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MAIN FEATURES OF THE TERTIARY RELIEF OF THE SUDETES MOUNTAINS

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INTRODUCTION

The Sudetes, middle mountains of Europe, are composed primarily of Palaeozoic and Mesozoic rocks. Their specific morphological style distinguishes them from other mountains. Their northern or, more specifically, north-eastern edge

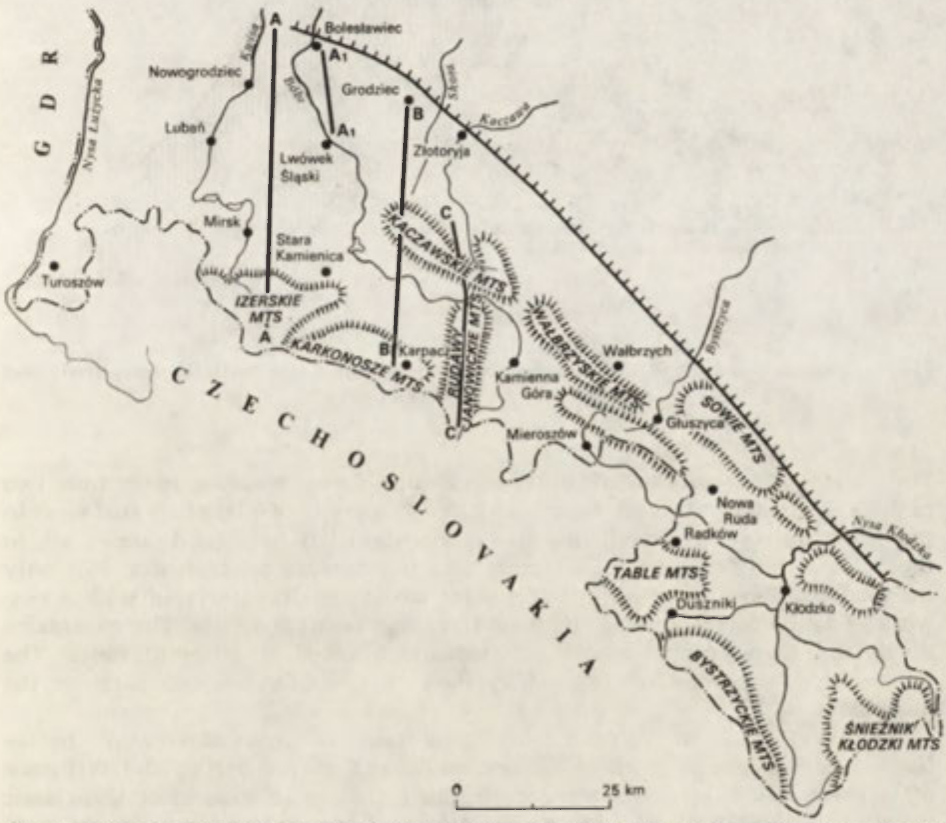

Fig. 1. Map of the Polish part of the Sudetes showing names of mountains, rivers and place-names mentioned in the article

A — A, A_1 — A_1, B — B, profiles described in Figs. 13 and 14, C — C, profile described in Fig. 16

is clearly rectilinear, which agrees with its tectonic origin (fault). On the other hand, the interior of the mountains resembles rather an upland rising from 400 to 700 m a.s.l. High but also flat ridges (from 1,200 to 1,400 m high) constitute their highest part. The highest elevation, Śnieżka, rises as a separate cone to 1,602 m a.s.l. (Fig. 1).

Large, intermontane basins divided by flat ridges are the main characteristics of the Sudetes morphological style. Those ridges are nothing but morphological planation surfaces cutting rocks of different age and different resistance (Fig. 2).

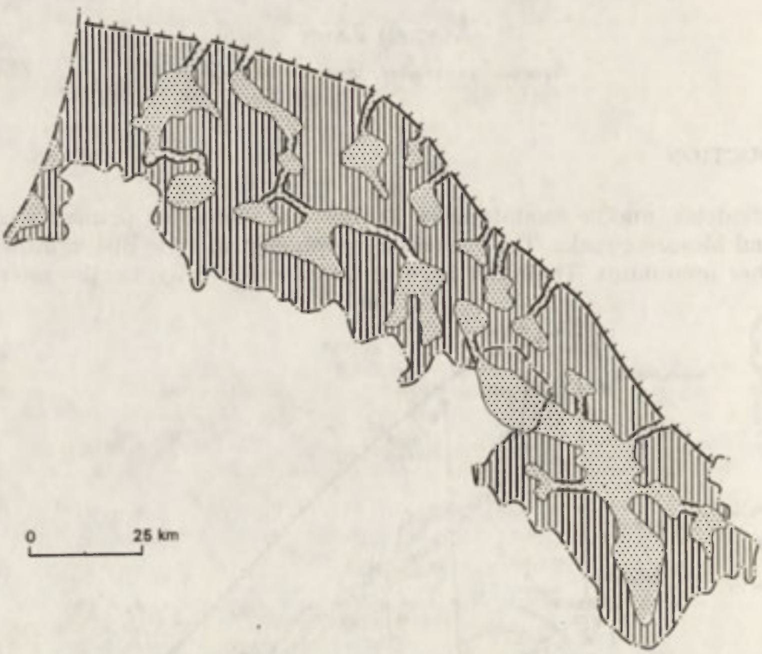

Fig. 2. General features of the Sudetes relief: mountains and foothills (hachured) and basins and gap valleys (blanks)

The origin and evolution of the Sudetic land-forms resolves itself into two problems: the formation of basins and the formation of planation surfaces. In the scientific research conducted so far attention has been paid, above all, to the relationship between these forms and the mountains' tectonics. Not only external Sudetic Threshold, but also their whole area is interlaced with a network of faults corresponding, in general, to the basins contours. The mountains divide into two tectonic blocks uplifted and lowered at different times. The bottoms of the basins are formed by these tectonically lowered parts of the mountains.

Let us examine the Sudetic land-forms from the point of view of the influence of egzogenic, climatic factors while still remembering the influence of tectonics. Such attempts were made more than once soon after the classic work of Jessen (1938) who recognized traces of tropical and subtropical morphology in the relief of European middle mountains remarkably well. Now that the geomorphological processes of the tropical zone have been well understood, and many works and monographs have been published it is not out of place to examine the Sudetes from this angle.[1]

The Sudetes are composed of crystalline blocks with two large synclines, i.e. North and Intrasudetic ones stretching between them. The youngest deposits of those synclines come from the Cretaceous to Santonian inclusive. After orogenic movements of the Laramide phase in the Upper Cretaceous the Sudetes were already a land mass in the Campanian and Maestrichtian floors. They remained a land mass for the whole Palaeogene and were elevated at the end of the Oligocene (the probable age of the Marginal Sudetic Fault); the Neogene seas flooded regions North of the Sudetes, and if they reached mountains they did it only from the west (Turoszów). The mountains edge along which tectonic movements were repeated several times formed their margin. Thus, the egzogenic degradation of the mountains lasted in different climatic conditions for at least 80 mill. years. Tropical and subtropical processes were active on this land in the Upper Cretaceous and Palaeogene for the longest period of time. Those were the conditions of humid tropic al zone, most frequently, however, a tropic with changing seasons, i.e. humid and dry ones (savanna climate). The influence of the tropical and savanna climate, the steppe-desert one (the Sarmatian) inclusive, was stronger in the Miocene and Pliocene (according to Sadowska 1977 the type of climate of the south-eastern part of the United States of America). In the Pleistocene the Sudetes underwent a cold, periglacial climate degradation. The Holocene was too short a period to introduce greater changes in this course of events.

Each climatic cycle was marked by a specific type of weathered rock products and deposits (regolith) as well as by a specific group of forms. This second climatic feature is of a greater importance because forms survive in a better way and last for a longer period of time than loose materials. For all that time the Sudetes remained mountains and as such they remained an area of erosion and denudation — deposits and weathering wastes were not very likely to be preserved. What is preserved, however, is typical forms — the counterparts of different climates. To decode different overlapping generations of these forms is the aim of the present study.

Syngenetic sediments in the Sudetic submountain area preserved in depressions make this reconstruction easier. It is worth mentioning that, so far, a basic mistake has been made in the analysis of the Sudetes relief. That mistake was to put a time equality sign between a form in the mountains and sediment in the forefield of the mountains. This rule applies to all cold, arid, and temperate climates, but it does not apply to tropical ones. What is active in their environments is an intensive chemical weathering (kaolinization, lateritization), while the morphological surface is protected by a thick forest. There are no syngenetic sediments in the forefield of rain tropic mountains. Only a change of climate and devastation of tropical forest may result in setting weathering material in motion, washing it and removing it outside the mountain area. Although clays and redeposited kaolins can be found in tectonic troughs in the Sudetic forefield, their age does not correspond to the age of Sudetic forms. They are younger than the forms. The diagram shows the principles of correlation between the Sudetic relief and sediments (Fig. 3).

[1] The present article is a summary of a more extensive work written in Polish. Materials and data from references have been quoted in detail there. From the general studies characterizing tropical and subtropical morphology of both rain tropics and subarid or savanna tropics the following important works should be quoted: Alexandre, Alexandre-Pyre (1970), Birot (1966), Bremer (1971,1973), Budel (1957, 1977), Louis (1964), Thomas (1974), Zonneveld (1975).

The rate at which geomorphological processes are active in different climates is not known well enough as yet, though much has been written on that subject. If we assume, for the sake of simplification, that it is equal or approxi-

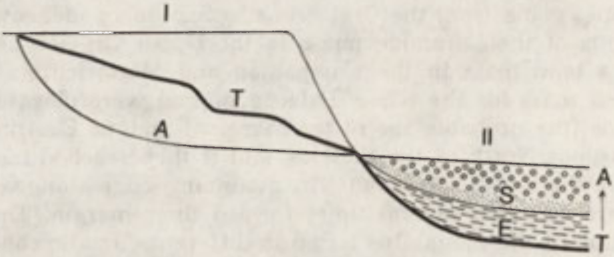

Fig. 3. Diagram showing the relation of degradation surface in the mountains (I) to the accumulation area in the forefield of the mountains (II)

T — surface of tropical morphogenesis relief with epigenetic sediments (E) of the downward sedimentation cycle, A — surface of arid morphogenesis with syngenetic sediments (S) of the upward sedimentation cycle

mate, the effect of their action will always be a time function. The Sudetes have been exposed to degradation processes for 80 mill. years. 70 mill. years out of this 80 mill. fall to the action of tropical and subtropical climates beginning from the Upper Cretaceous, through the whole Palaeogene and Miocene. Thus, 87% of time falls to the evolution of the tropical generation of forms, some 10% of time falls to the transitory, semiarid generation, the remaining 3% fall to cool climates stage interrupted by the action of temperate climate processes. The fact that, so far, so much has been written on external features of the glacio-postglacial morphology in the Sudetes (slopes), and that the presence of arid climates (pediments) in them has been emphasized is due to the simple reason that both the generations, as the youngest ones, dominate the external features of the mountains surface, or, speaking more precisely, among mezo- and even microforms. This 'make-up' of the surface overlaps with the proper, vast Sudetic morphology deriving from the long period of hot climates. The major effect brought about by the hot climates was the morphological inversion of the Sudetes. And this is our main subject.

MORPHOLOGICAL INVERSION

The Palaeogene encountered two huge tectonic troughs in the Sudetes corresponding to the North and Intrasudetic Synclines. Both the synclines are represented by the youngest Sudetic marine sediments — the Upper Cretaceous sandstones. These formations are, in general, situated high up and constitute the well-known Sudetic table mountains. The synclines' wings underwent a far-reaching degradation, so that huge morphological depressions stretching through the whole Sudetes were formed in their place. The line of these depressions corresponds in a substantial degree to the route of the Main Intrasudetic Fault. The relation of these Intrasudetic depressions, which can be defined as the central morphological depression of the Sudetes, to both the synclines and to the old mountain massifs is shown in the map (Fig. 4). This picture is very symptomatic and typical. What is the axis of the Sudetes is not mountain ridges, but huge intermontane depressions. These are the effects of morphological degradation younger than the youngest sediments of both the synclines,

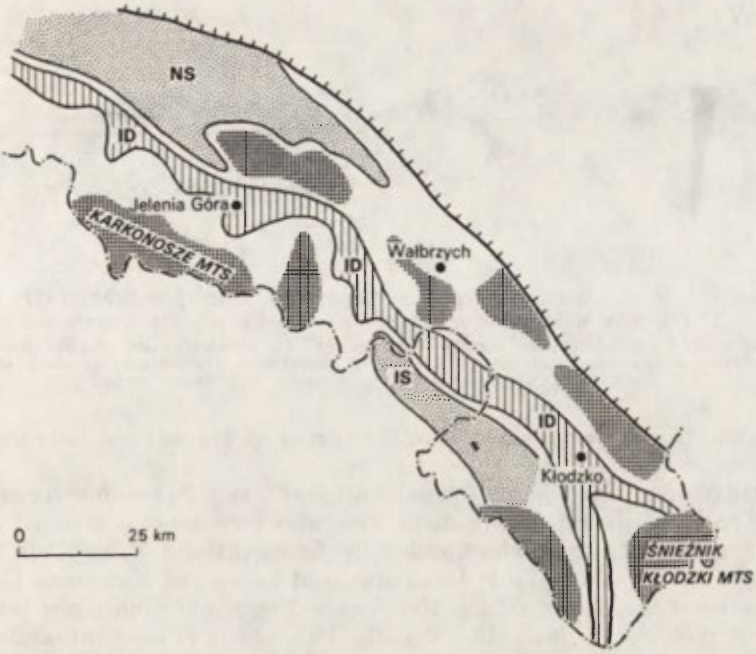

Fig. 4. Position of the axis of Intrasudetic morphological depressions (ID) in relation to two major Sudetic tectonic troughs (synclines), i.e. the North Sudetic one (NS) and the Intrasudetic one (IS). Positions of major Sudetic massifs and groups of mountains (chequered pattern) are also marked in the map. Notched line — Sudetes edge

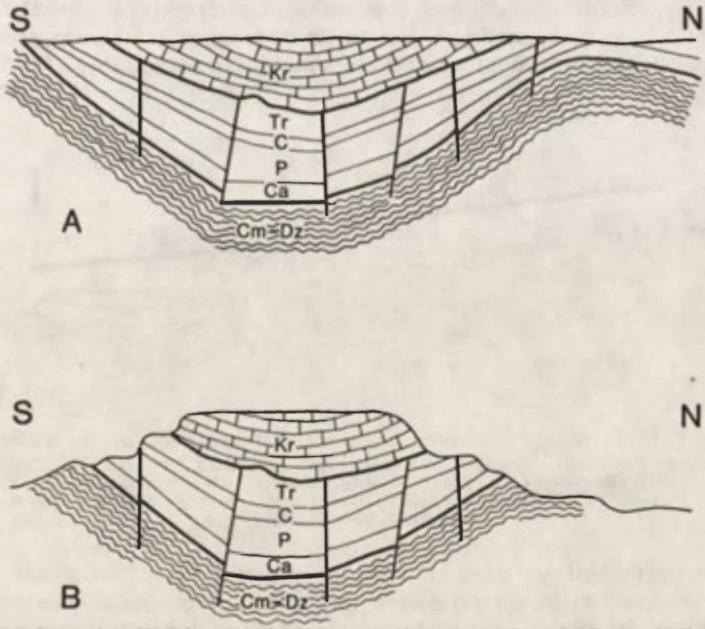

Fig. 5. Inversion of relief in the Sudetes on the example of North Sudetic Synclinorium. Geology according to J. Milewicz (simplified section)

Cm, Dz — Older Palaeozoic, Ca — Carboniferous, P — Permian, C — Zechstein, Tr — Triassic, Kr — Cretaceous. Transverse faults lines. A — Morphological situation before inversion, B — after inversion

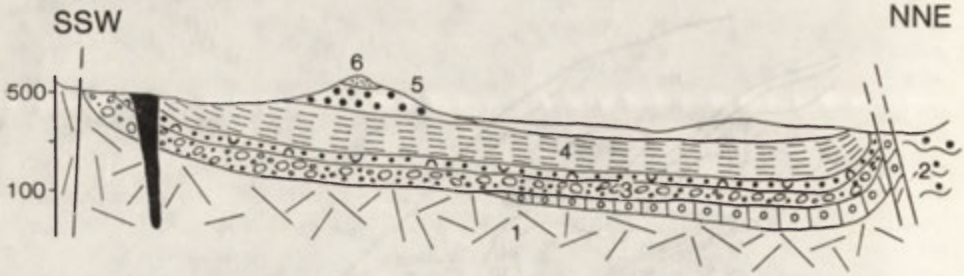

Fig. 6. Section of the Wleń Graben (according to J. Gorczyca-Skała 1977) showing a typical morphological inversion of a Cretaceous trough

1 — greenschists, 2 — metamorphic schists (Palaeozoic), 3 — conglomerate, shales (Rotliegendes and Zechstein), 4 — siltstone (Turonian), 5 — quartz sandstones (Coniacian), 6 — limy sandstones (Coniacian). Syncline is cut with faults and basalt dyke

i.e. than the Upper Cretaceous. Thus, the period of degradation falls mainly in the Palaeogene.

Degradation affected hard, coherent Mesozoic and Palaeozoic rocks. Metamorphic rocks occurring among them were also considerably affected (Figs. 5 and 6). A geomorphologist who watches the Ścinawka and Nowa Ruda Depressions from the top of the Table Mountains, and Lesko and Kamienna Góra Depressions from the height of the Cretaceous Mieroszów sandstones (examples are many) receives an impression that the Palaeogene erosion introduced very old changes in the Sudetes. It inverted relief and damaged hard Palaeozoic rocks. Crystalline rocks of the Karkonosze Massif and the Śnieżnik Kłodzki Massif resisted degradation. The extent of this morphological inversion is, on the average, 200 to 500 m. The cause of the morphological inversion can be found in the peculiar character of the action of intertropical climate processes which react not to rock hardness, but to its hydrogeological properties such as porosity, permeability, chemical and mineral composition (Fig. 7). The rocks

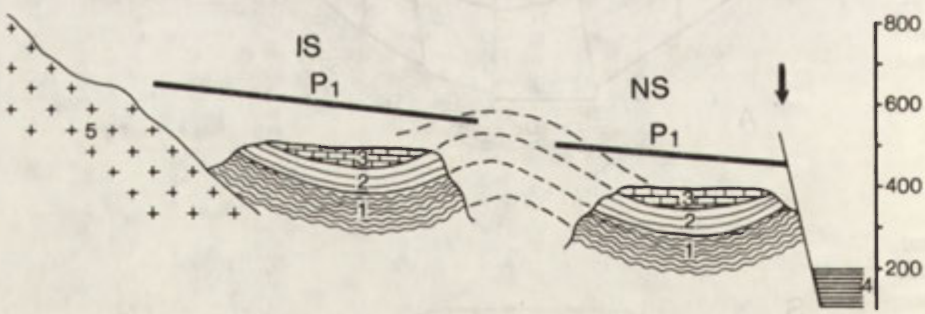

Fig. 7. Diagram of Palaeogene morphological inversion in the Sudetes

1 — Precambrian, Palaeozoic rocks, 2 — Carboniferous, Permian, Triassic, 3 — Cretaceous, 4 — Miocene, 5 — Crystalline rocks of Inner Sudetic massifs. NS — North Sudetic Trough, IS — Intrasudetic Trough, P_1 — Palaeogene planation surface. Pointer indicates the Sudetes edge (Marginal Sudetic Fault)

of greatest permeability, marked with the index 4 in a four-grade scale, i.e. jointed Cretaceous sandstones resisted the action of chemical weathering processes best and for the longest period of time.[2] They did not decompose because

[2] According to M. Rozycki's results of reasearch published only partially in *Przewodnik XLIII Zjazdu Polskiego Towarzystwa Geologicznego* (Guide to XLIII Meeting of the Polish Geological Society) in 1975.

they did not retain waters and were not exposed to their chemical action. The rocks marked with the index 1 in the hydrological scale (all schists and slates, crystalline schists and clay-pelitic marls in it), i.e. rocks retaining water in the conditions of a tropical climate were exposed to intensive chemical weathering.

Morphological inversion is a phenomenon widely-known in the intertropics. The author of the present article had an opportunity to see its huge forms in the Republic of Zaire (Katanga). Many authors have written on this inversion, for example Louis (1967).

SUDETIC BASINS

The same general problem of the dependence of the Sudetes relief upon the degree of the rocks chemical weathering resistance can be found in the origin of intermontane basins. Although their contours correspond to the network of tectonic systems, this does not mean that tectonic vertical movements brought about the formation of basins. The statement about lowering the bottoms of basins by tectonic 'thrusting' of the surface repeated by different authors (Berg 1926, Walczak 1968) has never been proved. On the contrary, what can be found at the bottom of Sudetic basins is relics of kaolin weathering products, i.e. typical weathering wastes originating in the tropical of subtropical climate of the Tertiary period (e.g. the Mirsk Basin, Jelenia Góra Basin), and that is why the origin of basins should be connected with intensive chemical weathering. The fact that Sudetic basins form closed morphological units independent of the mountains margin is symptomatic. They are bases of denudation for the surrounding mountain area, and rivers flow radially to them. The only links between basins and the mountains margin are narrow valleys of river gap type (Fig. 2), frequently with incised meanders draining the basins out. Such phenomena where a basin is opened with a somewhat wider depression are exceptional. And, though the supposition that the Sudetes drainage is of a regressive character (as the result of the headward erosion) immediately occurs on this basis, in fact, it is not true. The rivers (discussed later) are epigenetic, and their different sections acted regressively in certain periods of time.

Three basins of the Western Sudetes, i.e. the Jelenia Góra Basin, the Stara Kamienica Basin and the Mirsk Basin exhibit the greatest number of typical features having a bearing on the general issue of the origin and evolution of the Sudetic basins (Fig. 8). Their bottoms are graded, composed of cut rocks of an older bed, and their slopes are steep. Rivers flow to them from different sides, so that the basins are river knots. They have, however, one outflow which is a narrow valley (gap). What is most characteristic and typical of all the basins is the fact that convex forms occur at their limits. Each basin is divided in a way into two smaller basins (valleys) by ridges stretching along the middle of these forms. It is most clearly visible in the Jelenia Góra Basin (the Staniszów Hills), but forms are identical in the remaining two basins in spite of being more degraded. These forms are composed of harder, more effectively weathering and erosion resistant rocks, but their origin is not due to this fact. According to the view accepted here on the connection of concave forms with the degree of rocks water contents, it was rivers that brought about lowering of margins of basins bottoms, but not by their erosive actions. They simply provided waters and rushed chemical weathering. Experts in contemporary tropics (Bremer 1971 and Gellert 1971 among others) agree upon the fact that the weathering is most intensive at the feet of slopes. It is there, then, that aggressive chemical waters flow from the slopes, and the weathering wastes thickness is greatest. Rivers that were draining the basins worked most effectively in that place when removing the weathering waste. Lateral development, i.e. constant expansion of the bottoms of basins, is then characteristic of tropical basins. The development pattern of basins for which chemical weathering was the leading factor of rocks decomposition is shown in Fig. 9.

