monitoring of ecosystems' program is described in the instruction prepared and available at the Voivodship Stations of Environmental Monitoring (Breymeyer *et al.* 1981). The observation net will be quite dense; in each of the 49 voivodships of Poland the area for the monitoring of pine forest has been delimited (Fig. 6). The first stage of the ecosystem description is the phytosociological record (the method of Braun-Blanquet is commonly used in Poland). Phytosociological record introduces the ecosystem examined into the European classification of forest associations making the comparison of ecosystems easier and allowing to draw some general conclusions applied to the whole class. Two parallel programs of field observations will be carried out in the described forest sites: 1) control of selected bioindicators which provide information about the flow and storage of pollutants in the ecosystem, and 2) control of functioning of ecosystem measured by the rates of basic ecosystem processes, production and destruction of organic matter.

Assuming that air pollution attacks the pine forest from above, monitoring should be carried out in the vertical (Fig. 7). Pine needles collected from top branches, from lower branches an from the litter will be analysed for SO_2 pollution. Also the mosses and the lichens distributed at several levels will be analysed for heavy metals content. The litter and upper soil layers in these ecosystems should be analysed thoroughly, because they are the final sinks for pollutants. Complete chemical analysis of litter and soil samples is needed. Also on sites not having

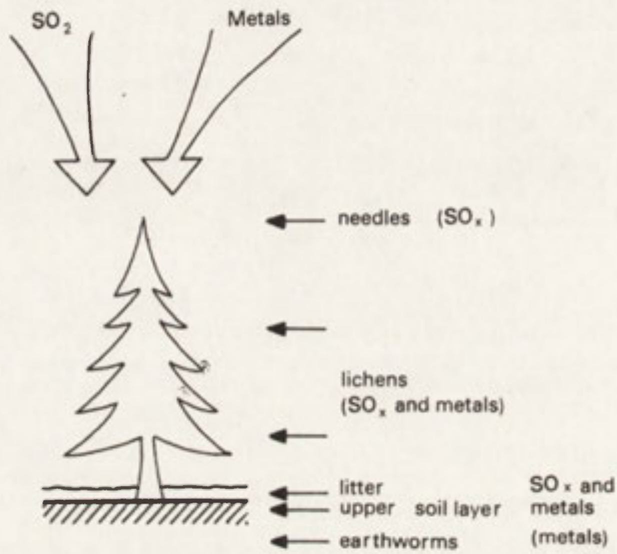

Fig. 7. The levels of registering of flow of pollutants through pine forest ecosystem (after Breymeyer 1981)

acid soils earthworms should be caught and their body tissues should be chemically analyzed. Gullvag (1978), Czarnowska and Jopkiewicz (1980) state that earthworms act as metals accumulators in the soil (especially zinc and cadmium). These bio-indicators make it possible to register the vertical transfer of pollution in the forest. Pine needles and lower plants (mosses and lichens) make it possible to map the distribution of pollutants; the maps of pollution spread over vast industrial regions are known in our climatic zone (Fig. 8).

The monitoring of the functioning of ecosystems will be made by measuring the intensity of production and decomposition of organic matter. In order to estimate the productivity of green material in pine forest, a number of samples of organic fall should be collected; they allow one to estimate easily the annual production of needles and leaves (in the case of mixed forest). For a selected series of trees, simultaneous estimates of increments of wood are made using standard forestry methods. Decomposition of organic matter is estimated by the loss of litter in bags placed on soil surface for one year. Constant measurements of production and decomposition rates of organic matter conducted over several years allow one to construct simple budgets of organic matter in pine forests and follow the changes in the state of these ecosystems. On the basis of simultaneous monitoring of changes in the rate of ecosystem processes and in the content of sulphur and metals in various ecosystem components, the maps presenting the dependence of the state of ecosystems on the state of pollution will be prepared.