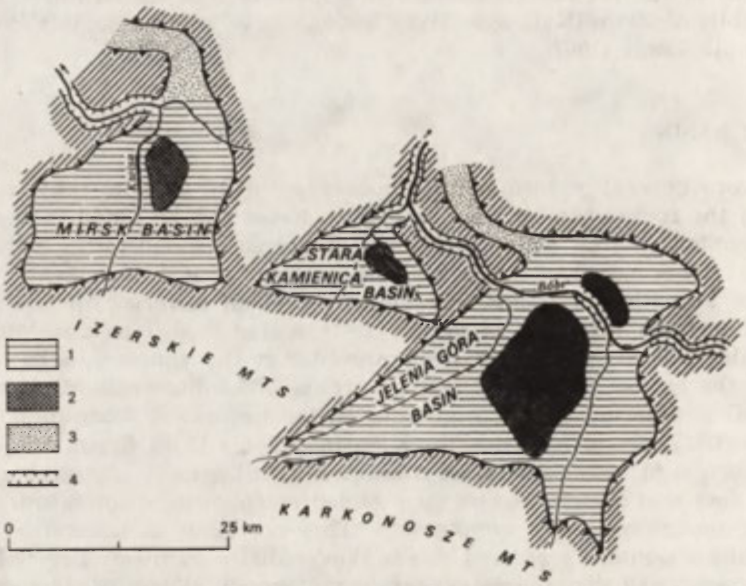

Fig. 8. Tree basins of the Western Sudetes: Jelenia Góra Basin, Stara Kamienica Basin, and Mirsk Basin

1 — flat basin bottoms, 2 — internal basin hills, 3 — old valley forms, 4 — gaps

Fig. 9. Stages of the Tertiary development of the Jelenia Góra Basin when chemical weathering of rocks was the leading destructive process

1 — granite, 2 — granite cut with hard dyke rocks (Staniszów Hills), 3 — Tertiary waste mantles (regoliths)

Mezoforms of basins bottoms and slopes also testify to the fact that basins were created mainly by chemical weathering of rocks in tropical conditions. Tors characteristic of granitic areas, i.e. the ones of the Karkonosze Mountains and the Jelenia Góra Basin, belong to such mezoforms of basin slopes. In spite of appearances, the bottoms of basins are not perfectly even. Both the granitic knobs, i.e. the ones discovered when boring and those occurring as rather low hills of small, domed inselbergs, exist within their limits. They were described several times from the northern part of the Jelenia Góra Basin (Schwarzbach

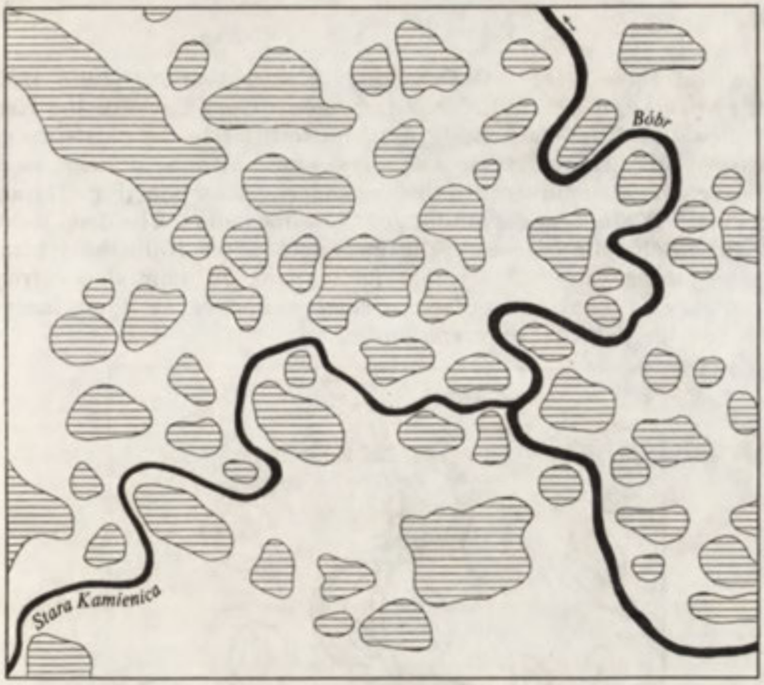

Fig. 10. Meander character of the Bóbr and Stara Kamienica rivers and their valleys passing hard knobs of bed-rock composed of granite and gneiss (hachured area)

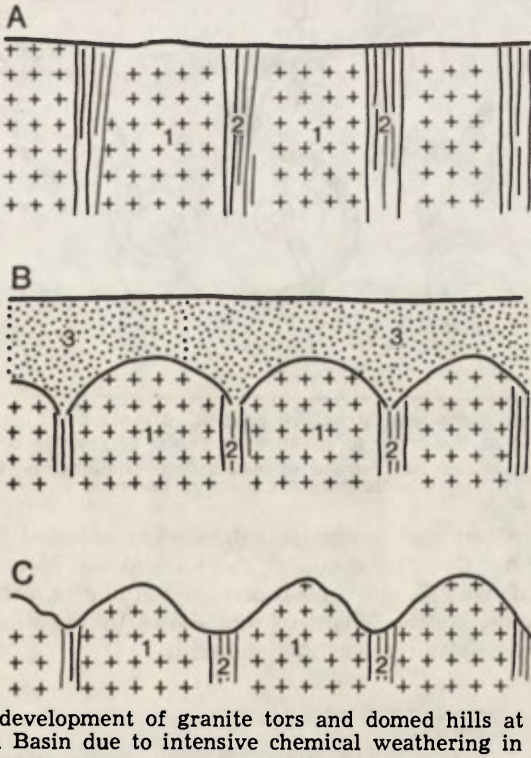

Fig. 11. Stages of development of granite tors and domed hills at the bottom of the Jelenia Góra Basin due to intensive chemical weathering in the Tertiary

1 — monolithic granite, 2 — granite loosened with interstices of joints, 3 — weathering waste (saprolite and regolith). A — initial stage, B — basin bottom in tropical climate stage, C — contemporary relief of basin bottom

1942). Some of them were transformed by glaciers actions (Jahn 1952). The course of rivers, i.e. the Bóbr River in the Jelenia Góra Basin or the Kamienna River in the Stara Kamienica Basin (Fig. 10) testifies to the existence of those knobs. Rivers form characteristic meanders which may be defined as pseudo-meanders, i.e. the structure controlled meanders. A section (Fig. 11) and map (Fig. 12) show the origin and evolution of those meanders. The deep weathering is faster in closely jointed rocks. The meanders differ from the typical ones, among other things, in the fact that inclinations of their slopes frequently appear contrary to what takes place in river meanders, i.e. their inner slopes are steep, and the external ones are gentle.

Fig. 12. Formation of meanders (structure controlled meanders) of the Bóbr River by adapting of the river to subsurface knobs of granite bed-rock

1 — initial stage of river on the surface of weathering products, 2 — stage of river after skeletonizing hard knobs of bed-rock

Not only basins but also mountain ridges were affected by the process of chemical weathering. Granitic slopes of the Karkonosze Mountains (Jahn 1962) were formed in this way as subsurface forms remaining in a thick waste mantle and regolith till now. As the height of tors shows the weathering reached 20–30 m below the external surface of the mountains.

MORPHOLOGICAL PLANATION SURFACES

The Sudetic morphological planation surfaces are very difficult to reconstruct because all that region was affected by several block movements. Each block, either tectonically uplifted or lowered, destroyed the morphological order deriving from the climate. It can be seen particularly well in the Main Intra-sudetic Fault line. It clearly changes the position of planation surfaces lying to the North and South of it (Fig. 13). Not the Fault line but lithological reasons,

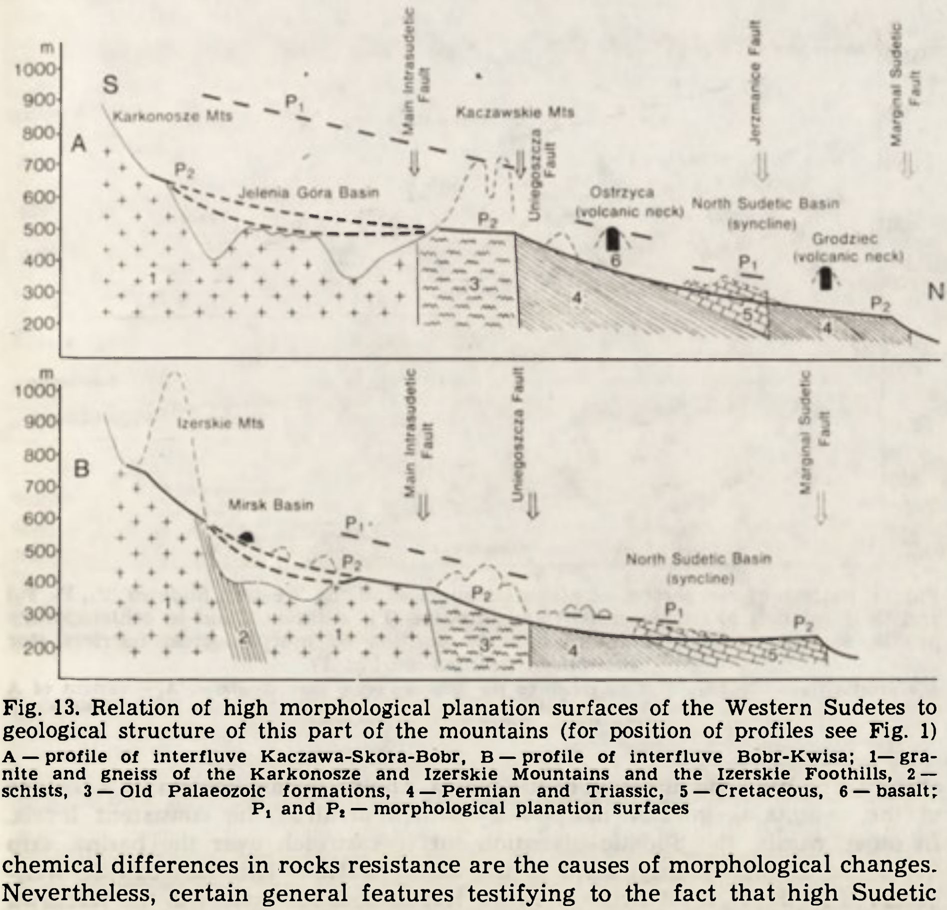

Fig. 13. Relation of high morphological planation surfaces of the Western Sudetes to geological structure of this part of the mountains (for position of profiles see Fig. 1)
A — profile of interfluve Kaczawa-Skora-Bobr, B — profile of interfluve Bobr-Kwisa; 1 — granite and gneiss of the Karkonosze and Izerskie Mountains and the Izerskie Foothills, 2 — schists, 3 — Old Palaeozoic formations, 4 — Permian and Triassic, 5 — Cretaceous, 6 — basalt; P_1 and P_2 — morphological planation surfaces

chemical differences in rocks resistance are the causes of morphological changes. Nevertheless, certain general features testifying to the fact that high Sudetic levels developed in the conditions of a tropical climate remained. According to the author's conception set forth earlier (Jahn 1953) three basic levels, denoted here with letters P_1, P_2 and P_3, can be distinguished in the Sudetes. The oldest one corresponding to the mountains summit plane (P_1) is the Old Palaeogene plane. A younger one is the Oligocene level, or very likely the Lower Miocene one (P_2), and, finally, the youngest one is the Pliocene level (P_3) (Fig. 14). Their pattern presented in a very simplified way appears as a pencil of lines parting from the Sudetes margin deep into the mountains (Fig. 15). The highest level recalls the least concave inclined plane of the most constant inclination. The concavity of profiles deepens in the younger levels.

The fact that it is just intertropical rivers that have the least concave profiles is well-known. Deepening of the profile, working out concavity of erosional graded curve is a phenomenon typical of the temperate climates rivers. Testifying to this is a comparison by Louis (1973) who compared the profiles of intertropical African rivers (the Ruvuma River in Tanzania) with those of the Central European rivers (the Rhein, the Elbe). The Palaeogene Sudetic rivers and the planation surfaces levels corresponding to them exhibit, then, typical features of intertropical morphology.

The high Sudetic morphological levels are inclined in two directions, i.e., a) generally from the South to the North, from the mountains interior to its

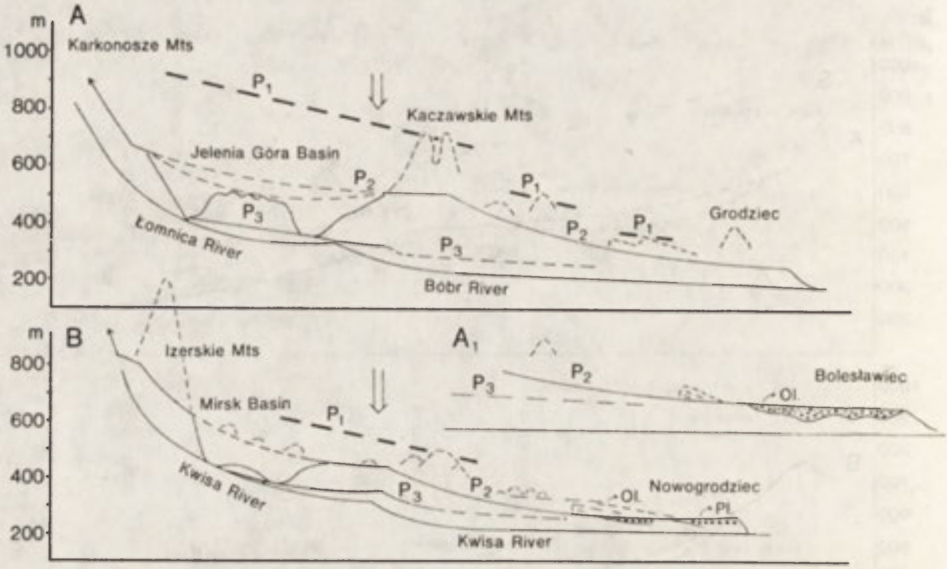

Fig. 14. Pattern of morphological planation surfaces of the Western Sudetes (P_1, P_2, P_3) and their relation to Oligocene (Ol) and Pliocene (Pl) sediments and to contemporary profile of those valleys. Pointers indicate position of morphological barriers (for position of profiles see Fig. 1)

A — profile from the Jelenia Góra Basin to the Sudetes edge near Grodziec, A_1 — variant of A profile along the Bóbr River right bank to Bolesławiec, B — profile from the Mirsk Basin along the Kwisa River to Nowogrodziec

margin, and b) in the direction of the basins. The basins are seemingly a feature of the mountains interior morphology which disturbs the consistent levels. In other words, the Sudetic planation surfaces stretch over the basins, skip them and, simultaneously, bend in the basins section. This fact can be well-observed in the P_1 level strike from the Karkonosze Mountains to the Kaczawa Foothills. The level's continuity is represented by the Rudawy Janowickie

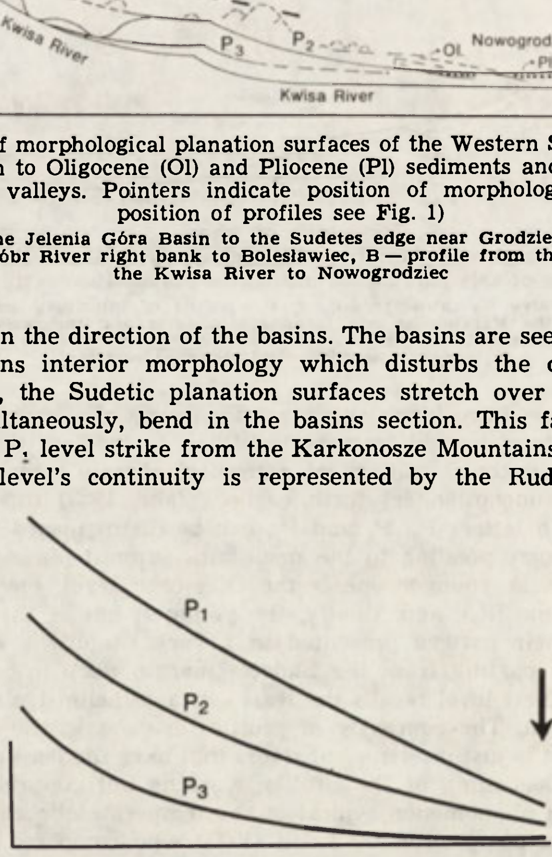

Fig. 15. Diagram of morphological pattern of Sudetic levels. Position of mountains edge is marked with a pointer P_1, P_2, P_3 — planation surfaces

Range — this fact has been already noticed by Cloos (1925) — because their tops fall consistantly to the North. On the other hand, levels come down in relation to the Jelenia Góra Basin. which can be noticed exceptionally well in the strike of P_2 (Fig. 16).

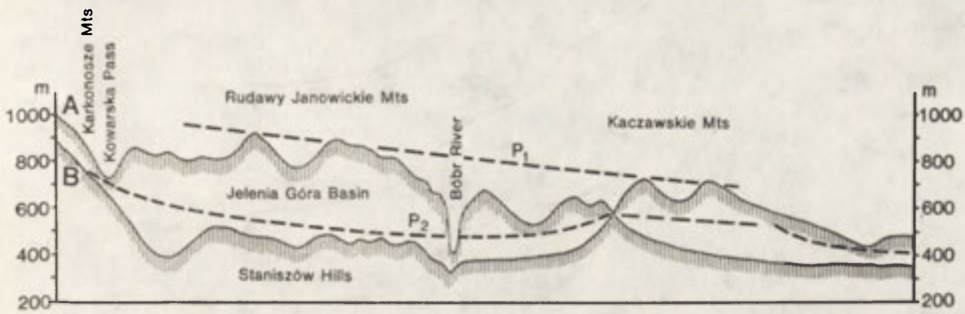

Fig. 16. Position of morphological planation surfaces — P_1 and P_2 between the Karkonosze and the Kaczawskie Mountains (C — C in Fig. 1)

A — profile from the Kowary Pass along the Rudawy Janowickie Ridge, B — profile from Borowice through the Jelenia Góra Basin (Staniszów Hills)

It follows, then, that the Sudetic Basins did not exist in the period of the oldest Sudetic planation in the Older Palaeogene and that they were formed due to the above-mentioned morphological-climatic processes when relief was adapting itself to the existing tectonic lines during the Palaeogene and Neogene. The changing climate created better and better conditions for the formation of a 'normal', i.e. concave erosional river curve. Contemporary longitudinal rivei profiles are the examples of such a curve.

MORPHOLOGICAL BARRIERS

When observing the profiles of those rivers one should pay attention to their one more specific feature. They are not uniform but consist of several concave sections. The profiles are slightly inclined in the basin sections, but the stream gradient increases considerably in the sections between basins. As a result the profiles assumed the shape of steps or tiers. The following profiles can be distinguished: two-step ones as the Bóbr River, the Bystrzyca Dusznicka River and the Nysa Kłodzka River, one-step ones as the Kwisa River and the Bystrzyca Świdnicka River, and uniformly concave profiles without steps as the Kaczawa River (Fig. 17).

Each step is a certain morphological threshold, a local denudational base as Walter Penck understood it, or a 'morphological barrier' as we shall call it here. By the notion of barrier we mean those clearly convex sections of the longitudinal profile of a valley where the erosive actions of river were restrained for a longer period of time. The conformity of barriers to faults lines or a greater rocks resistance attests to tectonical or lithological causes of the localization of thresholds. But, as in case of the origin of basins, we shall not consider the said rock conditions or factors as the immediate cause of barriers formation.

The fact that barriers were formed in the already existing Tertiary valleys means that the hot climate conditions contributed to the preservation of the barriers and that fact is born out by the lack of tropical rivers erosive capacity. The thresholds are not gullied there, waterfalls and swift currents of the 'sula'

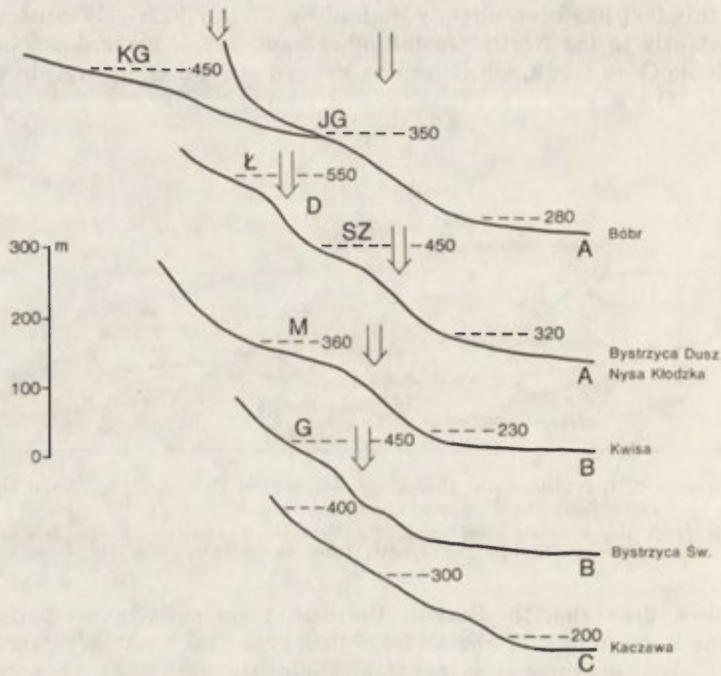

Fig. 17. Simplified longitudinal profiles of main Sudetic valleys. Pointers indicate the position of morphological barriers. Dashed horizontal lines and numbers indicate position and absolute altitude of basin bottoms. For position of rivers see Fig. 1

A — two-step type, B — one-step type, C — uniformly concave type; KG — Kamienna Góra, JG — Jelenia Góra, Ł — Łężyce near Duszniki, D — Duszniki, Sz — Szczytna near Duszniki, M — Mirsk, G — Głuszyca

type (Zonneveld 1972) have persisted there for millions of years. Structural thresholds and rock bars constitute important local erosion bases in tropical conditions (Bremer 1971, 1975). It is most probable, then, that ungraded and seemingly very young profiles of the Sudetic rivers are, in fact, very old, and their breaks were formed as early as in the tropical stage of the development of valleys. Such a conclusion agrees with the origin of basins which were also formed as weathering-denudational tropical hollows. The Sudetic thresholds are divided by basins of different levels.

The second conclusion arises from the character of valleys steps. Nowadays, they are clearly rejuvenated and correspond to valleys gap sections. This rejuvenation might have been done by erosive actions, more precisely, by the actions of headward erosion. To make it happen rivers had to regain their erosive capacity, which naturally requires a change of climatic conditions. The Sudetic rivers, at the present stage of their development, attacked the steps of longitudinal profile effectively. They damaged them and caused recession for at least the whole Pleistocene. Nevertheless, those thresholds are so well-marked that the Quaternary proved to be too short a period to make the removal of the longitudinal profile barriers possible, especially because, as geologists maintain, vertical tectonic movements still persist in the old faults line in the Sudetes. Genieser (1936) simply considered the thresholds in the Bóbr and Kaczawa rivers basin as the result of the Quaternary movements, which, as it later transpired, is not true in the light of the interpretation presented here. To sum up the view on the origin of forms called here 'morphological barriers' of the Sudetic valleys, it should be emphasized once again that, although they have structural foundations, their existence testifies to intertropical morphogenesis of valleys. And another conclusion. After the barriers had been formed climatic changes occurred which intensified rivers erosive activity. At that time, sharpening of steps by headward erosion occurred.

Thus, we are approaching the basic problem put forward at the beginning of the present article, i.e. whether the Sudetic rivers and valleys are epigenetic or regressive, or, in other words, if they were formed on the old, uplifted mountain surface as rivers flowing from the interior to the edge of the mountains. It is beyond all question that the old Palaeogene surface reveals itself in the pattern of river systems. The asymmetry of their basins is well-known and symptomatic. Extended right basins are characteristic of the Western Sudetic rivers (the Kwisa, Bóbr and, especially, the Kaczawa rivers) while extended left basins are characteristic of the Eastern Sudetic rivers (the Nysa Kłodzka with the Bystrzyca Polanicka rivers and the Ścinawka River). This pattern imitates the two Cretaceous synclinoria and the general inclination of the Palaeogene surface.

However, the existence of steps and morphological barriers in the longitudinal profiles of rivers and the fact that the hydrographic pattern adjusted itself to basins indicate regressive transformations of the Sudetic river and valley system. The transformation took place in the Neogene after the main Sudetic movements had occurred.

CLIMATE AND TECTONICS

When we look at the whole evolution of the Sudetic relief we can notice that factors controlled by climate and tectonics contributed to it. Tropical chemical weathering was of the greatest importance there. The action of this process, however, was not too effective because this weathering itself blocks the way of progress as the waste mantle collects. It would be difficult to imagine that the Sudetic basins several hundred metres deep could have been formed only by way of chemical decomposition of rocks in hydrological knots, especially if we know that the maximum depth of weathering reaches only 100 m. The relics of waste mantles only several metres thick can be found in those basins even today. The basins could develop only when the weathering products were removed from time to time. This might have happened only when rivers deepening their valleys and extending backwards their courses were opening the basins outflows. Tectonic movements might have stimulated rivers activity, and that is why it should be assumed that each removal of aggraded weathering wastes was due to the tectonic stage. The amplitude of movements, i.e. the difference between an uplifting block and motionless surroundings was greatest at the margin of the Sudetes, and, therefore, stimulators of river action existed mainly near the Marginal Sudetic Fault. In each period of the Sudetes morphological development in the past there existed a situation reminiscent of the contemporary relief of the mountains. Young or rather rejuvenated topography, with narrow deeply incised valleys at the mountains margin, and the old relief, with gentle slopes and wide basins in the interior of the mountains.

It is worth mentioning here that tectonic movements produce slightly different effect in the relief of tropic than in the topography of the temperate zone. Bremer (1977) drew attention to that fact. In the tectonically uplifted regions the ground-water level is lowered, rocks become relatively dry, and so they do not undergo intensive chemical weathering. The bottoms of valleys and basins, though lowered, are constantly humid, so their rocks are affected by strong chemical weathering. Degradation takes place there, especially when a certain part of weathering wastes can be carried away. Such a situation persisted in the Sudetes for the whole Palaeogene and resulted in the great morphological inversion.

Therefore, the Sudetes appear to be mountains with a very special and original relief where climatic generations of forms were developing at a time of highly stimulated tectonic movements of the block type. Forms expressing a specific type of climate were placed on the tectonic skeleton.

What is known is a fairly strange fact that the Sudetes are devoid of loose Tertiary sediments. What is there is only the Quaternary sediments several score metres thick deposited mainly at the time when the outflows of the Sudetic valleys were closed by the Scandinavian ice sheet. For the whole Palaeogene and Neogene the Sudetes were degraded intensively, but the products of that degradation were carried away by rivers ouside the mountains area. This fact itself indicates lively tectonics accompanying the egzogenic degradation of the Sudetes. The lack of deposits is all the more significant because well-marked basins, which could and should have been the place where rivers accumulated, existed there at the end of the Palaeogene. The contemporary bottoms of Sudetic basins and valleys come from the Pliocene. They are erosive forms without any traces of a greater sedimentation. Thus, the mountains had been an active block in relation to the forefield till the Upper Tertiary. There is also some evidence that nowadays, the block is also uplifting constantly stimulating the rivers erosive action. Zeuner (1928) wrote on those movements in the eastern part of the Sudetes, and the new research (Oberc, Dyjor 1969; Dyjor 1966) seems to confirm this thesis.

SYNGENETIC SEDIMENTS

The products of morphological degradation were deposited in the forefield of the mountains. Immense sedimentary deposits of sands and clays including also redeposited kaolins can be found in the immediate vicinity of the Sudetic Threshold, in deep tectonic grabens as, for example, the Roztoka Graben where the thickness of deposits approaches 300 m (Dyjor, Kuszell 1977). The sediments of the foresudetic area can be recognized as syngenetic sediments in which processes destructive for the mountains were recorded according to the diagram presented (Fig. 3). Redeposited kaolins do not correspond directly to the stage of intensive weathering of the mountains, but originate in the period following that stage. Tectonic stillness prevailing especially in the middle of the Palaeogene was undoubtedly conducive to intensive weathering, but not to the removal of its products.

In the Oligocene and at the beginning of the Neogene a substantial part of these weathering wastes reached the Sudetic forefield. One should here take into consideration reversible series of sedimentation which begin with a fine-grained sediment corresponding to the chemical wastes mantle removed from the Sudetes, and ending with sands and gravels deriving from the erosion of the bedrocks. This fact was noticed by Dyjor (1966). What is also typical of those syngenetic sediments in the foresudetic area is kaolinic gravels and sands in which unweathered quartz is mixed with kaolinized felspar, and which form a counterpart to the process of removing waste mantles from the mountains.

Quartzitic crusts, with the Oligocene flora occurring in them (Milewicz 1964) discovered, among other things, near Bolesławiec constitute another syngenetic sediment characteristic of the Sudetes. Blocks of that quartzite occur everywhere in the Izerskie Foothills, which testifies to a much greater expansion of those crusts. The process of silication influenced the depressions of the Sudetic foothills (Milewicz's Pyrzyce Basin) by silica solutions produced in the tropical climate. Therefore, silicated crusts are the counterparts to the tropical process of kaolinization; they are chemically syngenetic, i.e. synchronous sediments of the mountains tropical stage. In the nearby Ore Mountains, fairly thick (up to 4 m) quartzitic crusts occur together with laterite-kaolinic mantles as relics of the Upper Cretaceous and Palaeogene planations (Kral 1976).

CONCLUSIONS

The problem of the Tertiary evolution of the Sudetes still requires much work, many new facts and materials. Up to the present, it has been impossible to estimate the conditions in which the Sudetic weathering wastes originating in that period and generally considered to be the product of an intertropical climate were formed. Conclusions drawn on this subject so far are far from being accurate (Walczak 1968). Palaeobotanical materials do not provide a satisfactory answer, and, in the case of the Sudetes, we tend to rely on the analyses of sporomorphs from the Tertiary sediments in the forefield of the mountains (Sadowska 1977) and on a general discussion on the Tertiary climate in Europe (Büdel 1977, Hüser 1973, Schwarzbach 1968). In the lithostratigraphic analyses of the Tertiary in the Sudetes information was more readily borrowed from the profiles of syngenetic sediments of the Sudetes Foreland. The Tertiary diastrophic cycles of the Sudetes were discovered in this way. Particular credit for that discovery should be given to Pernarowski (1963), Dyjor (1966) and Oberc and Dyjor (1968). The present article throws new light on the problem by taking geomorphological elements and their generations as a basis for the reconstruction of the Sudetes development in the Tertiary.

The following are the main conclusions drawn from the analysis.

1. The generation of forms deriving from the intertropical stage of the development of the Sudetes constitutes the most important element in the relief of the mountains. Those forms have been preserved till now, although they underwent a certain modification in the younger stages of the mountains development, in the temperate and cold climates.

2. The major effect of the intertropical morphogenesis can be seen in the morphological inversion which took place at the end of the Cretaceous and in the Palaeocene.

3. Morphological planation surfaces of the Sudetes also exhibit the character of forms formed in a hot climate despite perturbations they experienced due to block tectonic movements. They are reflections of denudational bases (river valleys) considerably less inclined (concave) than the contemporary valleys. Some of the sediments including quartzitic crusts are their counterparts.

4. The Sudetic basins being the most important forms in the morphology of the mountains were formed in intertropical conditions, and their development was made easier by intensive chemical weathering. Their dependence on tectonics and lithology is indirect. Those factors created the framework for hydrological conditions which directly influenced intensive chemical weathering of rocks.

5. A storeyed pattern of basins noticeable in the longitudinal profiles of the Sudetic rivers (steps) testifies to the existence of morphological barriers separating the basins. Their origin can be referred to the intertropical stage of the

mountains development, and their cuttings (gaps) to younger stages corresponding to a different climatic morphogenesis.

6. The Sudetic river drainage is epigenetic, corresponding to the Palaeogene surface of the mountains. The drainage was modified by regressive action of rivers in younger periods.

7. A small number of weathering products deriving from the intertropical stage of their development was preserved in the Sudetes. They have not been identified properly as yet, though their presence is undisputed. A greater number of those materials occurs in the lowered area of the forefield of the mountains, in tectonic troughs protected against erosion. A part of them consists of redeposited sediments.

8. Not only macroforms, i.e. inversive forms and basins can be explained by the influence of the process of intertropical morphogenesis. Mezoforms, isolated residual hills, domed inselbergs, winding valleys course adapted to them (pseudomeanders), and, finally, tors so typical of granitic areas also belong to the Tertiary generation of forms connected with a hot climate.

9. The specific morphological style of the Sudetes results from the fact that two curves, that of a changing tectonics and that of a changing climate, overlapped in their development. The most important generation of forms, that of the intertropical morphogenesis, might have developed only in the conditions of vivid tectonics whose part was to rejuvenate morphological exposure of rocks to the influence of climatic processes. The same actions of tectonics made the process of smoothing over the tropical generation easier in the younger Tertiary and the Quaternary.

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TYPES OF OUTWASH FORMS IN NORTH-EAST POLAND

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INTRODUCTION

The differentiated activity of proglacial waters leads to the origin of various outwash formations. There is a close relation between the outwash formations and the quantity and the origin of the outflowing waters. Different forms originate as a result of supraglacial streams activities, different in the zone of

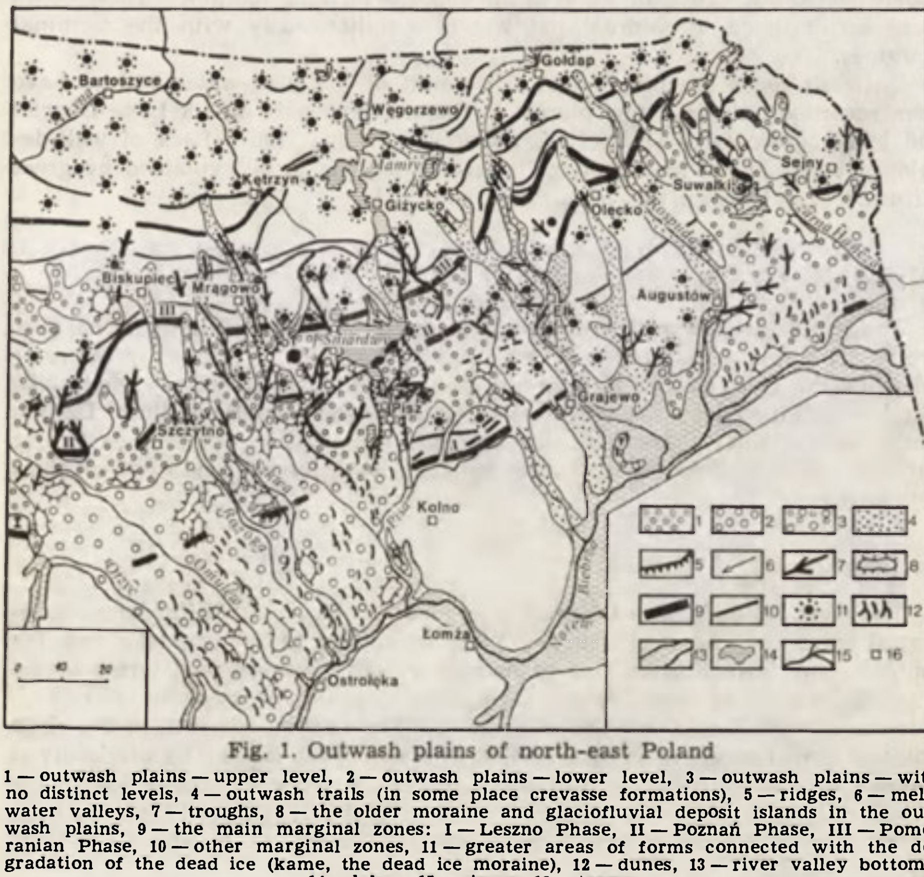

Fig. 1. Outwash plains of north-east Poland

1 — outwash plains — upper level, 2 — outwash plains — lower level, 3 — outwash plains — with no distinct levels, 4 — outwash trails (in some place crevasse formations), 5 — ridges, 6 — melt-water valleys, 7 — troughs, 8 — the older moraine and glaciofluvial deposit islands in the out-wash plains, 9 — the main marginal zones: I — Leszno Phase, II — Poznań Phase, III — Pomeranian Phase, 10 — other marginal zones, 11 — greater areas of forms connected with the degradation of the dead ice (kame, the dead ice moraine), 12 — dunes, 13 — river valley bottoms, 14 — lakes, 15 — rivers, 16 — towns

in- and subglacial outflow activities, and finally still others, which differ mainly in structure, where waters are becoming free of dead ices. The type of formations and sometimes their structure depend on the glacier frontland topography.

Differentiation of the outwash forms is related to its distance from the glacier. In its direct vicinity many small and elementary forms originate, while the big forms, genetically more composed, originate on the further frontland.

Typological differentiation of outwash forms will be presented on the example of north-east Poland (Fig. 1). Two categories of short outwash cones can be distinguished: transitional cones which are protractions of moraine in the distal direction, and cones which are found at the mouth of the melt-water valleys. Besides there are also outwash plains and narrow, prolate outwash trails.

SHORT OUTWASH CONES

Transitional outwash cones are best developed at the frontland of Leszno (Brandenburg) Phase terminal moraine. Those are small forms, rarely exceeding 1 km in length, with considerable slope in the distal direction, reaching in their proximate part 5–6°. They are composed of sands and heterogranular gravels, poorly sorted out, often the same as the deposits forming moraines. These cones were accumulated by supraglacial waters simultaneously with the terminal moraines.

Outwash cones accumulated at the mouth of the melt-water valleys have been recorded only in a few places: in the southern part of Ełk Lake District and in Mrągowo Lake District (K. Świerczyński 1959, 1967). Lack of well-developed cones at the mouth of melt-water valleys is to be explained by great diffusion of outwash plains in north-east Poland.

OUTHWASH TRAILS

The name outwash trail, proposed by R. Galon (S. Kozarski 1965) for narrow, prolated outwash areas, has been agreed upon. Outwash trails, those of the river Rospuda, the river Czarna Hańcza and Ełk area divided sometimes whole lake districts, originated on the old depressions and subglacial flows lines. Despite similar assumptions, there occur differences in relief and structure of particular outwash trails, caused in each case by slightly different conditions of their development.

THE RIVER ROSPUDA OUTWASH

The river Rospuda outwash trail is divided into two quite different morphological stretches: the northern one from its source to Bolesta lake and the southern one from Bolesta lake to Augustów. The southern part forms a vast outwash level rising from 130 m a.s.l. in the vicinity of Augustów to 164 m a.s.l. between village Raczki and the lake Bolesta. The northern stretch of the river Rospuda trail has the form of a trough with numerous lakes. The glaciofluvial deposits do not form here a continuous plane. They appear most often in the trough enlargements or in the side troughs. In the region of Filipów village the sandy-gravel deposits form terraces and kame ridges (J. Kondracki, S. Pietkiewicz 1967).

Morphological features and the type of deposits indicate that the river Rospuda outwash trail has a subglacial origin. It is to be mentioned here that in the northern part the subglacial outflow predominated all the time, while in the southern part only in the initial period of the river Rospuda depression formation; later, the waters flowed between the blocks of dead ice.

THE RIVER CZARNA HAŃCZA OUTWASH

In the Suwałki Lake District area four larger, meridionally prolated outwash areas appear, linked from the northern side with the vast plane of the Augustów outwash. Furthest to the west appears the river Czarna Hańcza outwash, and connected with it the glaciofluvial outflow from the Jeleniewo snout (S. Pietkiewicz 1928), then an outwash spreading along the river Wiatrołuża, then to the east the outwash stretching from the village Trakiszki in the direction of lake Gremz.

In the Suwałki Lake District, the river Czarna Hańcza outwash trail, with the Jeleniewo glaciofluvial outflow through is the most interesting one.

The river Czarna Hańcza outwash commences in the north with the trough-type lake Hańcza, at the altitude of 230–235 m a.s.l., and in the vicinity of Suwałki it appears at the altitude of 180–185 m a.s.l.

The thickness of the glaciofluvial deposits filling the river Czarna Hańcza depression reaches a maximum 30–40 m (Ber 1974). Locally, especially in the neighbourhood of the morainic hills, it is only some few metres.

The river Czarna Hańcza cuts fairly deep through the vast outwash, denoted by Pietkiewicz (1928) as the IV level. Underneath the outwash surface, a few well-developed terrace planes appear. Pietkiewicz (1928) distinguished terrace I, terrace II and III.

In the vicinity of the village Osowa and the village Bród, terrace II stretches as the altitude of 177–181 m a.s.l. (i.e. 3–4 m over the river Hańcza), terrace III at 188–190 m a.s.l. (i.e. 10–12 m over the river Hańcza), and the outwash level (IV) appears at the altitude of 195–198 m a.s.l. (i.e. 9–10 m over the III level).

In a detailed analysis one can distinguish in the river Czarna Hańcza valley terraces lower than those described by Pietkiewicz (1928) and Ber (1974). They remain in a residual shape. In the vicinity of the village Sobolewo appear five terraces and the sixth, the highest — an outwash. Their relative heights, measured from the bottom of the valley (I), are as follows: II — 2–3 m, III — 6–7 m, IV — 11–12 m, V — 23–24 m and VI — 26–27 m.

The higher terrace planes (III, IV, V), appearing in the river Czarna Hańcza valley, have similar structure. In the zone up to 2–3 m deep generally coarse-grained material lies and it is poorly sorted out. Further down appear gravel and fine-grained bedded sands, better sorted out. The coarse-grained deposits lie discordantly on sands and gravels. They are divided by a clean shearing surface, which justifies the theory that those are erosive-accumulative levels. Thin sands are older according to Ber (1974); they originated in the Leszno Phase, while deposits in the top, sedimented by quick-flowing, deep and heavily loaded waters, are younger.

When discussing the age and genesis of the levels appearing in the valley of the river Czarna Hańcza one should consider their characteristic location. They are well-developed in the upper section of the valley (they nearly reach the river source) and in the side outwash affluents, e.g. in the Szeszupka valley. Down the river, four levels still appear in the vicinity of Głęboki Bród, and they disappear further to the east.

Morphology, location of terraces and features of the deposits which form them, seem to prove that those are outwash planes of erosive-accumulative character. They originated in the period of the glacier degradation during the Pomeranian Phase. In connection with the change in the glacier front position, and the change in the system of tunnels and crevasses through which the melt-waters flowed aut, the 'erosion base' plane changed, which led to deposit cutting, mainly in the upper stretch of the valley.

In the interstadial Bolling or Allerod, and in the Holocene, the lowest terrace over the flood-land and the valley bed have been probably formed.

EŁK OUTWASH

In the Masurian Lake District, the Ełk outwash trail is morphologically the best-developed one: it cuts through the whole lake district, and is drained by the river Elk.

The thickness of the glaciofluvial deposits forming the Ełk outwash trail is changeable. In its distal part, between Ełk and Grajewo, it reaches 20–30 m. Gravels and sands fill here a deep crevasse, reaching up to deposits of Middle Polish Glaciation. In the middle and the upper stretch the outwash thickness is smaller, and locally is only 1.5–2.0 m (e.g. in the east of Elk — Fig. 2), and by the Straduńskie lake, on the surface, erosive sheared boulder-clay appears.

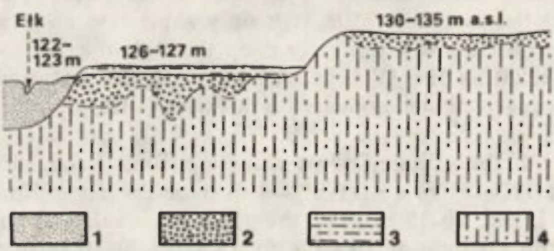

Fig. 2. Schematic cross-section through the outwash planes
1 — river sands and gravels, 2 — thick glaciofluvial gravels and sands, 3 — very fine and dusty glaciofluvial sands, 4 — boulder clay

The Elk outwash trail functioned all the time during the Baltic Glaciation period. Because of that some few accumulative and erosive levels have been formed, especially well-developed in the middle and distal sections. Those levels are closely connected with particular phases of glaciation. The oldest appear in the distal part of the outwash, while in the proximal direction, the younger and newer levels appear all the time.

Level I stretches at the height of 117 to 123 m a.s.l., II at 125–126 m a.s.l., and III at 130–133 m a.s.l. The morainic hills, surrounding the outwash, reach up to 150–157 m a.s.l. Level I is composed of sands and gravels in the top, poorly sorted out. In the southern direction, it turns into sandy islands in the proglacial stream-valley of the river Biebrza, while to the north, it stretches as the lowest outwash plane along the whole outwash trail. It merges with the marginal area spreading to the west of the river Gołdapia.

Levels II and III commence in the marginal area of the Leszno Phase close to Grajewo, and gradually disappear to the south. There is no equivalent in the northern direction. Level III is much damaged. Level II forms a compact surface, slightly enlarging in the southern direction. The discussed levels, in their proximal parts, are the erosive surfaces.

The origin of the erosive planes in the marginal area of the Leszno Phase, and just in its foreland, is to be related to the intensive outflow of melt-waters, probably from the subglacial tunnel. Only in the further foreland, where the fall of water was reduced and its transport force lost strength, in the distance of 4–5 km from the glacier front, accumulation of the carried-out material occured. Erosion was caused by the change in the situation of the glacier front.

In the end of the Leszno Phase, the outwash plane spreading on the east side of the Elk valley was accumulated. It is the highest level in that part of the outwash trail. It reaches up to 131–126 m a.s.l. Hipsometrically, this plane has no equivalent to the north or to the south. It appears that it joins with the recessive moraines of the Leszno Phase occurring in the vicinity of Ełk.

The next stage of the glaciofluvial outwash has been marked by formation of the successive outwash level. It commences in the marginal zone of the Poznań (Frankfurt) Phase and runs to the east of Ełk, on the western side of the Selment Wielki lake, and to the south of Ełk it joins with the high level which is situated on the north of lake Toczyłowo. The root parts of that plane reach the height of 140–145 m a.s.l., and in the distal part 125–126 m a.s.l. So it cannot be related with the above-mentioned high outwash level, because it is lower than that.

Thickness of glaciofluvial deposits, forming that plane, show considerable changeability. To the east of Elk it is 2–3 m, and near the height's edge, clay appears on the surface. On the west side of the outwash trail, north of Ełk, the plane in question is of the character of the erosive melt-water level. To the south, the deposit thickness rise over 4 m.

To the north of lake Laśmiady, in an area of about 10 km, still younger high outwash level appears, which joins with the marginal area of the Pomeranian Phase.

Higher levels within the Ełk outwash trail are not synchronous. On different stretches they are of different heigths, and join with the stage disappearance of the glacier (Fig. 3).

Fig. 3. Elk outwash trail. A scheme illustrating the connection between the outwash and erosive planes with the phases of the Baltic Glaciation

OUTWASH PLAINS

Outwash plains occupy vast areas in north-east Poland. To the largest of them belong Augustów, Kurpie and Masurian outwash plains, with which the Orzysz outwash in the north-east is connected.

AUGUSTÓW OUTWASH PLAIN

On the prolongation of the Suwałki Lake District spreads a vast plain of the Augustów outwash plain. Augustów outwash plain, south of lake Wigry, is situated at the level of 149–151 m a.s.l. and consecutively reduces the level to 117–118 m in the south-east direction. The thickness of deposits forming the Augustów outwash plain exceeds in many places 40 m. They fill a large depression, the bottom of which is formed by clays and sands of an older phase of Middle Polish Glaciation, and in the southern part by the marginal loams

(Żurek 1975). According to Ber (1972) the process of erosion on the present Augustów Plain began in the Middle Polish Glaciation period, and lasted through the whole Eemian Interglacial. This caused a lowering of the terrain, and created the predisposition for intensive water flow and an accumulation of outwash deposits in the period of the last glaciation. In the southern part of the glaciofluvial accumulation, existence of a large ice lake, whose range is not well known, was a very favourable one.

In the Augustów outwash plain, more distinct levels are not found, which testifies that the erosive impulse coming from the glacier did not reach much farther south. The change in situation of the erosive base, marked in the earth relief in the form of levels was marked clearly only within the Czarna Hańcza outwash which had been formed mainly with the help of subglacial outflows.

ORZYSZ OUTWASH PLAIN

East of lake Śniardwy spreads the outwash area bearing the traditional name of Orzysz outwash plain. In fact it is the eastern part of the Masurian outwash plain. Orzysz outwash plain is found in the zone of a deep valley, cutting through the bed of the quaternary deposits, and in the zone of old and glaciofluvial flows (Słowański 1971). Certainly, it created the predisposition for the flow of glaciofluvial waters, also in the last period of glaciation.

Sands and gravels of Orzysz outwash plain, of 5–10 m thickness (locally about 20 m) cover the loams and marginal silts (muds), as well as older glaciofluvial deposits of decadent Middle Polish Glaciation. The present outwash plain surface originated in three consecutive phases of Baltic Glaciation. It is reflected in the deposits and in the distribution of absolute heights. Here, three separate areas may be distinguished: south-east, north-east, and west.

The south-east area, the oldest one, was accumulated in the Leszno Phase the north-east one in the Poznań Phase, and the youngest one, the west area, in the Pomeranian Phase.

MASURIAN OUTWASH PLAIN

The vest outwash plain area spreading between the maximum range of the Baltic Glaciation, and the marginal zone running to the north of lake Śniardwy and to the south of Biskupiec, and between Pisz in the east and Nidzica in the west, has been called the Masurian outwash plain. In the hitherto existing literature (Kondracki 1952, 1972 b, c; Bogacki 1967; Słowański 1971) the southern part of that area, covered by Pisz Forest, was called Pisz outwash plain, while the western part, covered by Napiwoda Forest, had no separate name.

Origination of the Masurian outwash plain was conditioned by the existence, at least in its southern part, of an old depression. According to Różycki (1972 a, b) on the back of the terminal moraines of the Mława Stage, running across Kurpie Plain, an immense final basin had been formed, and deepened during Eemian Interglacial by rivers flowing to the north. In the northern part of this depression, the Leszno Phase glaciation overthrust.

The glaciofluvial deposits in the southern part of the outwash most frequently cover clay of the Middle Polish Glaciation, while in the middle and the northern part they cover glacial silts, or sands and gravels, originating from this glaciation recession. Thickness of sands and gravels which form the Masurian outwash plain is changeable: it measures from a few to 30 m. The glaciofluvial deposits belonging to the Leszno Phase have a very limited surface. During that period, accumulation of the outwash sands occurred mainly in the area of the Kurpie Plain.

The next stage of the Masurian outwash plain accumulation is connected with the origin of the marginal zone running to the south of lake Śniardwy. Deposits connected with that zone cover considerable areas, particularly in the eastern part of the Masurian outwash plain. Sands and gravels which form it are characterized by thicker pieces than in the younger outwash deposits. Outwash plain of the discussed zone have a very diversified relief. Here appears a great number of depressions various in shape with no outlets, in the extreme cases reaching up to 20 within one square kilometre. The accumulation here occurred surely on the surface of vest patches and lumps of dead ice.

In the western part of the Masurian outwash plain the problem is still more complicated. The glaciofluvial deposits of the discussed stage probably do not appear on the surface, which indicates the character of the relief. There are no clear outwash levels: only along the troughs and the upper parts of the river valleys somewhat lower surface are developed. Starting in the north, the outwash plain forms a homogeneous surface, consequently falling in the southern direction. Configuration of the contour lines indicates that is has the shape of a large cone. The relief of the outwash plain changes only north-east of Nidzica; here appear well-developed outwash levels. They have been formed by waters flowing from the direction of Olsztyn and along the river Łyna valley.

The western zone of the Masurian outwash plain originated as a result of the accumulation of melt-waters flowing out from subglacial and inglacial tunnels during the period of glacier stagnation on the moraine line of the Pomeranian Phase and the younger ones, namely recession moraines. Glaciofluvial waters, when flowing on the outwash, spread widely, accumulating a vast plain in the shape of a cone.