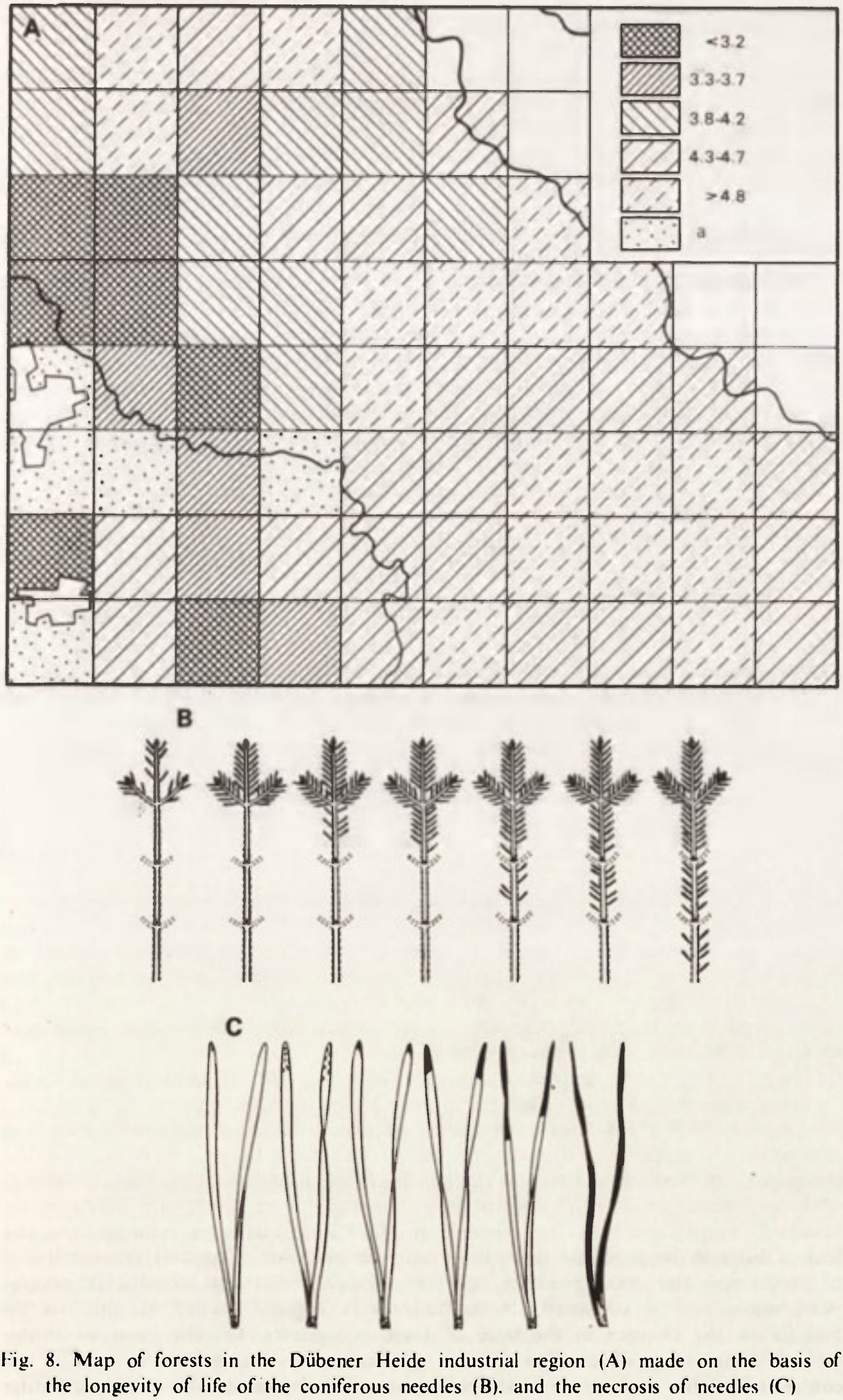

Fig. 8. Map of forests in the Dübener Heide industrial region (A) made on the basis of the longevity of life of the coniferous needles (B), and the necrosis of needles (C)

a areas where the Scots pine is eliminated totally (after Jager 1980)

The program 'Monitoring of ecosystems' is cheap, it requires standard chemical laboratories and qualified personnel, which is in surplus. Field methods are simple and commonly known, described in ecological literature. The first Voivodship Stations for Environmental Monitoring started their activities in 1982.

CONCLUSIONS

The current level of air-born pollution in Central, East, and North Europe is a danger to a biosphere, especially to coniferous forests ecosystems. These sensitive ecosystems have been poisoned and destroyed in many parts of Europe in the last years. The next ecosystems in danger in our European conditions are the lakes; in other, not so highly populated, parts of the world the different types of ecosystems are devastated or even removed from the surface of the earth. Only the large programs of the biosphere control can provide us with early signals and eventual protection of ecosystems in danger.