During the Pomeranian Phase and during the younger periods of glacier degradation in the eastern part of Masurian Plain, and maybe in the vicinity of Nidzica, a lower outwash plane originated. At that time, the outflow of melt-waters was limited to some exact routes, located predominatingly along subglacial troughs. The widest and the best-developed low outwash level runs from lake Niegocin to the north-east shores of lake Śniardwy, and further to the south in the direction of Pisz, and along the upper part of the river Pisa. Beside that, the low outwash level accompanies the trough of Mikołajki and Bełdany lakes, and the trough of Mrągowo lake and Mokre lake.

The glaciofluvial water running along narrow outwash trails cut through the older deposits, and deposited the younger, sandy layers of 2–4 m height. The process of erosion was initiated by the change in the glacier-front position, which gave the erosive base for melt-waters. A greater slope of the surface was also very conducive to cutting through the proximal part of the outwash plain. Further to the south, already in the area of Kurpie outwash plain, younger and younger deposits overlapped.

KURPIE OUTWASH PLAIN

A continuation of the Masurian outwash plain, in the southern direction, is the vast Kurpie Plain. The Kurpie outwash plain developed on the area of an old depression. During the Mława Stage, before the glacier front, a large ice dam lake originated, which included the southern and the middle part of the Kurpie Plain (Różycki 1972 a, b); whereas on the back of Mława Stage moraine, the final basin developed, which embraced the northern part of Kurpie Plain, and the southern part of the Masurian Plain.

During the period of degradation of the Mława Stage glaciation the glaciofluvial waters accumulated gravels and sands. There is little to be said about the original expansion of those deposits, because they are preserved in the shape of islands only. Their distribution indicates that the glaciofluvial accumulation at the decline of Middle Polish Glaciation took place on a very large area.

The basic stage of the Kurpie outwash plain formation happened during the consecutive phases of the Baltic Glaciation. At that time both fine and very fine sands were accumulated. Segregation of the Kurpie outwash plain glaciofluvial deposits according to their age is very difficult on the vertical profile as well as on the surface, because here occurred the overlapping of ever younger deposits.

Accumulation on the whole area of the Kurpie outwash plain occurred, one can imagine, only during the Pomeranian Phase (Fig. 4). The peripherial depressions were filled earlier with glaciofluvial deposits, on which overlapped younger deposits. They are characterized by very fine granulation and homogeneous mineralogical composition (Bogacki 1967, 1969). Accumulation of those outwash sands lasted longest in the eastern part of Kurpie Plain, and took place during the final stages of degradation of the Pomeranian Phase glaciation. The melt-waters running at that time over the surface of the low outwash level which developed within the limits of Masurian Plain spread widely after reaching the Kurpie outwash plain, accumulating very fine and dusty deposits.

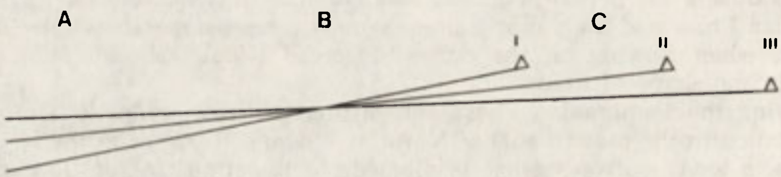

Fig. 4. General scheme illustrating the regularity of glaciofluvial accumulation and erosion

I — Leszno Phase, II — Poznań Phase (subphase), III — Pomeranian Phase; A — Extramarginal outwash plains, area of accumulation and overlapping of the younger glaciofluvial layers over the older ones, B — So called 'hinge' zone (transitional), C — The inner outwash plains, area of the periodic glaciofluvial erosion

The erosive impulse towards the south was weaker and weaker as it reached more or less the southern border of Masurian Plain. Because of that the Kurpie outwash plain was not cut through by the melt-waters. The border line between the Masurian outwash plain and the Kurpie outwash plain is like a 'hinge' zone over which erosion took place, and below which accumulation, as well as the overlapping of the ever younger glaciofluvial deposits, went on all the time.

CONCLUSIONS

Taking into consideration the glaciofluvial outflow during the last glaciation, the north-east area of Poland can be divided into two zones — external and internal. The periglacial external zone is characterized by the scantiness of outwash forms. Here originated only the extramarginal plain of Kurpie outwash plain, and a row of distal valleys of melt-waters. The glaciofluvial waters, in the external zone, used the earlier depressions on the old glacial area.

The main area of the glaciofluvial-water activities was the internal zone.

It is characterized by outwash forms of great opulence and differentiation of outwash forms. Melt-waters of the internal zone flowed directly to the *pradolina* of the Biebrza river, or into/onto the external zone area.

In the West-Poland area, small outwash forms have characteristics similar to those in north-east Poland (Augustowski 1959, 1962; Bartkowski 1961, 1972; Kozarski 1965; Żynda 1967). Generally, however, considerable differences in distribution and general formation of the outwashes in west and north-east Poland have been observed. To the west of the Vistula river valley clear zones in the distribution of the outwashes with consecutive phases of the Baltic glaciation were distinguished. The largest outwash plains spread directly in the foreland of the Pomeranian Phase moraine. They form vast, quite compact surfaces, which narrow in the southern direction and pass gradually into the valley outwashes drained at the present time by the rivers Wda, Brda, Gwda and Drawa. In the distal stretches, contrary to those in north-east Poland, those outwashes were considerably cut through by the melt-waters and the river-waters. Changes in the planes close to the existing erosive base were very favourable to intensive erosion. During the Baltic Glaciation, the glaciofluvial waters in western Poland flowed out to the consecutively younger *pradolinas*.

In the Masurian and Suwałki Lake Districts there are no latitudinal zones of the Würmian (Young Glaciation) relief. The Masurian and Suwałki outwashes form in their proximal stretches generally narrow trails, which enlarge to the south and transform into vast outwash plains. Thus the situation is different from that in the Pomeranian Lake District, and such like that in the area of Lithuania and White Russia.

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THE VALUE OF FIX-TIME INTERVAL AIR TEMPERATURE DATA IN THE EVALUATION OF MESOCLIMATIC CONDITIONS

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AIM OF RESEARCH

The problems discussed in the present paper should be regarded as a continuation of our earlier studies on criteria for the evaluation of mesoclimatic conditions in the highlands (see literature). This time our attention has been concentrated on a search for a correlation between the mean temperature extremes and the mean temperatures at fixed times in particular months. This procedure is intended to reveal the seasonal character of the relationship between the temperature at 1 p.m. and the maximum temperature, as well as between the minimum temperature and the temperature at 7 p.m. and at 9 a.m. The seasonal character results here from the periodical and non-periodical activity of factors such as the duration of insolation, the weather pattern and the local circulation and exchange of heat.

The modifying influence of relief on the air temperature daily course was analysed separately for convex and concave relief forms in the mountains vertical profile. As guiding criteria for typological purposes those analyses which revealed the greatest number of significant correlations with the values of other climatic elements and indices were accepted.

Bearing in mind the fact that for the different relief categories the frequency distributions of daily temperature extremes are different, the correlation between the maximum and minimum temperature values corresponding to the lower $\leqslant 10\%$ and upper $\geqslant 90\%$ decil and the mean monthly temperatures at fixed times in chosen months were examined. A similar test was applied to the values of daily temperature extremes corresponding to the $\leqslant 5\%$ and upper $\geqslant 95\%$ quantiles. The statistical significance of the resulting correlations served as a basis for singling out those seasons of the year, in which it was easiest to pinpoint the features of climatic differentiation on the basis of means at the fixed times.

SOURCES

The data used in the study consisted of daily observations of extreme temperatures and temperatures at fixed times in the Low Beskides (Polish West Carpathians) from 15 stations of the state meteorological network for the period 1951–1970. Eight of these stations lie on convex and seven on concave relief forms. The classification of stations within the valley group was simpler and more uniform than that on convex relief forms, which consisted of stations situated on high terraces, in the middle and upper parts of a slope and on a ridge. Thus they represented various conditions in the mesoclimatic sense.

For particular thermal characteristics the mean and extreme values, the errors of the mean values and their standard deviations were calculated. Correlation coefficients and equations of linear regression were calculated for the relationship between the mean monthly temperatures at fixed times and the corresponding means and absolute values of temperature extremes.

CHARACTERISTICS OF THE CLIMATE IN THE AREA UNDER INVESTIGATION

The area investigated comprises the Low Beskides with a relief type of low and medium-high mountains, the Foothills with an upland relief and the Jasło-Sanok Basin (Doły Jasielsko-Sanockie). The area extends from 240 to 1000 m a.s.l. Two climatic vertical zones can be distinguished here, because the annual mean temperature ranges from about 8° in the lower portions to 4° on the main ridge. The temperate warm vertical zone extends to an average height of 570 m a.s.l., but the isotherm of 6° separating it from the temperate cool vertical zone runs on the convex relief forms at a height of 620 m, and on the concave ones at a height of 460 m a.s.l. The moderate cool vertical zone extends up to the ridges of Low Beskides (Hess et al. 1976).

A characteristic feature of the Low Beskides is a high frequency of winds from the quadrant N and S — over 50% of cases in a year. This is connected with a facilitated air flow through the depression, which is the mountain group in the Carpathians being considered here. It ensures a good ventilation of those valleys following a meridional course. The frequency of western winds in the Low Beskides is 10–20% lower than in other parts of West Carpathians, owing to their being sheltered from the west by higher chains of the Beskides and to the meridional direction followed by these valleys. The winter half-year is characterized by a high frequency of winds with a component N and S and by a greater contribution of the advective factor to the formation of weather. In the summer half-year the number of calms increases by 10–15% as compared to the winter months.

EFFECT OF THE RELIEF FORM ON THE PROBABILITY OF OCCURRENCE OF AIR TEMPERATURE READINGS AT SPECIFIED HOURS OF THE DAY

In order to illustrate the range of differences between the values of extreme temperatures, as well as of the temperatures at the fundamental climatologic observation hours for extreme relief forms two stations were chosen: Wysowa and Ptaszkowa, lying at similar heights a.s.l. (525 m and 522 m, respectively). The former represents the bottom of a valley, the latter — a typical ridge situation.

For the two places just mentioned the cumulative frequency of extremes and of temperatures at observation hours within the lower (25%) and upper (75%) quartile were determined. They are represented in Figs. 1 and 2.

Both on the convex relief form and in the concave one there is a distinct conformity between the yearly course of maximum temperature and that of temperature at 1 p.m. The smallest differences occur from May to September

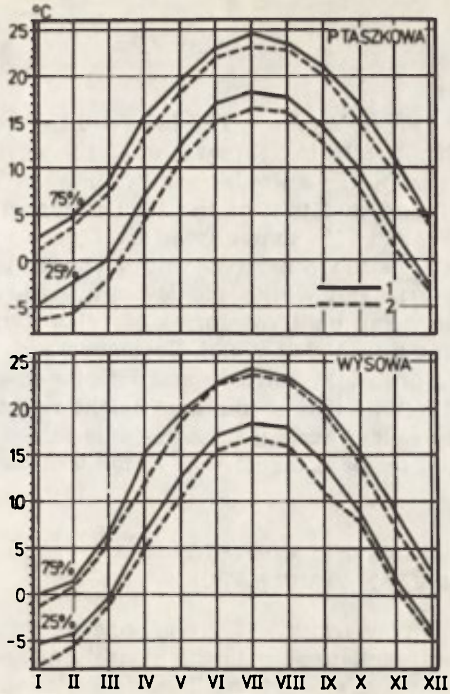

Fig. 1. Annual course of the temperature at 1 p.m. and of the maximum air temperature characterized by the values of 25% and 75% of probability of their occurrence at the stations at Ptaszkowa and Wysowa

1 — maximum air temperature, 2 — temperature at 1 p.m.

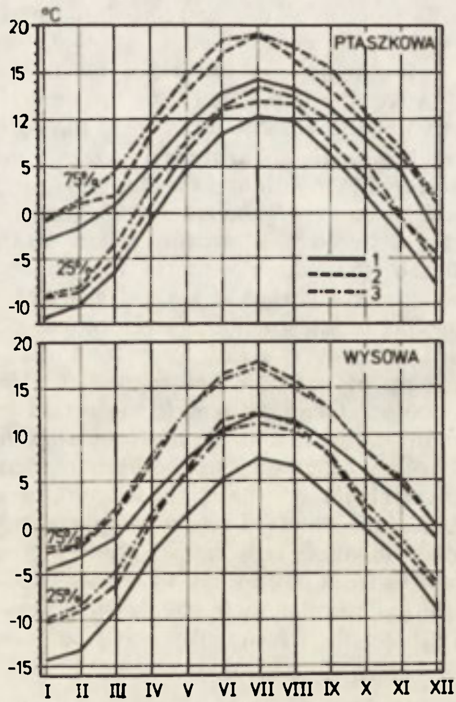

Fig. 2. Annual course of the temperature at 7 a.m. and 9 p.m. and of the minimum air temperature characterized by the values of 25% and 75% of probability of their occurrence at the stations at Ptaszkowa and Wysowa

1 — minimum air temperature, 2 — temperature at 7 a.m., 3 — temperature at 9 p.m.

with a probability of 75% in Wysowa. The largest differences appear in Ptaszkowa with a probability of 25% in February, when the weather is very variable.

A comparison carried out in a similar manner between the yearly course of the minimum temperature and that of the temperature at 7 a.m. and 9 p.m. at a probability of 25% and 75% shows great divergencies (Fig. 2). Particularly large differences between the compared values appear in the summer half-year in the concave form and within the lower quartile they subsist also in January and February. For both categories of relief form these differences become distinctly fainter in October and November and the temperatures at 7 a.m. and 9 p.m. at a probability of 25% and 75% become close to each other.

From the above it follows that at the same height a.s.l. the differentiation of the temperature daily course during a year is determined by the influence of the relief form and the seasonal regularities in the weather pattern.

CORRELATION BETWEEN THE MONTHLY MEAN TEMPERATURE AT 1 P.M. AND THE MAXIMUM MEAN TEMPERATURE

The monthly mean temperature at 1 p.m. reveals throughout most of the year highly significant correlations with the monthly mean maximum temperatures.* According to Student's test t the linear correlation coefficients r given in Table 1 are, in the vast majority of cases, significant at the level $\leqslant 0.1\%$. This shows that, within a day, the time interval with temperatures approximating maximum is longer than the corresponding time interval, in which the minimum temperatures appear (see next chapter).

The values of coefficients r of the correlated thermal parameters on the convex relief forms and in the concave ones reveal differences. The monthly mean temperatures at 1 p.m. in concave relief forms are characterized (especially in March) by a weaker dependence on the annual mean temperature.

However, irrespective of the kind of relief form the correlation between the mean temperatures at 1 p.m. in an arbitrarily chosen month and the mean maximum values, both for this month and for the remaining ones, is manifested by the high coefficients r (compare Tables 1 and 2). This proves that there exist close interdependencies between the monthly mean maximum values in the course of a year. Thus, if, for example, the mean temperature in July at the second observation hour over a period of several years at a given place in the mountains vertical profile is known, the yearly course of the monthly mean maximum temperature on convex relief forms and in concave ones can be reproduced with the help of equations of regression. Most suitable for this purpose are the mean temperatures at 1 p.m. in the period from June to October. It should be pointed out, however, that the mean maximum temperature values from December to February calculated on the basis of regression equations, in which the independent variable are the mean temperatures at 1 p.m. from the summer period, exhibit larger standard errors compared with similar characteristics obtained for other months. This results from a considerable variability of maximum temperatures from day to day in winter (Hess et al. 1977), as well as from a marked differentiation of their values in the mountains vertical profile, particularly during the then frequently occuring fohn effects (Obrębska-Starklowa 1973).

* In the present paper only examples of the dependencies discussed in chosen months are given; however, an analysis of these correlations has been carried out for all months of the year.

TABLE 1. Correlation coefficients (r) determining the relationship between the mean annual air temperature and some characteristics of maximum temperature, and the mean monthly air temperature at 1 p.m. in some chosen months on convex (1) and in concave (2) relief forms in the Lower Beskid

Climatic elements and indices	Mean monthly air temperature at 1 p.m.													
	I		IV		V		VII		IX		X		XI	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
t_r	0.963	0.942	0.961	0.987	0.973	0.977	0.971	0.965	0.968	0.969	0.960	0.935	0.967	0.942
t_{rm}	0.979	0.942	0.975	0.972	0.986	0.995	0.979	0.970	0.993	0.974	0.993	0.957	0.985	0.958
t_{mx} I	0.960	0.989	0.845	0.946	0.870	0.969	0.846	0.948	0.875	0.965	0.917	0.961	0.962	0.989
IV	0.964	0.899	0.991	0.957	0.990	0.934	0.986	0.905	0.993	0.914	0.983	0.916	0.971	0.910
V	0.943	0.862	0.994	0.958	0.997	0.960	0.991	0.945	0.995	0.932	0.979	0.897	0.961	0.880
VII	0.936	0.885	0.994	0.972	0.995	0.962	0.999	0.989	0.995	0.967	0.971	0.859	0.950	0.871
IX	0.960	0.964	0.978	0.978	0.991	0.994	0.980	0.987	0.997	0.996	0.993	0.994	0.972	0.959
X	0.983	0.918	0.953	0.889	0.965	0.965	0.946	0.879	0.980	0.914	0.997	0.995	0.980	0.971
XI	0.996	0.906	0.926	0.853	0.939	0.951	0.921	0.880	0.949	0.886	0.975	0.955	0.991	0.967
Number of days with:														
$t_{max} < 0^0$	−0.984	−0.900	−0.945	−0.890	−0.963	−0.971	−0.956	−0.900	−0.966	−0.910	−0.974	−0.971	−0.986	−0.960
$t_{max} > 25^0$	0.910	0.901	0.961	0.982	0.983	0.965	0.977	0.969	0.974	0.956	0.955	0.896	0.944	0.900
$t_{max} > 30^0$	0.842	0.810	0.868	0.935	0.905	0.852	0.889	0.938	0.895	0.894	0.894	0.708	0.891	0.755

Note: In the present paper correlation coefficients (r) are significant at the following levels: 1) on the convex forms: $r > 0.75$ on the 0.1%, $r = 0.62–0.75$ on 1%, $r = 0.5–0.62$ on 5%, 2) in the concave forms: $r > 0.80$ on the 0.1%, $r = 0.70–0.80$ on 1%, $r = 0.59–0.70$ on 5%.

Abbreviations: t_r — mean annual air temperature, t_{rm} — mean annual maximum temperature, t_{mx} — mean monthly maximum temperature.

TABLE 2. Dependence of the mean monthly maximum temperature (y) on the mean monthly air temperature at 1 h p.m. (x) in the Lower Beskid range

Parametr y	Convex relief forms			Concave relief forms		
	Equation of regression	r	$\pm\breve{b}$	Equation of regression	r	$\pm\breve{b}$
I	$y = 1.07+0.88\ x$	0.960	0.4°	$y = 0.85\ x+0.81$	0.989	0.1°
IV	$y = 2.14+0.96\ x$	0.991	0.2°	$y = 0.89\ x+2.73$	0.870	0.3°
V	$y = 1.94+0.99\ x$	0.997	0.1°	$y = 0.92\ x+2.74$	0.934	0.4°
VII	$y = 1.62+x$	0.999	0.1°	$y = 0.91\ x+3.39$	0.936	0.3°
IX	$y = 1.52+0.99\ x$	0.997	0.1°	$y = x+1.22$	0.941	0.3°
X	$y = 1.17+1.01\ x$	0.997	0.1°	$y = 1.02\ x+0.86$	0.944	0.3°
XI	$y = 1.37+0.94\ x$	0.991	0.2°	$y = 0.91\ x+1.62$	0.971	0.2°

$\breve{b}$ — standard error of unknown value.

The monthly mean temperatures at the second observation hour may also be useful for calculating the frequency of days with characteristic air temperatures in a year (Tables 1 and 3). The best results are obtained for the number of frost days ($t_{max} < 0°$) and of hot days ($t_{max} > 25°$), which are closely correlated with the mean temperature at 1 p.m. in each month (the majority of $r > 0.9$). The number of very hot days ($t_{max} > 30°$) can be determined by the above-mentioned method only by means of the data at 1 p.m. from the months from April to September. In Table 3 equations are given, from which some annual characteristics of maximum temperature can be obtained with the highest accuracy. It is an astonishing fact that in the computation of, for example, the absolute maximum air temperature, or of the number of days with $t_{max} > 30°$ on convex relief forms the temperature at 1 p.m. from the winter months should be used, while in the concave forms — the temperature at 1 p.m. from the warm half-year should be used.

CORRELATION BETWEEN THE MONTHLY MEAN TEMPERATURE AT 7 A.M. AND 9 P.M. AND THE MONTHLY MEAN MINIMUM TEMPERATURE

The monthly mean temperatures at 7 a.m. on convex relief forms reveal weaker relationships with the annual mean air temperature and with the annual mean minimum temperature compared with the corresponding relations for the evening observation hour at 9 p.m. (compare Tables 4 and 5).

When intercorrelating the mean monthly temperature at 7 a.m. in the course of a year it was found that insignificant results (at a level $\leqslant 5\%$) and less accurate ones (at a significance level of 1–5%) are obtained when, in the determination of monthly mean minimum temperatures in the remaining months, the mean temperatures at 7 a.m. in September are used for convex forms, and for concave ones — in October and May. Similar calculations carried out using the monthly mean temperature at 9 p.m. for September and October alone turn out to be unsuitable for convex forms.

As was pointed out in earlier papers, in the Low Beskides the latter months are characterized by the greatest contrast in the distribution of minimum temperatures on the convex relief forms and in the concave ones (Hess et al. 1976, 1977). Thus, in September slight frosts occur occasionally on convex forms, while at the bottoms of valleys they are a rule (Fig. 3). In such places, lying above 450 m a.s.l., the probability of the occurrence of frosts exceeds 10% and the temperature falls may reach $-6°$, $-8°$.

TABLE 3. Dependence of some chosen characteristics of the maximum and minimum air temperature on the mean temperature at the observational hours: 7 a.m,. 1 p.m. and 9 p.m. in the Lower Beskid range

Parameter y	Convex relief forms			Concave relief forms		
	Equation of regression	r	$\pm\breve{b}$	Equation of regression	r	$\pm\breve{b}$
Absolute minimum of air temperature	$y = -2{,}23\, t_{9.XII} - 34.87$	−0.645	1.0°	$y = 0.72\, t_{9.VII} - 23.9$	−0.535	1.1°
Number of days with $t_{min} < -20°$	$y = 0.79\, t_{9.VI} - 8.54$	0.726	0.9	$y = 39.98 - 3.38\, t_{7.IX}$	−0.819	1.1
$t_{min} < -10°$	$y = 72.27\, t_9 - 2.83\, t_{9.VII}$	−0.950	0.4	$y = 149.25 - 11.76\, t_{7.IX}$	−0.974	1.3
$t_{min} < 0°$	$y = 152.78 - 10.41\, t_{7.XII}$	−0.988	1.8	$y = 857.1 - 47.0\, t_{7.VII}$	−0.979	3.0
$t_{min} < 0°$, $t_{max} > 0°$	$y = 4.19\, t_{9.V} + 28.04$	0.793	4.4	$y = 346.2 - 18.62\, t_{7.VI}$	−0.861	3.6
Duration of frostless period (in days)	$y = 6.05 + 15.05\, t_{7.IX}$	0.939	3.3	$y = 60.26\, t_{7.VII} - 787.8$	0.991	2.6
Average date of the first slight frost	$y = 209.15 - 6.13\, t_{7.VIII}$	−0.886	2.6	$y = 317.8 - 18.4\, t_{7.IX}$	−0.878	4.7
Average date of the last slight frost	$y = 210.79 + 7.27\, t_{7.IX}$	0.929	1.8	$y = 35.32\, t_{7.VII} - 272.6$	0.942	4.0
Absolute maximum of air temperature	$y = 1.34\, t_{1.II} + 35.76$	0.893	0.7°	$y = 1.82\, t_{1.VII} - 4.56$	0.852	0.4°
Number of days with $t_{max} < 0°$	$y = 50.02 - 11.86\, t_{1.XII}$	−0.994	1.0	$y = 277.5 - 14.23\, t_{1.V}$	−0.971	2.9
$t_{max} > 25°$	$y = 6.67\, t_{1.VI} - 101.4$	0.984	2.1	$y = 9.35\, t_{1.VI} - 158.1$	0.996	0.6
$t_{max} > 30°$	$y = 1.25\, t_{1.XII} + 3.29$	0.909	0.6	$y = 1.65\, t_{1.VIII} - 32.0$	0.973	0.3

$\breve{b}$ —standard error of unknown value.

TABLE 4. Correlation coefficients (r) determining the relationships between the mean annual air temperature and some characteristics of minimum temperature, and the mean monthly air temperature at 7 h a.m. in some chosen months on convex (1) and in concave (2) relief forms in the Lower Beskid range

Climatic elements and indices	Mean monthly temperature at 7 a.m.													
	I		IV		V		VII		IX		X		XI	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
	0.965	0.980	0.914	0.869	0.848	0.651	0.827	0.974	0.483	0.884	0.738	0.776	0.982	0.944
t_r	0.960	0.958	0.965	0.974	0.934	0.821	0.918	0.971	0.672	0.930	0.882	0.849	0.961	0.924
t_{rmn} I	0.978	0.986	0.951	0.905	0.902	0.682	0.873	0.957	0.641	0.980	0.901	0.776	0.968	0.938
t_{mn} IV	0.915	0.932	0.936	0.901	0.886	0.655	0.862	0.985	0.538	0.822	0.774	0.680	0.930	0.848
V	0.860	0.947	0.898	0.940	0.881	0.705	0.879	0.996	0.633	0.884	0.803	0.724	0.863	0.877
VII	0.914	0.951	0.953	0.943	0.935	0.730	0.925	0.990	0.696	0.906	0.881	0.773	0.908	0.910
IX	0.670	0.956	0.784	0.965	0.846	0.743	0.861	0.973	0.896	0.940	0.908	0.741	0.639	0.875
X	0.758	0.957	0.879	0.975	0.908	0.857	0.890	0.949	0.807	0.944	0.932	0.891	0.743	0.937
XI	0.979	0.987	0.935	0.878	0.879	0.694	0.855	0.958	0.540	0.931	0.796	0.842	0.993	0.983
Number of days with														
$t_{min} < -20^0$	0.576	−0.647	0.387	−0.814	0.331	−0.771	0.364	−0.665	0.453	−0.819	0.140	−0.711	0.620	−0.673
$t_{min} < -10^0$	−0.858	−0.962	−0.735	−0.932	−0.629	−0.722	−0.604	−0.964	−0.262	−0.774	−0.598	−0.793	−0.856	−0.934
$t_{min} < 0^0$	−0.982	−0.945	−0.957	−0.916	−0.915	−0.722	−0.903	−0.979	−0.622	−0.850	−0.832	−0.777	−0.988	−0.902
$t_{max} > 0^0$, $t_{min} < 0^0$	0.726	−0.745	0.554	−0.856	0.425	−0.606	0.412	−0.860	0.238	−0.658	0.301	−0.436	0.724	−0.566
Duration of the frostless period (days)	0.617	0.948	0.708	0.899	0.793	0.610	0.835	0.991	0.939	0.899	0.865	0.656	0.575	0.871

Abbreviations: t_r — mean annual air temperature, t_{rmn} — mean annual minimum temperature, t_{mn} — mean monthly minimum temperature.

TABLE 5. Correlation coefficients (r) determining the relationships between the mean annual air temperature and some characteristics of minimum temperature, and the mean monthly temperature at 9 p.m. in some chosen months on convex (1) and in concave (2) relief forms in the Lower Beskid range

Climatic elements and indices	Mean monthly air temperature at 9 p.m.													
	I		IV		V		VII		IX		X		XI	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
t_r	0.958	0.995	0.992	0.979	0.973	0.987	0.970	0.983	0.948	0.995	0.934	0.985	0.995	0.957
t_{rmn}	0.928	0.928	0.936	0.915	0.915	0.897	0.919	0.925	0.969	0.927	0.966	0.972	0.947	0.933
t_{mn} I	0.961	0.951	0.912	0.929	0.887	0.914	0.874	0.957	0.927	0.953	0.956	0.948	0.943	0.916
IV	0.890	0.947	0.965	0.977	0.944	0.920	0.956	0.960	0.971	0.947	0.962	0.941	0.945	0.898
V	0.822	0.942	0.882	0.961	0.870	0.900	0.897	0.952	0.961	0.940	0.936	0.955	0.866	0.919
VII	0.870	0.943	0.890	0.945	0.863	0.903	0.878	0.939	0.952	0.940	0.952	0.972	0.891	0.948
IX	0.589	0.917	0.538	0.930	0.509	0.865	0.536	0.940	0.711	0.918	0.715	0.931	0.570	0.885
X	0.687	0.915	0.672	0.888	0.626	0.891	0.649	0.909	0.791	0.916	0.836	0.966	0.683	0.924
XI	0.966	0.986	0.978	0.944	0.960	0.978	0.949	0.961	0.947	0.985	0.947	0.995	0.990	0.978
Number of days with														
$t_{min} < -20^0$	0.606	−0.543	0.665	−0.508	0.703	−0.458	0.685	−0.535	0.538	−0.538	0.425	−0.663	0.673	−0.662
$t_{min} < -10^0$	−0.904	−0.929	−0.922	−0.909	−0.948	−0.879	−0.950	−0.924	−0.944	−0.927	−0.924	−0.956	−0.909	−0.938
$t_{min} < 0^0$	−0.956	−0.955	−0.964	−0.957	−0.944	−0.937	−0.938	−0.948	−0.952	−0.953	−0.938	−0.974	−0.981	−0.941
$t_{max} > 0$, $t_{min} < 0^0$	0.778	−0.725	0.766	−0.827	0.793	−0.664	0.766	−0.798	0.658	−0.729	0.625	−0.717	0.789	−0.634
Duration of the frostless period (days)	0.527	0.947	0.433	0.968	0.406	0.894	0.430	0.960	0.610	0.945	0.592	0.937	0.489	0.912

Abbreviations: t_r — mean annual air temperature, t_{rmn} — mean annual minimum temperature, t_{mn} — mean monthly minimum temperature.

The above facts have a bearing on the differences in the values of correlation coefficients on the convex and in the concave relief forms, as given in Table 4. The bottoms of concave relief forms constitute cold reservoirs in September, all over the vertical profile of the mountains, and in these at 7 a.m. the thermal stratification, typical of the night, has not yet been effaced by the influence of radiation; on the other hand, on the concave forms situated at various altitudes relatively to the valley's bottom and representing diverse microrelief conditions the temperature values in the morning after the beginning of insolation are influenced by local factors.

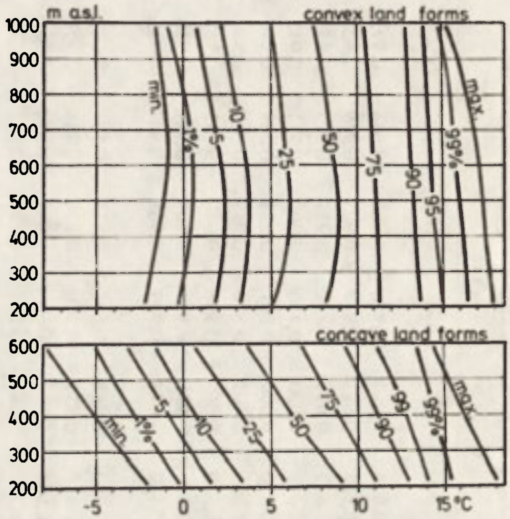

Fig. 3. Probability of the occurrence of minimum air temperature below determined values in September in the Lower Beskid range

In May and October the correlation between the temperature at the morning observation hour and the daily minimum is weaker in the concave forms than on the convex ones. On the contrary, the air temperature distribution at 9 p.m. (at the night's beginning) reveals all over the vertical profile of the mountains in May and October higher correlation coefficients with the minimum temperature in concave forms than on the convex ones (Table 5).

In the distribution of correlation coefficients of the mean temperature at the morning and evening observation hour with the mean minimum temperature in the same months a seasonal differentiation can be noticed. From November to April, irrespective of relief form category, they are decidedly higher and more stable ($r > 0.95$) than in the remaining period of the year (Table 6).

The determination of the absolute minimum temperature on the basis of monthly mean values at 7 a.m. and 9 p.m., as in the case of the number of days with $t_{min} < -20°$ does not yield satisfactory results (Table 3). However, fixed times data can be successfully used in the computation of the frequency of days with strong frost ($t_{min} < -10°$), with frost ($t_{max} < 0°$) and with slight frost ($t_{max} > 0°$, $t_{min} < 0°$), as well as the determination of the duration of the frostless period. For this purpose the mean monthly temperatures at the morning and evening observation hour from May to September are applicable. So far as the determination of the duration of the frostless period is concerned it should be pointed out that the mean monthly temperatures at 7 a.m. and

TABLE 6. Dependence of the mean monthly minimum temperature (y) on the mean monthly temperatures at 7 a.m. (x) and at 9 p.m. (x') in the Lower Beskid range

Parameter y	Convex relief forms			Concave relief forms		
	Equation of regression	r	$\pm\breve{b}$	Equation of regression	r	$\pm\breve{b}$
I	$y = 0.84\ x - 3.14$	0.978	0.2°	$y = 1.24\ x - 1.32$	0.986	0.1°
	$y = 0.71\ x' - 4.39$	0.961	0.3°	$y = 1.07\ x' - 2.97$	0.952	0.3°
IV	$y = 0.87\ x - 1.62$	0.936	0.4°	$y = 1.63\ x - 6.21$	0.901	0.3°
	$y = 0.52\ x' - 1.10$	0.965	0.4°	$y = 0.81\ x' - 3.25$	0.977	0.3°
V	$y = 0.70\ x - 0.16$	0.881	0.4°	$y = 1.97\ x - 14.47$	0.705	0.3°
	$y = 0.40\ x' + 2.28$	0.870	0.7°	$y = 0.80\ x' - 2.61$	0.900	0.6°
VII	$y = 0.69\ x + 1.67$	0.925	0.3°	$y = 3.61\ x - 44.50$	0.990	0.04°
	$y = 0.43\ x' + 5.08$	0.878	0.6°	$y = 0.87\ x' - 2.24$	0.939	0.4°
IX	$y = 0.76\ x + 0.52$	0.896	0.4°	$y = 2.38\ x - 17.01$	0.940	0.2°
	$y = 0.39\ x + 3.62$	0.711	0.6°	$y = 0.92\ x' - 3.23$	0.918	0.5°
X	$y = 0.91\ x - 1.14$	0.932	0.2°	$y = 1.12\ x - 3.11$	0.891	0.3°
	$y = 0.51\ x' + 0.40$	0.836	0.6°	$y = 0.87\ x' - 2.65$	0.966	0.2°
XI	$y = 0.92\ x - 1.44$	0.993	0.1°	$y = 1.02\ x - 1.94$	0.983	0.1°
	$y = 0.79\ x' - 1.81$	0.990	0.2°	$y = 0.94\ x' - 2.42$	0.978	0.1°

$\breve{b}$ — standard error of unknown value.

9 p.m. throughout the year permit its computation with a high accuracy for concave forms (r from 0.8 to 0.97). For convex forms similar calculations can be carried out only on the basis of monthly means at 7 a.m. from June to October.

THE APPLICATION OF SITE READINGS IN THE EVALUATION OF MESOCLIMATIC CONDITIONS IN MOUNTAINOUS AERAS

The most detailed picture of mesoclimatic conditions in the highlands has been obtained hitherto on the basis of the probability of the occurrence of extreme temperatures of specified values in diverse categories of relief forms (Hess et al. 1976, 1977). Considering, however, that the contrast of climatic conditions between these categories is determined by the fluctuation range of extremes in a many-year period and by the frequency in the highest and lowest intervals, it has been resolved to analyse the possibility of using in the characterization the extremes only within the upper and lower decil and in the lower $\leqslant 5\%$ and upper $> 95\%$ quantile. Special attention has been given to the relation between these site readings and the mean temperatures at the three observation hours. Thus, the correlation dependencies of the decil and quantile values of the mean maximum temperature on the monthly mean at 1 p.m. were calculated as well as those of the similar characteristics of the mean minimum temperature on the monthly mean at 7 a.m. and 9 p.m. For example, the data for February — the month with a high variability of thermal condiitons in a many-year period and of July, as the month representative for the thermal conditions in summer, were examined. Higher correlation coefficients were obtained for July than for February, because in winter the effect of the advective factor upon the course of air temperature is greater. It has also been found that, when investigating the relation between the monthly mean temperatures at fixed times and the extreme values within the lower

TABLE 7. Relationships between the mean values of temperature at 7 a.m., 1 and 9 p.m. in some chosen months, and the values of extreme temperatures within the lowest and highest decils in the Lower Beskid range

Parameter y	Convex relief forms			Concave relief forms		
	Equation of regression	r	$\pm\breve{b}$	Equation of regression	r	$\pm\bar{b}$
Value of t_{max} within the lowest decil (< 10%)						
— in II	$y_{10} = 0.80\,\bar{t}_1 - 5.57$	0.839	0.7	$y_{10} = 0.51\,\bar{t}_1 - 6.13$	0.655	0.6
— in VII	$y_{10} = 1.11\,\bar{t}_1 - 6.83$	0.956	0.7	$y_{10} = 0.81\,\bar{t}_1 - 0.009$	0.917	0.3
Value of t_{max} within the highest decil (> 90%)						
— in II	$y_{90} = 1.14\,\bar{t}_1 + 8.83$	0.889	0.8	$y_{90} = 1.55\,\bar{t}_1 + 8.16$	0.962	0.2
— in VII	$y_{90} = 0.93\,\bar{t}_1 + 8.64$	0.964	0.5	$y_{90} = 1.01\,\bar{t}_1 + 6.72$	0.951	0.2
Value of t_{min} within the lowest decil (< 10%)						
— in II (1)	$y_{10} = -21.8 - \bar{t}_7$	−0.532	0.7	$y_{10} = 1.66\,\bar{t}_7 - 11.70$	0.839	0.5
— in II (2)	$y_{10} = -20.3 - 0.92\,\bar{t}_9$	−0.673	0.7	$y_{10} = 1.40\,\bar{t}_9 - 14.56$	0.777	0.6
— in VII (1)	$y_{10} = 0.84\,\bar{t}_7 - 4.78$	0.872	0.4	$y_{10} = 3.84\,\bar{t}_7 - 52.30$	0.995	0.1
— in VII (2)	$y_{10} = 0.58\,\bar{t}_9 - 1.34$	0.904	0.6	$y_{10} = 0.92\,\bar{t}_9 - 7.43$	0.939	0.4
Value of t_{min} within the highest decil (> 90%)						
— in II (1)	$y_{90} = 7.18 + 1.33\,\bar{t}_7$	0.937	0.3	$y_{90} = 0.67\,\bar{t}_7 + 4.17$	0.800	0.5
— in II (2)	$y_{90} = 4.41 + \bar{t}_9$	0.953	0.3	$y_{90} = 0.67\,\bar{t}_9 + 3.41$	0.869	0.5
— in VII (1)	$y_{90} = 6.25 + 0.64\,\bar{t}_7$	0.872	0.4	$y_{90} = 3.63\,\bar{t}_7 - 40.85$	0.995	0.1
— in VII (2)	$y_{90} = 10.59 + 0.33\,\bar{t}_9$	0.677	0.9	$y_{90} = 0.90\,\bar{t}_9 + 1.28$	0.970	0.3

$\breve{b}$ — standard error of unknown value.

and upper decil, a greater number of correlations significant at the level of 0.1% are obtained than when five per cent extreme quantiles are taken into account. This should be explained by the skewness in the distribution of extreme temperatures. For both categories of relief form significant relationships between the extremes within the decils 10% and 90% and the mean temperatures at all fixed hours were obtained for July. Thus, in the author's opinion, the parameters mentioned from the period of full summer are best fitted for an evaluation of mesoclimatic conditions in the mountains vertical profile.

The equations of linear regression given in Table 7 represent the average dependencies of decil values of the maximum and minimum temperature on the mean temperature at 7 a.m., 1 p.m. and 9 p.m. in the vertical profile of the highlands. They are useful in a cartographic interpretation. If, for example, the mean monthly temperature at 1 p.m. is known at a given point of the profile, it is easy to compute the maximum temperature values within the lower and upper decil, or else, on the basis of the monthly means at 7 a.m. and 9 p.m. to find the upper and lower decil for minimum temperatures. The decil values obtained, transferred onto maps in great detail scale illustrate the quantity of an average climatic contrast produced under the influence of relief forms in a specified mountain relief type. Such maps constitute a valuable supplement to the maps of mean extreme temperatures in the individual months, because they illustrate the variability range of the elements discussed. Moreover, they represent a numerically large universe, contrary to the absolute values, which often have an accidental character.

CONCLUSIONS

In order to extend the evaluations of mesoclimatic conditions by characteristics of air temperature mean values at fixed times the relations between these elements and the mean monthly extreme temperatures were analysed.

In the present paper it was shown that there exist highly significant correlations between the monthly mean maximum temperatures and the monthly mean air temperatures at 1 p.m. On the basis of an arbitrary mean monthly value at 1 p.m. not only can the mean maximum for the same month be determined with the help of regression equations, but also similar values for other months can be reproduced with high accuracy, and the frequency of days with typical threshold temperatures in the year can be calculated.

The course of correlation coefficients between the mean minimum temperatures and the mean temperatures at 7 a.m. and 9 p.m. reveal a seasonal differentiation both on the convex and in the concave relief forms. The correlation coefficients of the mean minimum temperature with the mean temperature at 9 p.m. are higher over the year than with that at 7 a.m. In some months (May, September and October) there exists a great difference in the regime of thermal conditions between the convex and concave relief forms in the vertical profile of the highlands. The correlation coefficients for the parameters discussed are then low.

Most advantageous for mesoclimatic researches is the period of full summer, because the mean temperatures at 7 a.m. and 9 p.m. in summer months enable calculations to be made of the mean monthly minima and the numbers of days with typical minimum temperatures throughout the year.

The existence of relationships between the mean air temperatures at the three observation hours and the extremes within the lower and upper decil makes it possible to introduce new elements into the evaluation of climatic conditions in diverse relief categories and to construct detailed maps for extreme decil values supplementing the image of temperature differentiation given on the basis of mean extremes.

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AN OUTLINE OF A METHOD OF DISTINGUISHING THE CLIMATIC SEASONS

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INTRODUCTION

Hitherto the problem of seasonal structure of climate has rarely been considered in detail in the literature on climatology. This is reflected in the fact that very few works have been written on this subject either in Poland or in other countries. This may indicate that the problem under investigation is either very complicated and difficult to solve or irrelevant to climatology. However, the latter supposition must be rejected as groundless since a picture of climatic conditions of a given place or area will always be incomplete if the problem of its seasonal structure is neglected.

At the present stage of development of climatology as a science the concept of 'climatic seasons' is well established. Generally, climatic seasons are understood as periods of the year, comprising up to several months, characterized by similar climatic conditions. Most of the work done so far on the analysis of variation of weather conditions during the year over a multi-annual period have considered this variation, in lesser or greater detail for predetermined periods of time, as for instance for successive months of the year, summer half-year or winter half-year, successive quarters of the year, and so on. Such a picture of climatic conditions does not provide any information on the seasonal structure of climate, i.e. does not give any information about periods of the year characterized by a definite homogeneity of weather states investigated over a period of many years.

The main purpose of this article is an attempt to determine the seasonal structure of the climate and its characteristic features in the area of North-West Poland. In order to accomplish this task it is necessary to divide the year into periods (climatic seasons) which, from the point of view of weather conditions, are characterized by a definite homogeneity, and to determine the duration of these seasons as well as the dates of their beginning and end. Thus time parameters referring to each season are the final result of a previous analysis of weather conditions characteristic of particular days of the year over a period of many years. In this case the analysis of weather conditions for every year was performed according to principles of 'complex climatology'. The problem of the seasonal structure of the climate has been considered by the analysis of the frequency of occurrence of weather types which appear in successive pentads of the year. An attempt has been made to distinguish those seasons of the year within which the frequency of particular weather types, as well as the number of seasons that are likely to appear, reveals specific characteristics different from those of other seasons of the year.

Types of warm weather

Mean general daily cloudiness (in eleven-degree scale)	Precipitation	Minimum temperature of the air during day and night above 0°C — mean daily temperature (°C): 0,1 - 5,0	5,1 - 15,0	> 15,0
< 6	without precipitation	chilly weather with little cloudiness without precipitation 100	moderately warm weather with little cloudiness without precipitation 200	very warm weather with little cloudiness without precipitation 300
< 6	with precipitation	chilly weather with little cloudiness with precipitation 101	moderately warm weather with little cloudiness with precipitation 201	very warm weather with little cloudiness with precipitation 301
≥ 6	without precipitation	chilly weather with much cloudiness without precipitation 110	moderately warm weather with much cloudiness without precipitation 210	very warm weather with much cloudiness without precipitation 310
≥ 6	with precipitation	chilly weather with much cloudiness with precipitation 111	moderately warm weather with much cloudiness with precipitation 211	very warm weather much much cloudiness with precipitation 311

Types of transitional weather (ground frosty)

Mean general daily cloudiness (in eleven-degree scale)	Precipitation	Maximum temperature of the air during day and night above 0°, minimum ≤ 0°C — Mean daily temperature (°C): > 5,0	0,1 - 5,0	0,0 - (-5,0)	< -5,0
< 6	without precipitation	moderately cool weather with little cloudiness without precipitation 400	very cool weather with little cloudiness without precipitation 500	cold weather with little cloudiness without precipitation 600	very cold weather with little cloudiness without precipitation 700
< 6	with precipitation	moderately cool weather with little cloudiness with precipitation 401	very cool weather with little cloudiness with precipitation 501	cold weather with little cloudiness with precipitation 601	very cold weather with little cloudiness with precipitation 701
≥ 6	without precipitation	moderately cool weather with much cloudiness without precipitation 410	very cool weather with much cloudiness without precipitation 510	cold weather with much cloudiness without precipitation 610	very cold weather with much cloudiness without precipitation 710
≥ 6	with precipitation	moderately cool weather with much cloudiness with precipitation 411	very cool weather with much cloudiness with precipitation 511	cold weather with much cloudiness with precipitation 611	very cold weather with much cloudiness with precipitation 711

Types of frosty weather

Mean general daily cloudiness (in eleven-degree scale)	Precipitation	Maximum temperature of the air during day and night ≤ 0°C — mean daily temperature (°C): 0,0 - (-5,0)	-5,1 - (-15,0)	below -15,0
< 6	without precipitation	moderately frosty weather with little cloudiness without precipitation 800	rather frosty weather with little cloudiness without precipitation 900	very frosty weather with little cloudiness without precipitation 000
< 6	with precipitation	moderately frosty weather with little cloudiness with precipitation 801	rather frosty weather with little cloudiness with precipitation 901	very frosty weather with little cloudiness with precipitation 001
≥ 6	without precipitation	moderately frosty weather with much cloudiness without precipitation 810	rather frosty weather with much cloudiness without precipitation 910	very frosty weather with much cloudiness without precipitation 010
≥ 6	with precipitation	moderately frosty weather with much cloudiness with precipitation 811	rather frosty weather with much cloudiness with precipitation 911	very frosty weather with much cloudiness with precipitation 011

Fig. 1. Distinguished types of the weather

In order to solve the above-mentioned problem the author has adopted one of the methods of numerical taxonomy, namely the 'Wrocław dendrite' or the 'Wrocław taxonomy'.

CLASSIFICATION OF WEATHER STATES AND ITS PRINCIPLES

In the present paper the weather is treated as components (elements) of the climate, and cloudiness of the sky, precipitation, air temperature, etc., as weather elements. Thus the weather states observed and their reoccurrence over several years are the source of information about climatic features and seasonal structure of the climate. Because of a high variation in weather states found in nature and hence because of very low reoccurrence of every one of them, it was necessary to classify them and to introduce the notion 'weather type'. Thus the weather type is a more general characteristic of the weather defined by the features and variations of selected weather elements.

In complex climatology the weather is understood as some indissoluble whole, and weather types are established by analysing a set of selected numerical values of some larger or smaller group of weather types. For particular weather types sets of selected weather elements are differentiated in number, with the result that those types can be taken into consideration during practical man's activities. The weather types we have picked out are not universal. Only the principle of their construction is constant, and the weather types are compared according to the aim of the investigations. The same number of weather types are not used in all classifications, the same weather elements and variations of their numerical values are not always taken into account. Therefore it is essential to establish the particular weather types right at the beginning and to accept their classification with such variations in the values of selected weather types so as to complete successful investigations. In the present case weather types and sets of weather types have been distinguished, and the classification of weather states has been carried out analysing weather over a 24-hour period.

Weather states have been classified on a basis of selected weather elements. The air temperature (its mean, maximum and minimum diurnal values), and the diurnal degree of the cloudiness are taken into consideration. The air temperature has been examined from the point of view of its course during a 24-hour period and the diurnal mean value. On this basis three sets of weather types have been distinguished. The weather of every 24 hours has been classified first according to one of the above-mentioned sets, and then its type was determined within the framework of a given set.

Taking all the weather elements and variation in their values together it was possible to distinguish 12 types of warm weather, 12 types of frosty weather, and 16 types of intermediate (ground frosty) weather. They have been marked with numbers, and also their precise verbal characteristics has been given (Fig. 1).

THE METHOD OF DISTINGUISHING CLIMATIC SEASONS

The present study has been based on archival data analysing the results of observations at 39 meteorological stations over 15 years (1951–1965). After the classification of the weather for every 24 hours the frequency of the occurrence of particular weather types was determined in succeeding pentads of the year.

The acceptance of five-day periods has been governed by the length of observation series. Having at our disposal the results of meteorological observations over many years it seemed appropriate to determine the frequency of the occurrence of particular weather types on every succeeding day of the year. In the light of the data for 15 years the author decided that calculations made with such accuracy would be of no value since they would be made on the basis of insufficiently accurate data.