The powerful national and international organizations register, organize and encourage to develop the broad monitoring systems. The detailed list of national and international monitoring programs is provided by UNEP (1974), Smithsonian Institution prepares the Environmental Monitoring and Baseline Data Directory. The international symposia on monitoring problems were organized in various countries: in Sweden, Germany, USSR, USA. The UNESCO MaB (Man and Biosphere) program includes the project on environmental monitoring, INTECOL (International Association of Ecologists) organizes special monitoring sections at the world congresses. The Global Environmental Monitoring System (GEMS) is developed on the whole Earth by the UN agencies; this program includes the meteorological and ecological monitoring realized by the net of stations dispersed on the earth surface. It seems that ecological monitoring is a necessity of our time and that without ecological evaluation of any area the planning of its management and future uses is unrealistic.

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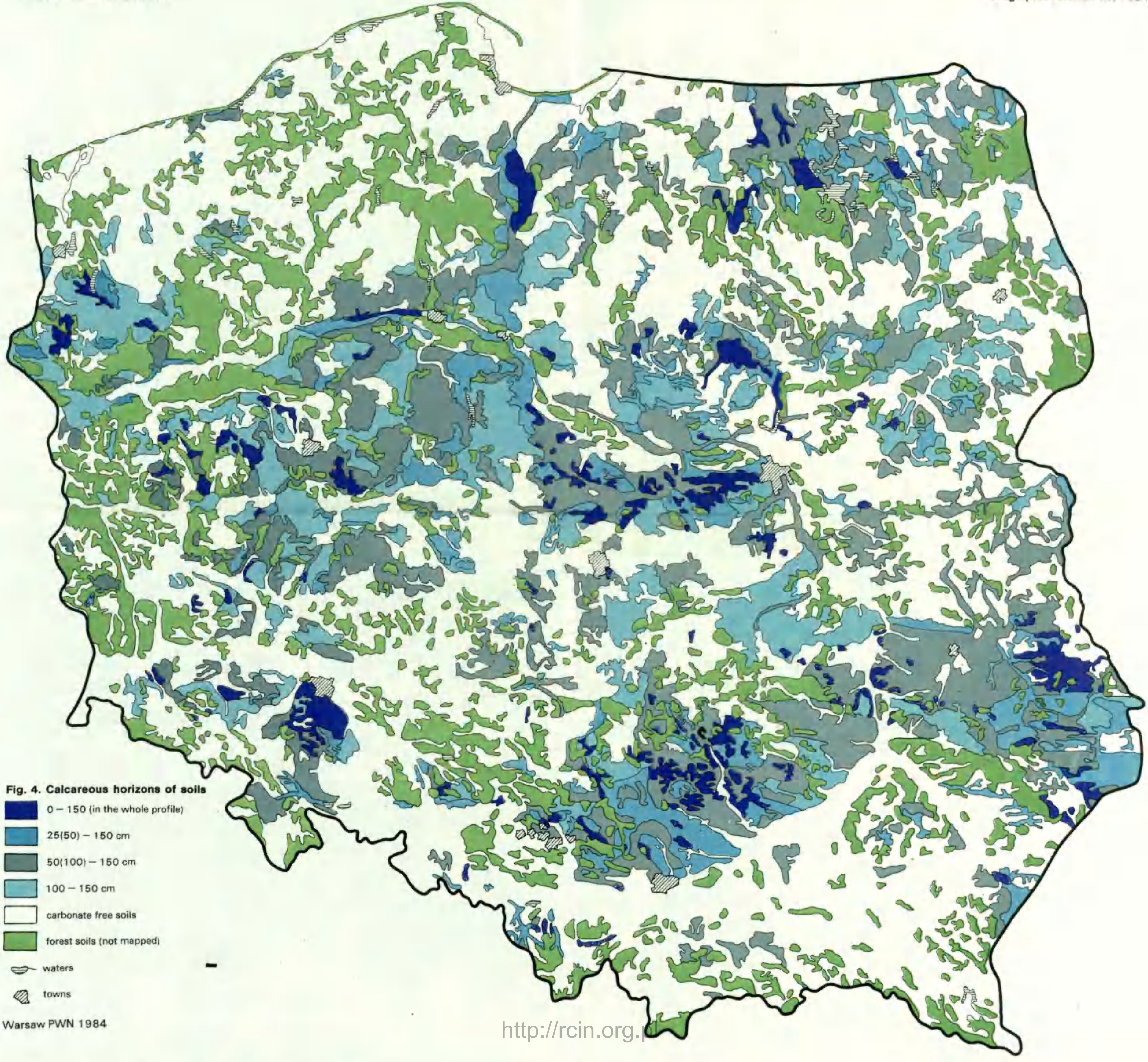