A more detailed analysis of the frequency of particular weather types in succeeding pentads of the year allows one to find differentiation between particular pentads. The number of weather types is not the same in all pentads of the year, and the occurrence of possible weather types is also differentiated. From this point of view every pentad of the year has some specific features. The differentiation of pentads varies. It is possible to notice that there are some groups of pentads which are similar, if one considers the frequency of weather types occurring in them.

The next stage of the investigation was to choose a method that would permit the estimation of the above variation of pentads in the year, within which weather conditions examined over many years are characterized by a definite homogeneity.

Generally speaking, methods allowing for a division of a given group (which in this case comprises 73 pentads), can be divided into several groups on the basis of quantitative features. Taxonomic methods have been considered as the most objective of them (Florek et al. 1951). And one of those taxonomic methods, the so-called Wrocław dendrite, has been accepted and applied in the present study. It permits a simultaneous examination of several features (in this case 40) and is regarded as one of simpler taxonomic methods characterized by comparatively large objectivism (Gługniewicz 1969; Jedut 1970; Perkal 1953; Steczkowski 1966). Using the dendrite it is possible to classify units according to a definite set of features, or to classify the investigated collection according to a number of types, that is typological classes (Lewiński 1968). The dendrite is a graphic picture presenting the smallest distances between the investigated units on a plane, which are understood as points of multi-dimentional space whose axes are their features. Particular units are connected according to the shortest distances. The matrix of geometrical distances measured between the investigated units described in the multi-dimentional space is the basis for the construction of the dendrite. The distances between every pair of spatial units (pentads) have been calculated by means of the following formula:

$$d_{ik} = \sqrt{\sum_{j=1}^{p} (y_{ij} - y_{kj})^2}$$

where:

d_{ik} — geometrical distance between pentads i and k,
i and k — investigated units — pentads ($i, k = 1, 2, 3, ..., m$),
j — examined features — weather types ($j = 1, 2, 3, ..., p$),
y_{ij} — value of feature j for unit i,
y_{kj} — value of feature j for unit k.

The taxonomic distance is a measure of the degree of variation in the examined units (pentads) from the point of view of the investigated features, and thus from the point of view of the frequency of the occurrence of particular weather types. The shortest distances (shortest sections) point to a very great similarity between units or their groups, while the longest sections indicate a smaller degree of similarity (comp. Fig. 2).

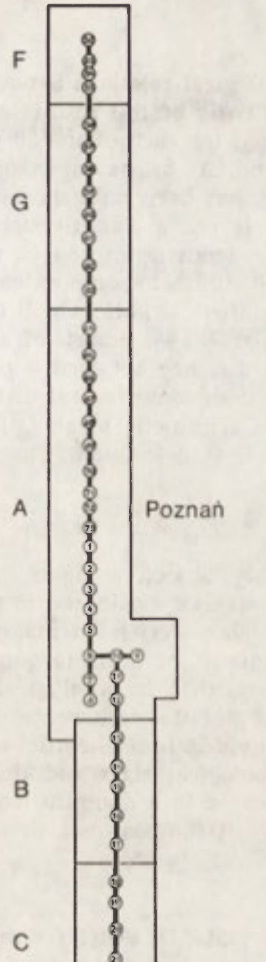

Fig. 2. Arrangement of pentads by means of the 'Wroclaw dendrite' method (A–F — typological classes)

The dendrite showing typological relations between the investigated pentads has been constructed on the basis of the results of calculations (Fig. 2). The dendrites have been constructed for each of the 39 meteorological stations over the area of North-West Poland. As an example, only one dendrite, made for Poznań meteorological station, has been published in the present work (Fig. 2). However, the dendrite itself is not a classification. Such a classification can be carried out by dividing the dendrite into parts, that is typological classes — groups comprising pentads which are to some extent homogeneous. It has been established that appropriate statistical indices will be the best criterion for the division of the dendrite into parts. Two subsets of a set are considered remarkably different if the shortest distance between a pair of pentads belonging to two various subsets is longer than some radical distance (D_{tk}). In order to estimate the critical distance the arithmetic mean ($\bar{x}$) of minimum distances and standard deviation (s) were first calculated. The critical distance was then defined by the formula:

$$D_{tk} = \bar{x} + 2s.$$

The criterion is reasonably objective since it results from a statistical distribution of the smallest distances considered in the dendrite (comp. Hellwig 1968). The acceptance of the above criterion makes it possible to distinguish within a set of 73 pentads subsets of units (groups of pentads) which are to a certain degree homogeneous, that is typologically homogeneous, from the point of view of the frequency of the occurrence of particular weather types. Finally, the year has been divided into climatic seasons. The membership of every pentad of a given typological class and the place of a pentad in the annual cycle have been presented in a diagram (comp. Fig. 2). Thus it is seen that the diagram is a picture of the seasonal structure of climatic conditions considered in the annual cycle.

CLIMATIC SEASONS OF THE YEAR IN NORTH-WEST POLAND

Thus it follows that the dendrites were made for 39 localities, and finally the year was divided into periods. However, the division differs from place to place. The next stage was to compare (identify) all seasons from all localities with one another. For this purpose, knowing the dates of the beginning and end, and the duration of particular periods, the average frequency of the occurrence of various weather types was established for these periods. The seasons selected in all 39 localities were numbered from 1 to 241. In order to compare these seasons, to establish their common features and to classify them, again the Wrocław dendrite was used as one of the methods of numerical taxonomy. The average minimum distance was established between particular units (in this case, between groups of pentads distinguished earlier), and the value of standard deviation was calculated from the distances considered in the dendrite $\bar{x} = 4.6119$, $s = 1.6248$.

The application of the above method resulted in the dendrite including 241 units (groups of pentads). In comparison with the dendrites made for particular localities this one exhibits a more complicated structure, which permits the distinction of some concentrations of units (Fig. 3). The criterion D_{tk} used to divide the dendrite into parts was an index of arithmetic mean ($\bar{x}$) calculated from all distances considered in the dendrite and from the standard deviation (s), which in turn was derived from these distances. The following criterion was used: $D_{tk} = \bar{x} + s$. The acceptance and application of such a criterion made it possible to distinguish six groups (concentrations) of units (Fig. 3). The concentrations are marked with successive letters of the alphabet: A–F. All the groups obtained, every one characterized by different parameters (different frequency of weather types), represent typological classes and each one of them exhibits some definite homogeneity.

The term 'climatic season' should be understood as a time period characterized by the same climatic conditions. In this case, a typological class comprises units with similar climatic conditions considered from the view-point of the frequency of particular weather types for many years. At the same time, the units (groups of pentads) in question represent definite time periods, and hence the particular typological classes many be regarded as climatic seasons and have the same symbols which have been accepted for typological classes, namely: A, B, C, D, E, F.

Having at our disposal information as to which units belong to particular typological classes and about time parameters of the units (dates of their beginning, end and duration) circular diagrams have been plotted. They show into which typological class a unit falls as well as the position of the unit in the year. The diagrams provide a picture of the seasonal structure of climatic conditions for particular localities. Each unit of the diagram represents a different time period of the annual cycle and usually exhibits individual features, belongs to a different typological class (represents some different climatic season). However, the latter is not a rule. It is possible for two units belonging to the same typological class to occur in one diagram (in one locality), but they are strongly differentiated by time parameters, and each one of them occurs in a different period of the year. This takes place when in a given locality or physico-geographical region a climate (season) with similar climatic conditions occurs twice a year.

The selected climatic seasons have not been designated as spring, autumn, summer and so on, because these names refer only to one period of the year, are names of definite periods of time, and indicate that climatic seasons do not reccur during the year. The year is a natural cycle for the majority of natural phenomena, e.g. processes occurring in the atmosphere. Therefore it is quite logical that periods with similar conditions are observed twice a year.

TYPES OF SEASONAL STRUCTURE OF CLIMATE AND THEIR SPATIAL VARIATION IN THE AREA OF NORTH-WEST POLAND

Diagrams presenting the seasonal structure of climatic conditions which have been plotted for particular localities permit the observation of some interesting facts, namely that the same number of climatic seasons do not occur in all localities. Besides, some seasons, that is climatic conditions characteristic of a given season can occur twice a year. It is possible to distinguish seasons which occur over the whole area of North-West Poland, as well as those which occur only in some regions of the Pomeranian Lake District or Great Poland Lowland.

The above facts lead to considerable differences in the seasonal structure of climatic conditions in particular localities. Seasons A and F may be found over the whole area in question. On the other hand, the most characteristic feature of season C is its twofold occurrence in the year, namely during the spring and autumn monts. But this phenomenon is limited in its extent since it does not appear over the whole area of North-West Poland. Only at the seaside, in the northern part of the Pomeranian Lake District season C occurs twice a year.

In all other parts of the region climate C occurs only in the second half-year from the end of season F till the begining of season A. All the remaining seasons may be found only in definite regions of North-West Poland and do not exhibit any tendency to appear twice a year.

In the light of the above facts it is clear that particular places are characterized by specific seasonal structures. Thus it seems appropriate to make an attempt at ordering all the localities investigated according to their seasonal structures, i.e. climatic conditions occurring in those places. The results of the ordering have been shown in Fig. 4.

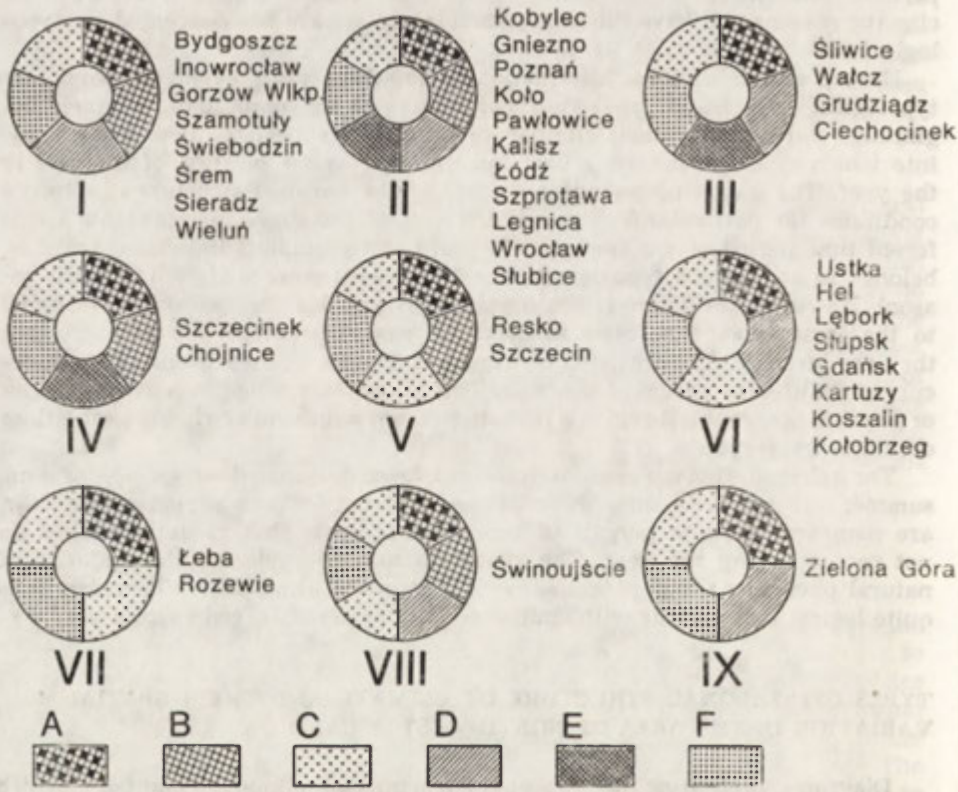

Fig. 4. Types of seasonal structure of the climate occurring in Nort-West Poland (A, B, ... — climatic seasons, I, II, III ... — types of seasonal structure of the climate)

Altogether, nine types of the seasonal structure of climate have been distinguished with information on their occurrence in individual localities. Particular types of seasonal structure of the climate have been numbered from I to IX.

According to the number of climatic seasons distinguished in the year it is possible to establish three groups of seasonal structures. The area of North-West Poland comprises regions where one may easily observe four, five, or six climatic seasons. The division of the year into four seasons is visible in types VII and IX. The only difference between them is that in type IX every season differs from the other ones, every one exhibits unique characteristics as to the

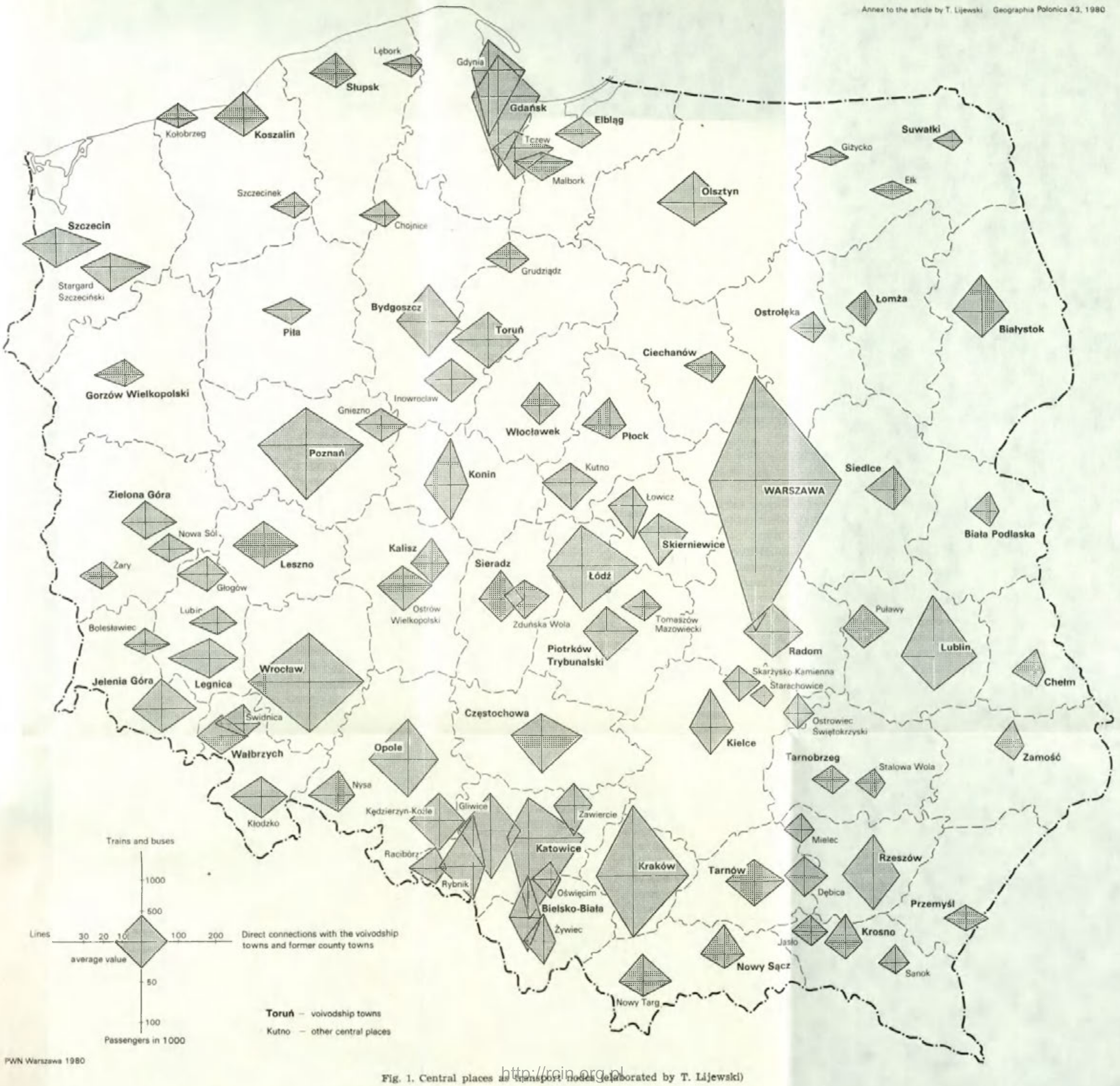

Fig. 1. Central places as transport nodes (elaborated by T. Lijewski)

frequency of particular weather types, whereas in type VII weather conditions characteristic of season C occur twice a year.

The division of the year into five climatic seasons is most often recorded in the majority of localities in North-West Poland. An increase in the number of seasons occurs in the first half-year only, that is during spring months. Types I, III, IV, V, VI are characterized by five climatic seasons. A detailed pattern of particular seasons has been shown in Fig. 4. In types I, III and IV no season reccurs in the same year, whereas types V and VI are distinguished by a twofold occurrence of season C in the same year. Types II and VIII are characterized by 6 distinct climatic seasons. In the former no season reappears, whereas in the latter, season C occurs twice during the year.

The analysis of the spatial extent of particular types of the seasonal structure of climate made it possible to draw a map showing in a clear and simple way areas exhibiting specific seasonal structures of climatic conditions (Fig. 5).

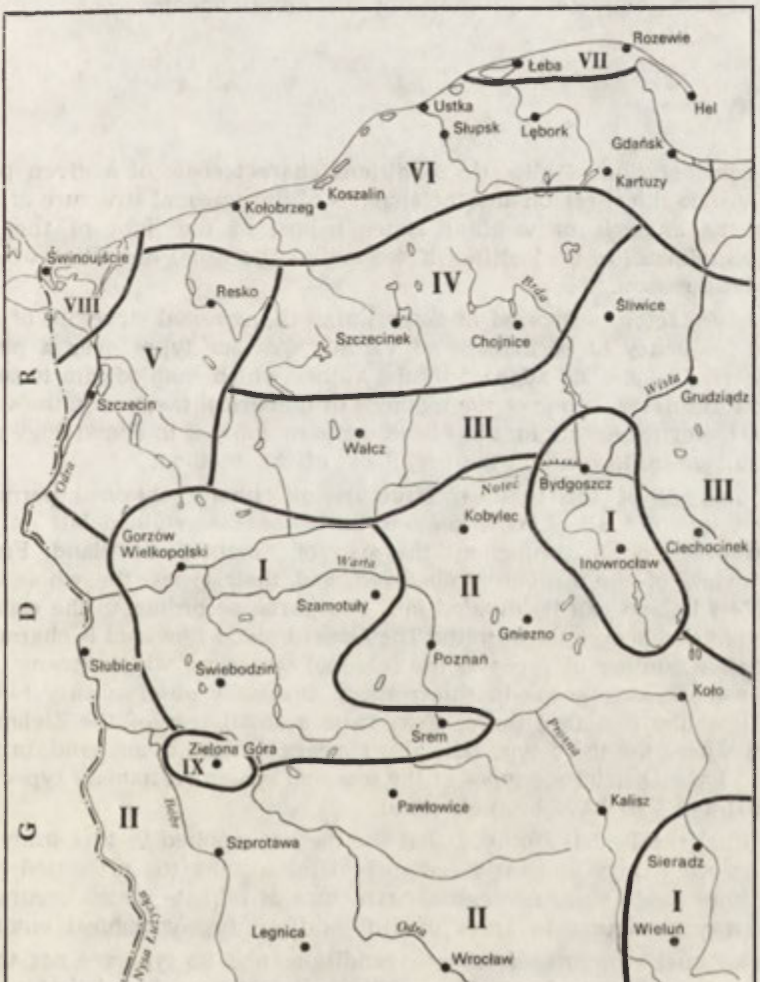

Fig. 5. Geographical extent of distinguished types of seasonal structure of the climate (I, II, III, ... — types of seasonal structure of the climate)

Particular areas have been given symbols corresponding to the type of the seasonal structure of climate observed in the area under investigation.

Taking into account the number and geographical extent of particular types of seasonal structures the area of Great Poland Lowland is found to be much more varied than the Pomeranian Lake District. In Great Poland Lowland only three types of the structure (I, II and IX) may be observed, and the other ones occur only in the Pomeranian Lake District. Types I and II can be considered dominant since type IX occurs only near Zielona Góra in the area of the Zielona Góra Rampart. It is seen that particular aspects of the structure, viz their geographical extent, correspond to large physico-geographical units. This partly confirms the correctness of the methodological procedure used in the present study. The above agreement is justified by, and confirms the influence of the terrain on the formation of a definite seasonal structure of climatic conditions considered from the view-point of local weather, because similar seasonal structures of climate were not observed in localities (areas) placed in territories with completely different physical environments.

SUMMARY

The consideration of climatic conditions characteristic of a given place or physico-geographical region and the analysis of the seasonal structure of climate through the analysis of weather states seems, in the light of the former studies on climate, to be justified if we accept the usual definition of climate and climatic season.

The basic factor considered in determining the seasonal structure of climate was the frequency of occurrence of various weather types over a period of many years. The method adopted by the author which enabled him to solve the problem formulated, is one of the methods of numerical taxonomy, the so-called Wroclaw dendrite. An attempt has been made to apply it to climatology and the final results seem to confirm the usefulness of this method.

The analysis of the seasonal structure of climate obtained permits the statement that not all climatic seasons have been ascertained but only some of those which occur throughout the area of North-West Poland. From the point of view of the structures observed, and their types, the whole area of North-West Poland can be divided into two parts, according to the occurrence of large physico-geographical units. The Great Poland Lowland is characterized by a smaller number of types of the seasonal structure, which means that the area is more homogeneous in this respect. One may observe only two types (I and II) of the structure there, apart from a small area of the Zielona Góra Rampart where the third type (IX) also appears. On the other hand, in the Pomeranian Lake District six types of the seasonal structure, namely types III, IV, V, VI, VII and VIII have been observed.

The final results have proved that the method applied in this study is logically correct. It may be considered correct for solving the presented problem in a definite range since no seasonal structure of climate which occurs in one locality may be found in areas of quite different geographical enviroment.

The seasonal structure of climatic conditions and its type are not the same over the whole area of North-West Poland. It has been found that particular physico-geographical regions have their own, often unique seasonal structure of climate which is not surprising because this conclusion displays and confirms

relations between the influence of the ground on the formation of local weather and hence on the formation of a definite seasonal structure of climate from this point of view.

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L'ÉVAPORATION POTENTIELLE EN POLOGNE

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INTRODUCTION

La croissance rapide de l'industrialisation, de l'urbanisation et de la production agricole en Pologne nécessitent un aménagement de l'eau adéquat à l'échelle nationale. C'est pourquoi la détermination de la structure du bilan hydrique en Pologne est une des tâches les plus importantes de la recherche hydrologique et climatologique. Indépendamment de l'évaporation réelle qui constitue la principale composante des pertes du bilan hydrique, la connaissance de l'évaporation potentielle est d'une importance particulière pour l'aménagement de l'eau.

Les recherches portant sur l'évaporation potentielle sont conduites en Pologne depuis plusieurs années. Ce problème a été étudié aussi bien par les hydrologues que par les climatologues. Les résultats obtenus sont toutefois difficilement comparables. Ces difficultés résultent de l'utilisation de méthodes différentes avec l'application de différentes formules empiriques. De plus les auteurs sont partis des différentes définitions de l'évaporation potentielle.

L'une des premières recherches a été celle de A. Schmuck (1949, 1953). L'auteur y a traité le problème de l'évaporation d'une nappe d'eau libre, en la définissant comme une "évaporation potentielle". Il l'a calculée en appliquant des formules dans lesquelles l'évaporation potentielle est soit fonction uniquement du déficit de saturation (Schmuck 1953), soit fonction non seulement du déficit de saturation, mais aussi de la vitesse du vent (Schmuck 1949). Les moyennes annuelles d'évaporation de la surface d'eau sur le territoire de la Pologne se situent selon Schmuck (1953) entre moins de 300 mm dans les montagnes (Sudètes) et plus de 800 mm dans les parties centrales et occidentales du pays. Les valeurs moyennes pour la saison de végétation: avril–octobre, se situent entre 470 mm dans les montagnes (Karpates) et plus de 740 mm en Pologne centrale (Grande-Pologne).

Parmi les chercheurs qui ont étudié l'évaporation potentielle sur le territoire polonais, il faut mentionner K. Matul (1972). Il a proposé une formule dans laquelle il a retenu le rayonnement net et la somme des moyennes quotidiennes des températures de l'air pour une période étudiée.

K. Matul et M. Dworska (1972) ont établi les cartes de l'évaporation potentielle et du rapport entre celle-ci et les précipitations atmosphériques en Pologne pour la période: avril–septembre, à l'exclusion des montagnes. Les valeurs moyennes de l'évaporation potentielle présentées par les auteurs sont relativement faibles. Ces valeurs se situent dans un intervalle assez étroit: entre moins de 500 mm pour les régions lacustres de Poméranie et de Suwałki, et 545 mm dans la partie sud-est du pays. Il est frappant de constater sur les cartes une faible variabilité dans l'espace de ce trait climatique sur le territoire polonais. Ceci résulte probablement de l'omission du facteur vent dans la formule. Les valeurs de l'indice: évaporation potentielle/précipitations, pour la période avril–septembre, se situent entre 1,1 sur la côte Baltique ou 1,2 au sud de la Pologne, et 1,6 sur la plaine de la Pologne centrale.

K. Wojciechowski (1968) a aussi étudié l'évaporation potentielle en Pologne en l'appelant "évapotranspiration potentielle". Pour calculer les moyennes annuelles il a appliqué la méthode empirique de Thornthwaite. Selon cet auteur les moyennes annuelles en Pologne se situent entre environ 560 mm pour la région lacustre de Suwałki au nord-est et 620 mm en Grande-Pologne, en Basse Silésie et dans la région Subcarpatique.

En plus des travaux déjà cités concernant l'ensemble du pays, il faut signaler aussi les travaux réalisés à l'échelle régionale ou locale.

MÉTHODE

Il semble bien que pour calculer l'évaporation potentielle la méthode combinée soit la plus adéquate. Cette méthode tire ses origines de celle de Penman (van Bavel 1966). Elle permet de déterminer l'évaporation potentielle d'une façon exacte, car elle est basée sur les lois physiques fondamentales. Ces lois sont définies par l'équation du bilan d'énergie et par les équations aérodynamiques décrivant les transferts de chaleur et de vapeur d'eau dans la couche limite de surface.

La définition de l'évaporation potentielle ainsi déterminée est la suivante: l'évaporation potentielle constitue la quantité d'eau qui pourrait être reconduite sous forme de vapeur d'eau dans l'atmosphère si la surface limite entre l'atmosphère et son substrat était constamment humide. On suppose à la fois que les conditions météorologiques existantes (comme la température et le déficit de saturation de l'air, la nébulosité, la vitesse du vent), ainsi que les propriétés physiques du substrat (comme la température de la surface active, sa structure géométrique, son albedo), sont inchangées.

Il est évident qu'en réalité ces suppositions ne peuvent être réalisées, car tout changement d'humidité à la surface limite entraîne la modification d'un ou de plusieurs des paramètres mentionnés. Malgré cela, une telle détermination permet d'obtenir des valeurs bien définies, et par là, comparables.

L'évaporation potentielle ainsi définie depend des facteurs suivants:

a) l'apport d'énergie à la surface limite par rayonnement et par conduction — ce dernier terme du bilan thermique, étant donné ses faibles valeurs numériques, peut être omis, surtout pour les périodes suffisamment longues;

b) le gradient vertical de l'humidité de l'air au-dessus de la surface limite;

c) le gradient vertical de la vitesse du vent;

d) le gradient vertical de la temperature de l'air.

L'équation de l'évaporation potentielle s'écrit ainsi:

$$E = \frac{10}{\varrho_w} \cdot \left[\frac{\frac{\Delta}{\gamma} \cdot \frac{Q}{L}}{\frac{\Delta}{\gamma} + 1} + \frac{\frac{k^2 \cdot u_a}{\left(ln \frac{z_a}{z_o} \right)^2} \cdot \varrho \cdot \frac{\varepsilon}{p} \cdot d}{\frac{\Delta}{\gamma} + 1} \right] = \frac{10}{\varrho_w} \cdot (E' + E'')$$

où:

E — évaporation potentielle (mm·période^{-1}),
L — chaleur latente de vaporsation (J·g^{-1}),
$\frac{\Delta}{\gamma}$ — paramètre dépendent de la température de l'air au niveau z_a,
Q — rayonnement net à la surface limite (J·cm^{-2}·période^{-1}),
ϱ — densité de l'air (g·cm^{-3}),
ϱ_w — densité de l'eau (g·cm^{-3}),
ε — rapport des masses molaires de l'eau et de l'air,
k — constante de Karman,
p — pression de l'air (hPa),
u_a — vitesse du vent au niveau z_a (cm·période^{-1}),
z_o — paramètre de rugosité (cm),
d_a — déficit de saturation de l'air au niveau z_a (hPa).

Ce qui constitue une certaine simplification dans la méthode combinée c'est la supposition que les profils de la température, de l'humidité et de la vitesse du vent dans la couche limite de surface sont logaritmiques. Un tel état de l'atmosphère n'apparaît, en réalité, que dans les conditions de stratification neutre. Il est reconnu toutefois qu'au-dessus d'une surface constamment humide n'apparaissent ni des gradients supéradiabatiques importants ni de fortes inversions thermiques. Il semble donc en conséquence que le principe posé devrait approximativement répondre aux conditions moyennes, surtout si l'on considère des périodes de longue durée, comme par exemple un mois.

L'avantage de la méthode appliquée consiste dans la possibilité de comparer les résultats obtenus dans n'importe quelles conditions climatiques. Grâce à cela on peut l'utiliser dans des études non seulement ponctuelles mais aussi régionales, et surtout pour des classifications climatiques. L'évaporation potentielle ainsi déterminée constitue donc un indice important du climat.

La méthode combinée permet aussi d'étudier la structure de l'évaporation potentielle qui se compose de deux termes: le terme radiatif E' et le terme aérodynamique E''. Le premier de ces termes E' que l'on désigne parfois sous le nom d'évaporation d'équilibre (Wilson, Rouse 1972 détermine les valeurs de l'évaporation potentielle dans des conditions de saturation totale de l'air ou d'absence de vent.

Le but principal de cette recherche était l'étude de la répartition géographique sur le territoire polonais pendant la saison de végétation de l'évaporation potentielle, de sa structure et des indices climatiques qui peuvent en être deduits. Partant de ce principe on a comparé l'évaporation potentielle avec le rayonnement solaire global et les précipitations atmosphériques, c'est à dire avec les principaux termes de dépense du bilan thermique et du bilan hydrique.

Les valeurs moyennes mensuelles de E ainsi que de E' et de E'' ont été calculées pour la décennie: 1956–1965, à partir des résultats des observations de 56 stations météorologiques en Pologne. Étant donné toutefois que les observations du rayonnement ont été insuffisantes, la valeur Q a été obtenue indirectement; elle a été calculée à l'aide des formules empiriques de Black et de Brunt (Olechnowicz-Bobrowska 1978).

Pour le calcul de l'évaporation potentielle on a retenu une valeur stable du paramètre de rugosité $z_o = 1$ cm, qui correspond aux conditions du gazon coupé court, tel qu'il devrait être sur le terrain des stations météorologiques.

DISCUSSION DES RÉSULTATS

Les sommes moyennes d'évaporation potentielle sur le territoire de la Pologne, pendant la saison de végétation, sont comprises entre environ 500 mm et plus de 800 mm (Fig. 1). Comme on peut le constater sur la carte, il y a une diminution de l'évaporation potentielle en montagne due à l'altitude: ceci est

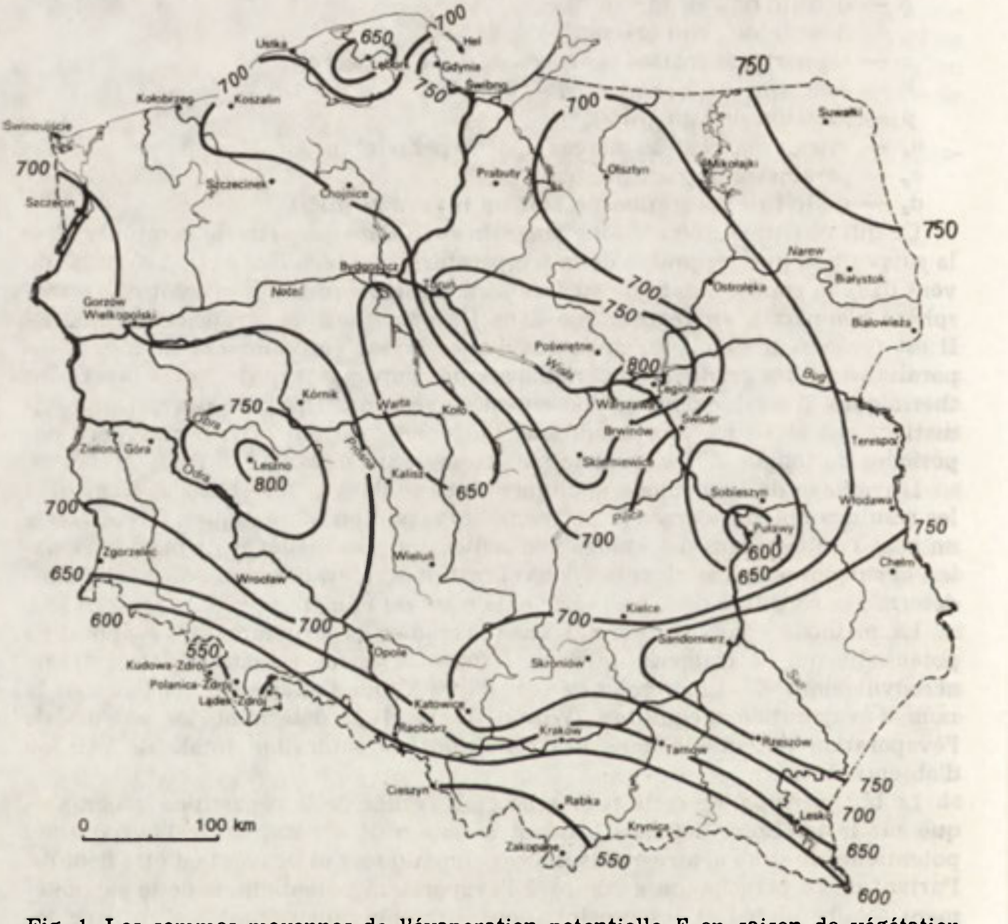

Fig. 1. Les sommes moyennes de l'évaporation potentielle *E* en saison de végétation (avril–octobre) en Pologne (mm)

valable aussi bien pour les Karpates que les Sudètes, où les sommes de *E* pour la saison de végétation sont les plus faibles. Les valeurs les plus élevées de *E* s'observent dans la vallée de la Vistule entre Varsovie et Toruń (de 750 mm à plus de 800 mm), dans le sud de la plaine de Grande-Pologne (près de 800 mm), dans la région lacustre de Suwalki et sur toute la partie sud-est du pays (plus de 750 mm). Sur la majorité du territoire de la Pologne les valeurs moyennes se situent dans l'intervalle d'environ 650 mm jusqu'à 750 mm.

On a caractérisé la structure de l'évaporation potentielle par le rapport E'/E. Les moyennes mensuelles de cet indice, calculées pour certaines des stations météorologiques représentatives des différentes régions climatiques de la Pologne, sont présentées sur des graphiques (Fig. 2).

Dans le climat maritime, représenté par Gdynia, le pourcentage du terme radiatif E' dépasse 50% d'avril à août; ce n'est qu'à partir de septembre que le terme aérodynamique E'' domine. En octobre, le pourcentage de E' tombe même jusqu'à 20%, ce qui est probablement dû aux vents relativement forts prédominant en automne sur la côte Baltique.

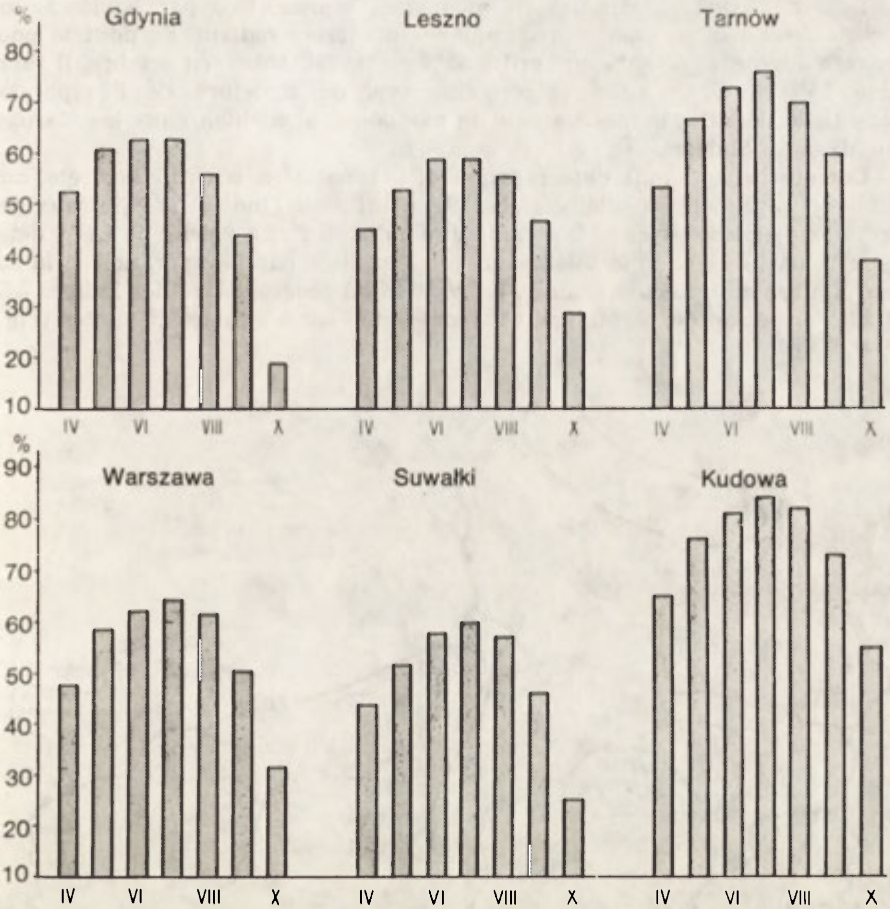

Fig. 2. Les variations de l'indice E'/E pendant la saison de végétation

A Suwałki, représentant les conditions climatiques des régions lacustres, on observe que, au début de la saison de végétation, le terme aérodynamique E'' est supérieur au terme radiatif E'. En mai E' et E'' sont à peu près identiques; par la suite, jusqu'au début de septembre, E' prédomine. Mais cette superiorité est toutefois très faible: le pourcentage de E' n'atteint les 60% qu'en juillet.

Les conditions climatiques de la Pologne centrale, représentées par Varsovie, sont caractérisées par l'égalité de deux termes E' et E'' en avril et septembre. Le pourcentage de E' varie entre 65% en juillet et 30% en octobre.

La station de Leszno présente un type légèrement différent de l'évolution de la structure de l'evaporation potentielle E. Le pourcentage du terme aérodynamique E'' y est beaucoup plus élevé qu'à Varsovie. Ceci est probablement dû aux grandes vitesses du vent observées à Leszno. L'indice E'/E y est, même dans les mois d'été (juin et juillet), inférieur à 60%; en avril et en septembre E'' predomine nettement.

La région Subcarpatique (Tarnów) est caracterisée par une nette prédominance du terme radiatif E'. Le plus fort pourcentage de E'/E, relevé en juillet, est supérieur à 75%. C'est seulement en octobre que le pourcentage de E'' est plus élevé.

Les conditions climatiques en montagne, représentées par Kudowa, sont caractérisées par une nette prédominance du terme radiatif E', dont le pourcentage augmente de 65% en avril à 85% en juillet. Même en octobre, il représente 55% de E. On retrouve ce même type de structure de l'évaporation potentielle dans les autres stations de montagne, aussi bien dans les Karpates que dans les Sudètes.

Comme nous l'avons déjà mentionné, l'évaporation potentielle a été comparée au rayonnement solaire global S, en utilisant l'indice LE/S, et aux précipitations atmosphériques P à l'aide de l'indice E/P. La valeur de LE/S détermine la part de l'énergie solaire qui serait utilisée par l'évaporation si la surface limite était toujours saturée. La répartition géographique des indices LE/S et E/P, en saison de végétation, est représentée sur les cartes ci-jointes (Fig. 3 et 4).

Fig. 3. Les valeurs moyennes de l'indice E/P en saison de végétation en Pologne

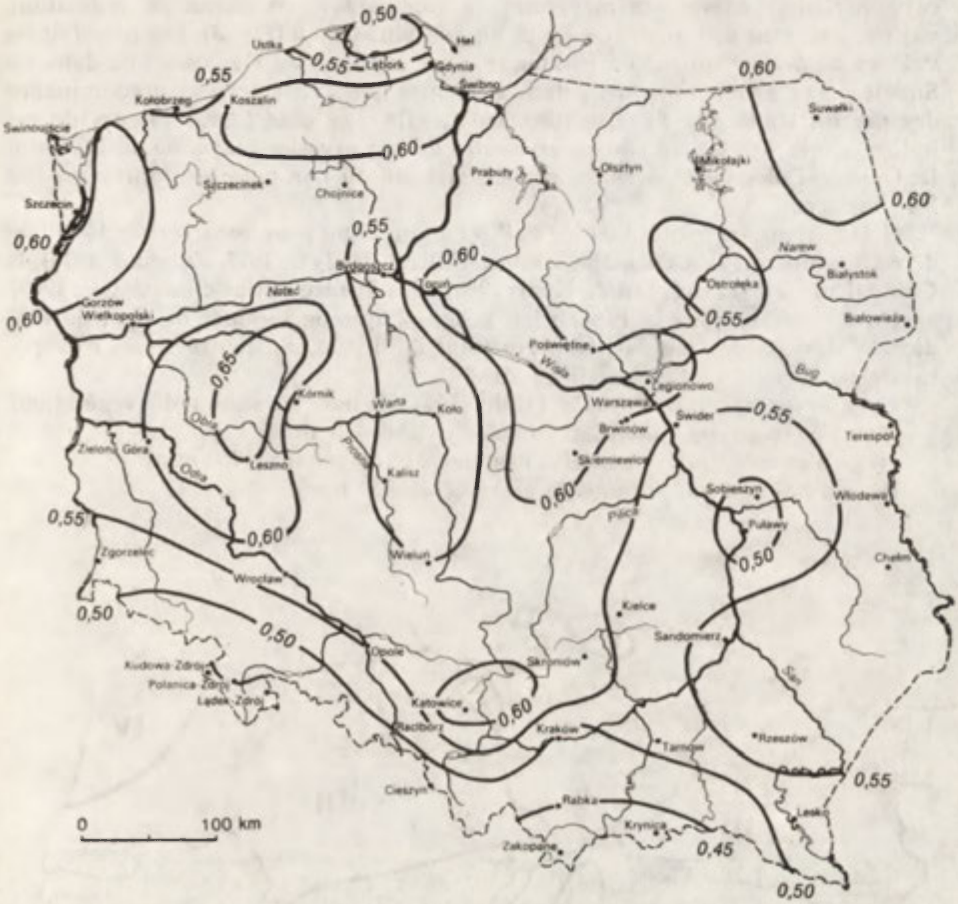

Fig. 4. Les valeurs moyennes de l'indice *LE/S* en saison de végétation en Pologne

Pendant la saison de végétation, les valeurs moyennes de *LE/S* sont inférieures à 1,0 et varient entre 0,45 dans les Karpates et les Sudètes et 0,65 dans la plaine de Grande-Pologne. Sur la majeure partie de notre pays, les valeurs de *LE/S* se situent entre 0,50 et 0,60, ce qui signifie que plus de la moitié de l'énergie fournie par le rayonnement solaire serait utilisée pour l'évaporation, si la quantité d'eau accessible n'était pas limitée. Il est intéressant de relever la présence de faibles valeurs de *LE/S* en montagne (inférieures à 0,50), bien que le rayonnement solaire pendant la saison de végétation y soit réduit par rapport aux autres régions du pays. Par contre, les valeurs relativement basses de *LE/S* sur la côte Baltique sont dues sans doute à la forte insolation de cette région, surtout dans la première moitié de l'été. Les valeurs assez élevées de *LE/S* que l'on observe en Haute-Silésie, sont certainement conditionnées par une réduction de l'énergie solaire, provoquée par la pollution de l'atmosphère. Des valeurs proches se retrouvent aussi aux environs de Varsovie, dans la région lacustre de Suwałki et en Poméranie.

Contrairement à l'indice *LE/S*, dont les valeurs sont toujours inférieures à 1,0, les valeurs moyennes de l'indice *E/P* sont, pendant la saison de végétation généralement supérieures à 1,0; les sommes d'évaporation potentielle en Pologne sont donc supérieures aux sommes des précipitations atmosphériques pour cette période. Les valeurs moyennes de l'indice *E/P*, en saison de végétation, varient entre un peu moins de 1,0 et un peu plus de 2,0 (Fig. 3). Les plus faibles valeurs de *E/P* se situent en montagne — autant dans les Karpates que dans les Sudétes — et c'est uniquement dans ces zones que l'on relève la prédominance des précipitations sur l'évaporation potentielle. Les plus fortes valeurs de cet indice, atteignant 2,3, se situent au centre du pays (vallée moyenne de la Vistule, Grande-Pologne) et dans les régions sud-est, où l'on note les déficits en eau les plus forts.

Il faut remarquer que l'indice *E/P* a été appliqué pour caractériser le climat de différentes régions du globe, comme l'URSS (Budyko 1975, Zubenok 1976), la Chine (Qion, Jih-Liang, Lin Zi-Kuan 1965) et la France (Atlas climatique... 1969).

On a constaté dans la répartition géographique de sommes de *E* et de l'indice *LE/S* certaines régularités permettant de distinguer quatre zones d'évaporation potentielle en Pologne (Fig. 5):

I — d'évaporation potentielle faible (500–550 mm en saison de végétation),
II — d'évaporation potentielle modérée (550–650 mm),
III — d'évaporation potentielle modérement élevée (650–750 mm),
IV — d'évaporation potentielle élevée (750–850 mm).

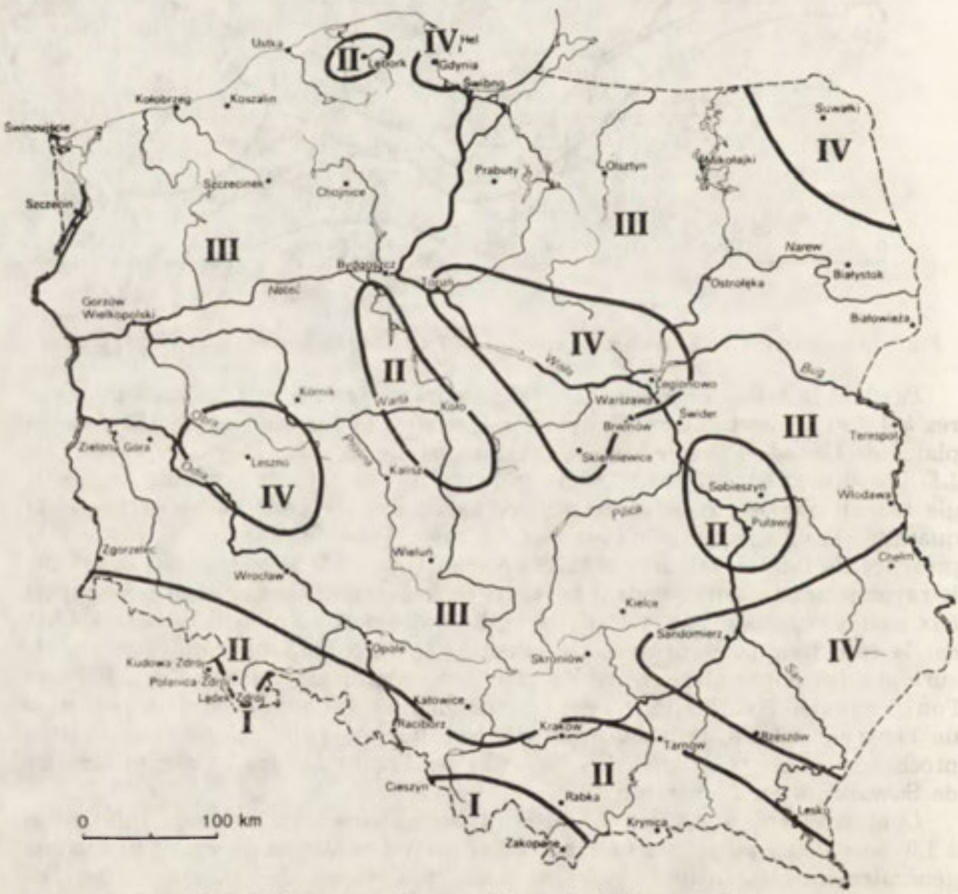

Fig. 5. Les zones d'évaporation potentielle en Pologne

CONCLUSIONS

1. L'application, dans cette étude, de la méthode combinée pour la détermination de l'évaporation potentielle, nous donne une nouvelle approche de ce trait du climat de la Pologne en saison de végétation. La formule utilisée pour déterminer l'évaporation potentielle, présente l'avantage, par rapport aux formules empiriques, de donner aux paramètres et aux fonctions intervenant dans le modèle un sens physique bien défini. De plus, ce modèle permet d'étudier la structure de l'évaporation potentielle en déterminant la participation des termes radiatif E' et aérodynamique E''. Pour ces raisons, il semble qu'en climatologie, ce modèle présente des avantages que n'ont pas les formules empiriques.

2. Les valeurs d'évaporation potentielle, trouvées dans ce travail, et leur répartition géographique en Pologne, diffèrent, par certains aspects, de celles qui avaient déjà été établies par d'autres auteurs.

3. Les sommes moyennes d'évaporation potentielle pour la saison de végétation se situent entre 500 et 820 mm.

4. L'évaporation potentielle diminue en fonction de l'altitude; elle atteint ses plus faibles valeurs en montagne (de 500 à 575 mm).

5. Sur la majeure partie du territoire de la Pologne, pendant la saison de végétation, le terme radiatif E' est supérieur au terme aérodynamique E''. Les valeurs moyennes de l'indice E'/E se situent entre 0,49 et 0,74. Les valeurs du terme aérodynamique E'' augmentent en fonction de la rugosité de la surface limite, ce qui entraîne une modification de l'indice E'/E.

6. À partir de l'analyse de la répartition géographique de l'évaporation potentielle et de ses indices, on a pu distinguer en Pologne quatre zones d'évaporation potentielle.