Fig. 4. Calcareous horizons of soils

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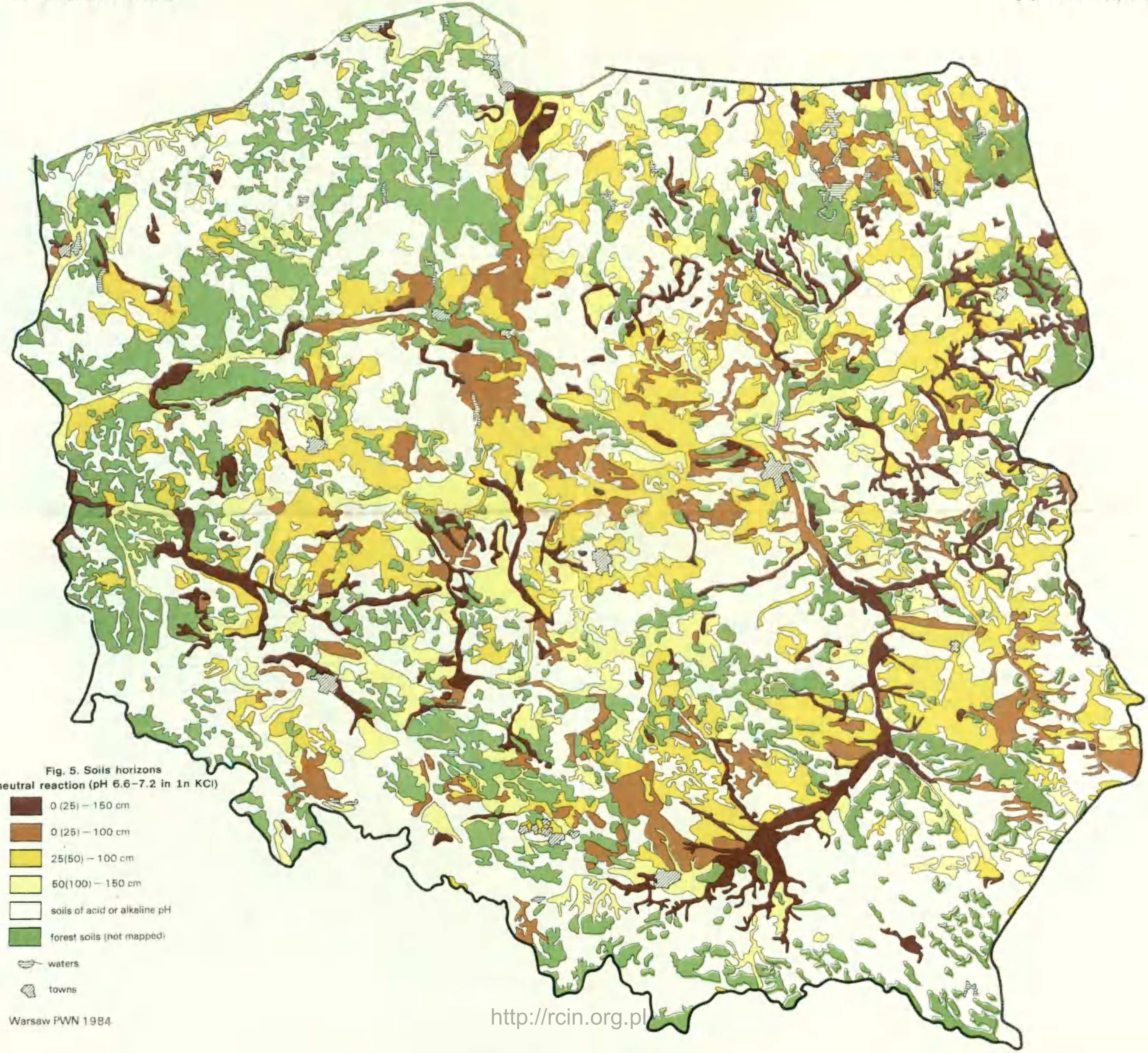

Fig. 5. Soils horizons of neutral reaction (pH 6.6–7.2 in 1n KCl)

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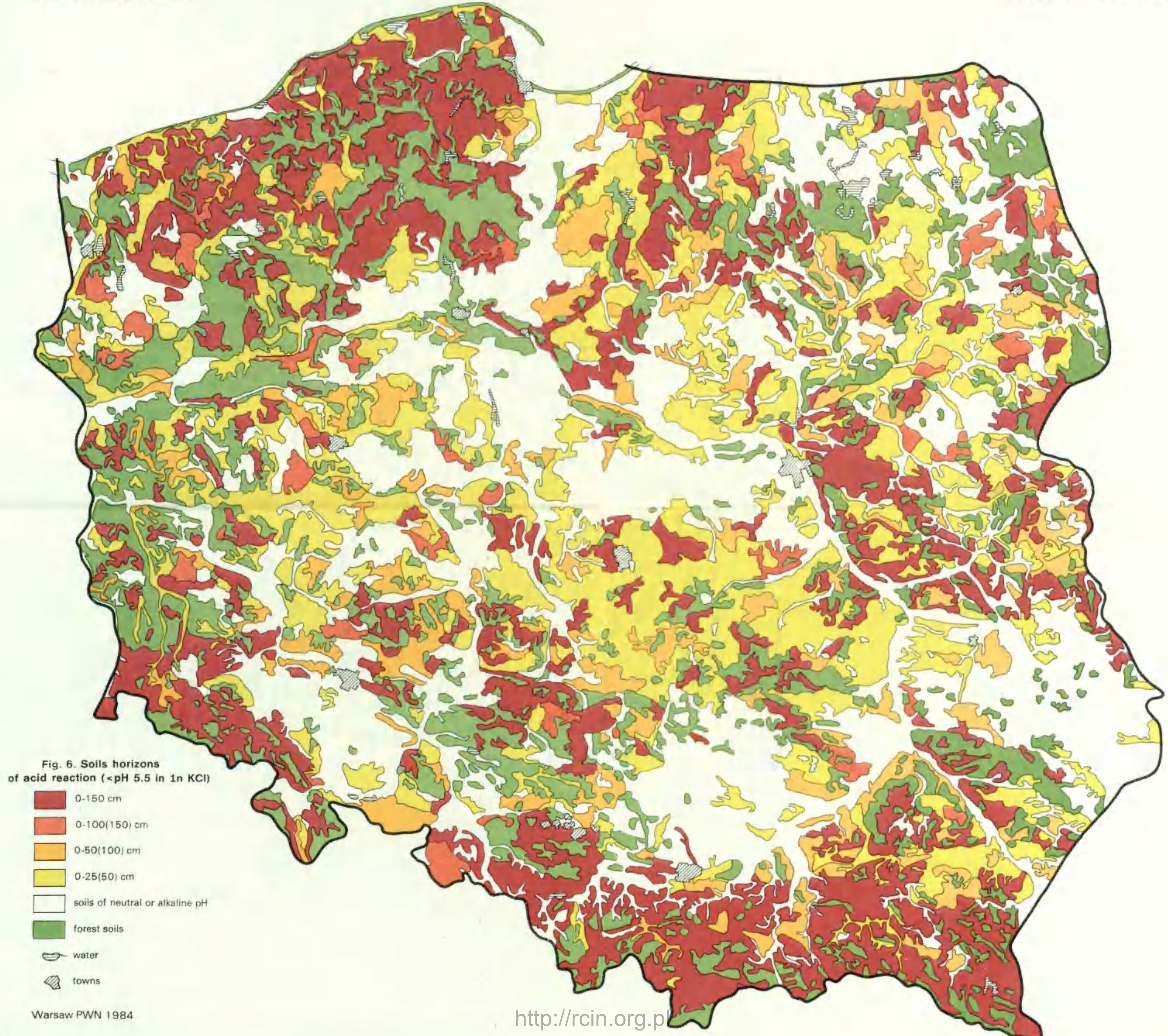

Fig. 6. Soils horizons of acid reaction (<pH 5.5 in 1n KCl)

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