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ZONAL AND AZONAL ASPECTS OF THE AGRICULTURE-FOREST LIMIT IN THE POLISH CARPATHIANS

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SITUATION OF THE CARPATHIANS AND STATEMENT OF THE PROBLEM

The mountain arc of the Carpathians, following a west-east course in the north-western part, has the character of a barrier with an altitude of 800–1500 m, and only isolated mountain groups exceed this altitude, reaching 2600 m as in the Tatra Mts.

The northern slopes of this part of the Carpathians within the frontiers of Poland are influenced by an atmospheric circulation which is of a predominantly westerly nature. A combination of the influence of polar-oceanic air masses (about 60% of the year) and polar-continental ones (26%) gives the climate of this part of Europe a transitional quality within the temperate climatic zone. The climate of the Polish Carpathians is characterized by diversified thermal conditions depending on the altitude as well as on a sufficient humidity of air. The soils are usually well provided with water available to plants.

Except for the crystalline-and-calcareous massif of the Tatra Mts. and the calcareous one of the Pieniny Mts., the area comprises sandstone and clay shale Flysch rocks. Their variable resistance to denudation, occurring during the whole Neogene and the Quaternary, caused the more resistant rocks to form higher peaks and slopes. This is why in the Carpathians, not only are there temperature gradations but also the inclinations of slopes and the soil skeleton content increase with altitude. Often, in the mountains, the problem of the course of boundaries defining the range of basic kinds of land use is reduced to hypsometric parameters (Galarowski, Kostuch 1965; Kurek et al. 1978). In reality such limits are more complex; sometimes even inversions of environments are observed, being conditioned by temperature as well as by surface relief and soils. The present paper aims to show this complexity, referring in particular to the range of arable land and the position of the agriculture-forest limit in the Polish Carpathians.

Land hunger in the period when Poland was partitioned (before 1914) caused an upward shift of the boundary of arable land, often beyond the limits of viability, even at great risk of crop failure (e.g., in a cool summer such as that of 1978). Therefore the problem under discussion also has a practical aspect. It is necessary, given rational agricultural and forest management and assuming mechanization of farming in the mountains, to determine what the course of this boundary should be, at the same time taking into consideration other economic functions of mountain territories, and especially protection against floods and erosion as well as the supply of pure water for urban-industrial agglomerations and agriculture.

CHIEF ELEMENTS RESTRICTING AGRICULTURAL LAND USE, CONNECTED WITH ALTITUDE

In mountainous areas the absolute and relative altitudes determine, in a fundamental manner, the parameters of temperature and humidity as well as — through the character of the mountain relief — the intensity of denudation processes, the technical possibility of tillage and the productivity of soils. Therefore, when analysing the agriculture-forest limit, it is necessary to consider the elements showing zonal differentiation: a) macroclimate, b) relief type and relative altitudes as well as slope angles.

VARIATION IN MACROCLIMATIC CONDITIONS

The general features of zonal climatic variation are shown in a transverse section across the Carpathians (Fig. 1). M. Hess (1965) delimits the boundaries of climatic zones on the basis of the value of the annual mean air temperature with which many climatic elements and indices are related by strict functional correlations. A change of the basic plant associations, typical for the separate climatic zones, reflects the changes in climatic conditions. The climate also limits the occurrence of many plant species. The majority of arable fields in the Carpathians are contained within the moderately warm zone, and their approximate upper altitude limit 600–750 m generally corresponds to the mean yearly isotherm $+6°C$. The cropping of wheat in the Carpathians reaches an average altitude of 450 m, and other cereals and potatoes occur even at the highest field points. The record for altitude is held by fields in the Beskids, namely 1100 m (Gorce Mts.).

The situation of this isotherm depends on the forms of surface relief and exposition. The climate of intermontane basins shows a very great variety of conditions for plant vegetation because there is a whole range of transitions from conditions typical for considerable continentalism in the Orawa-Nowy Targ Basin (altitude 500–600 m) to a distinctly milder climate of the Nowy Sącz Basin (about 300 m).

TYPES OF RELIEF — THEIR CONNECTION WITH ALTITUDE AND GEOLOGICAL STRUCTURE

The area of the Polish Carpathians is characterized by a large diversity of relief in spite of the apparent monotony of Flysch rocks. The relation, referred to earlier, of relative and absolute altitudes as well as slope inclinations with

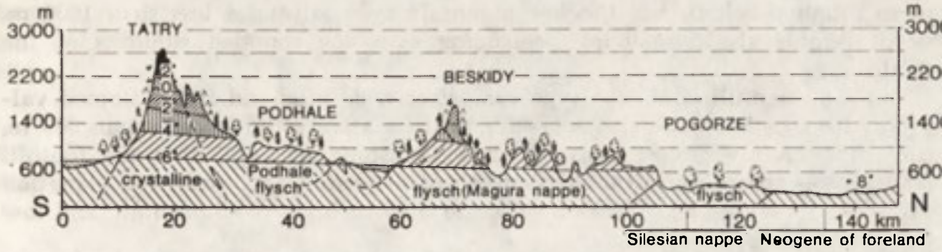

Fig. 1. Physico-geographical zones of the Carpathians (after Gerlach, Hess, and Starkel 1967)

Climatic zones (characterized in the table below) are marked by shading and discerned by mean yearly temperatures in intervals of 2°C. The tree symbols designate the zones of deciduos foothill forests, of the lower and higher forest zones, of dwarf pine, and Alpine meadows

Explanations of causal profile (after Hess 1965)

Climate type	Climatic zone	Mean altitude at upper limit (m)	Natural plant formation	Mean yearly temperature (°C) at upper limit	Yearly precipitation total (mm) at upper limit	Percentage of days with snowfall
Nival	cold	2665	rocky summits	−4	1625	85
Nival-pluvial	moderately cold	2200	alpine meadows	−2	1750	77
	very cool	1850	dwarf pine	0	1800	65
	cool	1550	upper forest zone	+2	1600	57
Pluvial-nival	moderately cool	1100	lower forest zone	+4	1400	45
	moderately warm	700	mixed foothill forest	+6	1000	30
	warm	250		+8	750	28

the resistance of rocks to weathering are best illustrated by cumulative curves of slope angles calculated for medium sized catchment basins (5–15 sq. km) with a uniform relief type (Fig. 2). In the Polish Carpathians three basic types of landscape may be described: mountains, foothills, valley and basin bottoms which occur in various climatic zones (Fig. 1).

(a) The mountain landscape type comprises ridges with narrow valleys separating them by steep slopes (at more than 20°), with relative altitude between 250–350 m and more than 1000 m, consisting mainly of resistant rocks (thick-bedded sandstones), in the Tatra Mts. granites and limestones, in the Pieniny Klippen Zone — limestones, and more stony soils.

Among the mountain landscapes there may be discerned: the high mountain type (with vertical intervals up to 1000 m, altitudes 1700–2500 m, occupied the zones above the forest limit, with features of a glacial relief; modelled by gravitational processes), the medium high mountain type with altitudes 1000–1500 m (and vertical intervals 400–800 m, contained by the forest zones, with more rounded relief), and the low mountain type (altitudes less than 1000 m, vertical intervals 250–350 m), protruding over the rounded summits of the foothills.

(b) The foothill landscape type comprises wide hills and flat-bottomed valleys, with mostly gentle slopes (5–20°), with relative altitudes less than 300 m, consisting mainly of less resistant shale-sandstone series. Within the foothill landscape — according to lithology, depth of dissection and conserved planation surfaces of varying age — it is possible to discern high, medium high, and low foothills (Starkel 1972).

(c) The type of intermontane basins and valleys comprises flat, terraced accumulation plains consisting of river and slope sediments.

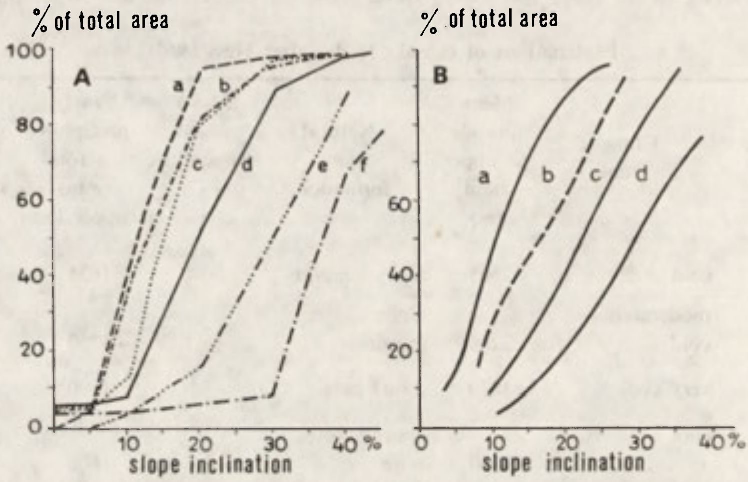

Fig. 2. Cumulative curves of slope angles frequency for various types of surface relief (based on the results from the paper by Starkel et al. 1973)

A. Cumulative curves calculated for selected representative areas: a — footslopes of Mt. Łopień (Beskid Wyspowy), b — foothills exceping those of Nowy Sącz district, c — medium foothills near Szymbark, d — valley of the Leśnica River (Gubałówka Foothills), e — ridge of Mt. Łopień, f — valley Jaszcze (Gorce Mts.)

B. Intervals of curves for: a — low foothills, b — medium foothills with mild slopes, c — medium and high foothils with steep slopes, d — low and medium high mountains with a proportion of mild slopes, e — medium high and low mountains with prevalent steep slopes

The system of enumerated relief types is differentiated spatially. Figure 1 shows the zonal distribution of the regional units characteristic of the Western Carpathians, where within the mountain limits the following are discerned: Carpathian Foothills (with foothill relief), Beskids (medium high and low mountain relief), Podhale (basin and foothill relief), and Tatra Mts. (high mountain relief). Within the separate regional units of the Polish Carpathians the percentages and the spatial distribution of the separate relief types may be very varied. A considerable mosaic of relief types leads to a large variation in land use. In the Beskids there mostly occur compact mountain groups with steep slopes, where usually a single mode of land use (pastures and forests) should be preferred, or isolated ridges with steep slopes protruding above rolling foothill country. In the first case the limit of the mountain region, in the second — the foot of a steep ridge will delineate a natural agriculture-forest limit in the Carpathians, often lowered in regard to climatic conditions (sometimes even as low as 300 m altitude). Therefore the limit between the types of foothill and mountain reliefs (differing in prevalent slope angles — Fig. 2) may be assumed as a general limit between a distinct domination of arable land and greenland (foothills) and a domination of forests (mountains).

SECONDARY (AZONAL) ELEMENTS LIMITING AGRICULTURAL LAND USE

Among the azonal elements superimposing themselves on the zonality of climate and relief the authors considered the influence: a) of the slope angle on soil erosion and technical possibilities of tillage, b) of the differentiation of the soil cover and c) of mesoclimatic conditions.

THE INFLUENCE OF THE SLOPE ANGLE ON SOIL EROSION AND ON TECHNICAL POSSIBILITIES OF SOIL TILLAGE

Slopes occupy a dominant position in the chief types of relief observed. The magnitude of the slope angle constitutes an essential parameter for their qualification for rational land use. This is connected with gravitation. On slopes, the force of gravitation is reduced to two components, one perpendicular and one parallel to the slope. In loose soils the equilibrium between these two components is determined by the angle of natural repose. For various types of loose soils this angle varies between 25 and 47°. Slope angles which oscillate near the angle of repose create potential conditions for permanent sliding of loose soils.

In the shale-sandstone series of the Carpathian Flysch there exist especially suitable conditions for processes of slipping, and these are sometimes observed at slope angles as low as 8°. Geological features, including situations where porous rocks cover underlying impermeable argillites, cause landslides to be a widespread phenomenon in some parts of the Carpathians. This is particularly marked during wet years (Gerlach 1966). Human activity accelerates landslide proceses by incorrect road construction. Deep excavations and steep undercutting, as well as jarring by heavy vehicles disturb the equilibrium of the land constituting the slopes.

Apart from landslides, which occur over about 4% of the Carpathian area, slopewash is the most important process affecting the slopes. The course and intensity of washing depend on the slope angle, and, above all, on the kind of plant cover growing on the slopes. Table 1 shows that from the point of view of protection against soil erosion, agricultural crops where upper parts are very poor in their shielding effect, and where roots are very weak in their soil binding power should be replaced by durable greenland on those slopes with greater inclination angles.

In the absence of effective soil protection by compact plant cover, a decrease in soil degradation on slopes can be brought about by ploughing at right angles to the slope. After considerable time this leads to a local decrease in slope angle and the appearance of a microrelief of so-called agricultural terraces. Such terraces modify and lessen the effects of slopewash. Their efficacy in checking soil degradation is limited. During a period of human management extending over some 300 years, agricultural terraces decreased the magnitude of soil degradation by only 40% (Gerlach 1966). The formation of high and steep escarpments between the separate terrace flats — besides causing variations in soil depth — leads to the occurrence among them of small slumps and slippings and thus makes soil tillage more difficult.

TABLE 1. Annual soil losses by slopewash in relation to slope angle and vegetation cover (according to Gerlach 1966, 1976 and Gil 1976). Figures are in tons/ha

Slope angle classes		Mecanical composition of soils	Woodland	Farmland areas			
				grassland		ploughed grounds	
per cent	degrees		mixed forest	meadow	pasture	winter corn	root crops
<10	6		0.0005	0.001	0.010	0.054	36.0
10–20	11	medium	up to 0.0015	up to 0.003	up to 0.030	up to 0.162	up to 108.0
20–30	17	loam*	up to 0.0028	up to 0.006	up to 0.050	up to 0.302	up to 201.0
>30	17		>0.0028	>0.006	>0.050	>0.302	>201.0

* Medium loam (ca 40% of < 0.02 mm grain size fraction).

TABLE 2. Limiting slope angles of agricultural tool-and machine usage (according to Martini 1965, selected data)

Type of machine or tool used	Limiting slope angle					
	across the slope		upslope		downslope	
	per cent	degree	per cent	degree	per cent	degree
Plough	17	9	80	39	30	17
Seeder	15	8	60	31	30	17
Tractor (classic)	20	11	25	14	25	14
Combine harvester	15	8	25	14	25	14

TABLE 3. Displacement rates of soil turned up by plough (according to Czyżyk 1955). Figures are in cms

Slope angle		Direction of ploughing					
		perpendicular to contour lines			following contour lines		
		slice of earth turned up by plough					
per cent	degree	downslope	upslope	result	downslope	upslope	result
14	8	31	15	16	48	44	4
19	11	51	21	30	46	33	13
26	15	24	10	14	41	32	9
Mean		35.5	15.3	20	45	36.3	8.7

A further important occurrence on agriculturally utilized slopes, especially in winter and early spring, is deflation on windward slopes and the deposition of soil eolic material on the leeward slopes. The deposition of soil eolic material in a zone of maximum deposition attains 350 m³/ha/y (Gerlach, Koszarski 1968).

The slope angle also decides the technical possibilities of soil tillage on slopes. It is necessary to consider two aspects of this problem: 1) the feasibility of using agricultural tools and machines at various slope angles, 2) the effects of using agricultural tools and machines (Tables 2 and 3). It follows from Table 2 that a rational use of particular agricultural machines and tools is possible only up to a definite slope angle called the angle limiting applicability. Exceeding it causes difficulties in the action of tools and machines and in applying correct agrotechnical measures, while the work carried out becomes uneconomic. The second aspect connected with the work of tools and machines on slopes lies in the results caused by the latter over a longer period of time (Table 3). The translocation of soil down the slope is considerable and leads to a destruction of soil and to a baring of the skeleton-rich subsoil in the upper parts of the fields.

Roads are a separate problem. In many cases considerable areas of fields, even with small slope angles, are cut off from access to agricultural tools and machines by a dense system of narrow and locally deeply incised roads. Larger slope angles therefore constitute a basic barrier in the arable use of slopes, from the point of view of soil protection from erosion as well as from the technical and economic one. Because of this, slopes in mountain territories should not be ploughed at angles exceeding 11°.

VARIATION IN THE SOIL COVER

Carpathian soils are characterized by great variations. Often within small areas a variety of soils may be found: shallow ones (5–25 cm) and deep ones (150–200 cm), sandy-stony ones and loamy-clay ones, strongly acid ones (podzols) and alkaline ones (pararendzinas or rendzinas), naturally poor (podzols) and rich in nutrients (loam or clay variants of brown soils or pararendzinas). Some soil areas are medium heavy and moderately moist (moderately stony loamy soils), others — difficult, permeable and excessively moist (loamy and clayey gley and pseudogley soils), or — again — too well drained and at least periodically insufficiently moist (sandy-stony podzolic soils).

The chief constituents of the soil cover in the Flysch Carpathians are loamy-stony and loamy-fine-sandy variants of mesotrophic brown soils (Table 4, item I.2 and II.4). Oligotrophic sandy-stony soils (Table 4, item I.1) and mesotrophic-eutrophic loam or clay soils (Table 4, item III.6–8) occupy smaller areas. Larger areas of loam and clay soils are found with the foothill type of relief, while the stony-sandy soils — with the mountain and high-mountain type of relief (Dobrzański 1963; Adamczyk et al. 1973; Komornicki 1975; Starkel 1972). The loamy variants of Carpathian soils are usually magnesium-rich, fairly well supplied with potassium and calcium, and poor or very poor in phosphorus. This is caused mainly by the mineral composition of the rock substratum.

In the zones of foothills and mountains occupying situations between about 300 m and about 1100 (1150) m altitude the variation of the soil cover in the Carpathians is paralleled by the substratum lithology and by the surface relief which is conditioned by the lithology (Adamczyk 1966; Adamczyk et al. 1973; Starkel 1972). The grain size of the rock substratum, its mineral composition, its susceptibility to weathering, and — in the Flysch Carpathians — also the thickness of sandstone-and-clay layers, are reflected not only in the surface relief (Starkel 1972), but in the variation of the basic properties of the soil cover as well (Fig. 3). A distinct predominance of the bioclimatic factor in soil formation is observed in higher situations (Adamczyk 1962, 1966), i.e. in the zones of spruce forest and dwarf pine (Fig. 1). Above the forest limit the differentation of soils and of the mountain pasture sod vegetation is again connected with the rock substrate (Adamczyk 1962). The zonality of mountain soils, among others stressed by Pelišek (1973), is less distinct in the Polish part of the Flysch Car-

TABLE 4. Productive and hydrological properties of the soil cover in the Carpathians as connected with surface relief and geological constitution

Surface relief	Rock substrate	Soil mechanical composition	pH in H_2O	Soil types and subtypes	Type of water regime in the soil		
					infiltrat-ional	infilreten-tional	reten-tional
	A. Stony and ofter excessively permeable soils, suited as forest land						
I[1]	1. granites, conglomerates, thick-bedded sandstones — medium- and coarse-grained	sandy-stony	3.5–4.5	podzolic, cryptopodzolic, podzolised brown	+ + +[2]	+	–
I[1]	2. medium- and fine-grained sandstones interlayered with clay shale	loamy-stony, stony-loamy	4.5–5.5	leached brown, acid brown	+ +	+ +	+
I[1]	3. limestones, dolomitic limestones, dolomites, marls	loamy-stony	7.0–8.5	rendzinas	+ + +	+ +	–
	B. Medium heavy soils, suited as arable land and orchard						
II	4. thin-bedded layers of sandstones and clay shales	loamy-fine-sandy — weakly or medium stony	5.0–7.0	leached brown, typical brown, lessive	+	+ + +	+
II	5. river alluvia	loamy-fine-sandy	6.0–7.5	warp soils	+	+ + +	+ +
	C. Heavy soils, suited for greenland use						
III	6. aleurites, menillite shales, loess-like sediments	fine-sandy-clayey — little or no stones	5.0–6.0	lessive (gray-brown podzolic), gleyed brown, pseudogley	–	+	+ + +
III	7. marly clay shales	loamy-clayey	7.0–8.5	gleyed pararendzinas	–	+	+ + +
III	8. variegated Eocene clays	clayey	5.0–6.0	gley, pseudogley	±	–	+ + +

[1]) I — steep slopes of ridges and valleys — mostly in mountain relief type, II — mild slopes of mountains and foothills as well as valley bottoms, III — flattenings of ridges and mild foothill slopes.

[2]) proportion of given type of water regime: – none, + small, + + medium, + + + large

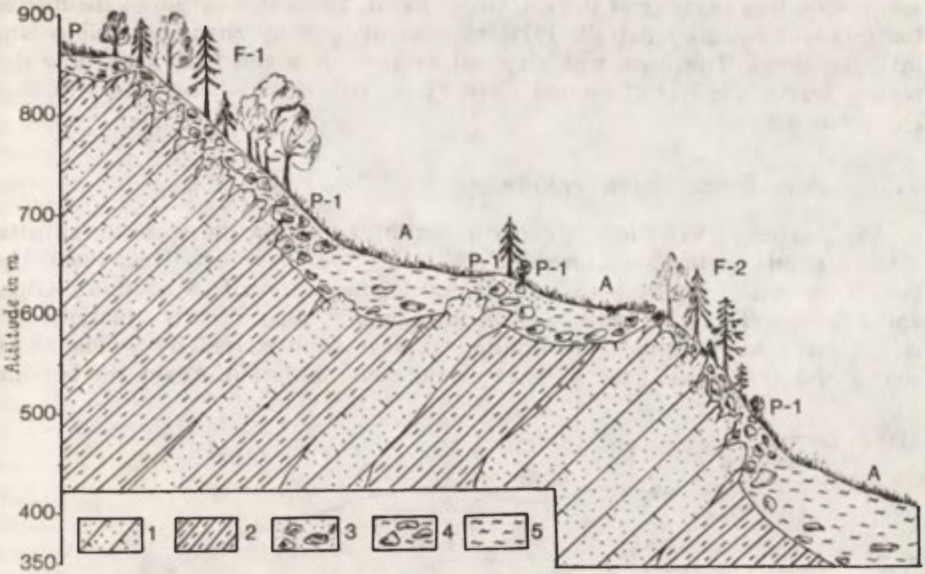

Fig. 3. Lithological conditioning of surface relief, soil cover and mode of land use in the Flysch Carpathians

1 — thick-bedded sandstones (medium- and coarse-grained), 2 — clay shales (sometimes marly), 3 — sandy-stony podzolic or cryptopodzolic or podzolised brown soils, 4 — loamy-stony leached brown soils, 5 — loamy or loamy-clayey leached brown and weakly leached brown soils (locally loamy-clayey pararendzinas), often gleyed at the bottom; A — arable land or greenland, F-1 — mesophilous fir-beech forests (*Fagetum carpaticum*), F-2 — acidophilous-mesophilous mixed deciduous or coniferous forests (*Luzulo-Fagetum, Abieti-Piceetum, Pino-Quercetum*), P — alpine greenland communities approaching association *Hieracio-Nardetum*, P-1 — post-agricultural or pasture waste land with plant cover approaching *Hieracio-Nardetum* or *Calluno-Nardetum*

pathians. Up to an altitude of about 1100 (1150) m there is often a lithologically conditioned azonality of soils and environments (Adamczyk 1962, 1966). A mosaic-like azonal distribution of agricultural and forest land in the Polish Carpathians is a natural phenomenon. Coniferous forest environments occur not only in the upper forest zone but also in the lower forest and foothill zones on soils originating from nutrient-poor rock substrates (Adamczyk 1966; Adamczyk et al. 1973). A similar inversion of the quality of soils and environments is found within the range of agricultural land.

The sandy-stony soils and the loamy-stony ones usually contain about 50–80% skeleton and occupy sites unfavourable to agricultural use (Table 4, item I) and are therefore suitable only as forest land. Poor drainage also limits the possibilities of obtaining greenland of good quality on such soils. However, this variant of the soil cover, and especially the sandy-stony soils, fulfils an important hydrological function in the renewal of deep water reservoirs (among others of mineral waters) and deserves special protection.

Better conditions for agricultural use are created by variants of loamy-fine--sandy and loamy-clay soils (Table 4, items II and III). They contain much less skeleton and are characterized by a greater stability of moisture content; moreover, they occur in more advantageous situations; however, arable land should be restricted to areas of soils with an infiltration-retention type of water regime (Table 4, item II), while gleyed soils with features of excess moisture (Table 4, item III) should be grassed over. Drainage by tiles or ditches, often applied by agriculturists, partly helps to improve the productive quality of too wet soils, but at the same time and to a greater degree it contributes to an all-over decrease in retention capacity of the catchment basin. The water surpluses mentioned for this soil category (Slupik 1973) may be utilized by changing arable land into greenland. The loam and clay soil areas with a retention type of water regime screen the loss of ground waters from rubble-and-stone covers in such environments.

VARIATION IN MESOCLIMATIC CONDITIONS

The degree of variation in climatic conditions within the separate climatic zones depends on the basic forms of relief and slope exposure (Hess 1969). The best temperature conditions for plant development prevail on southern slopes and hill tops (Table 5), while — when introducing crops in such situations — it is necessary to remember the limiting of vegetation caused by winds which change the conditions of the snow cover and cause deflation. Again, the bottoms

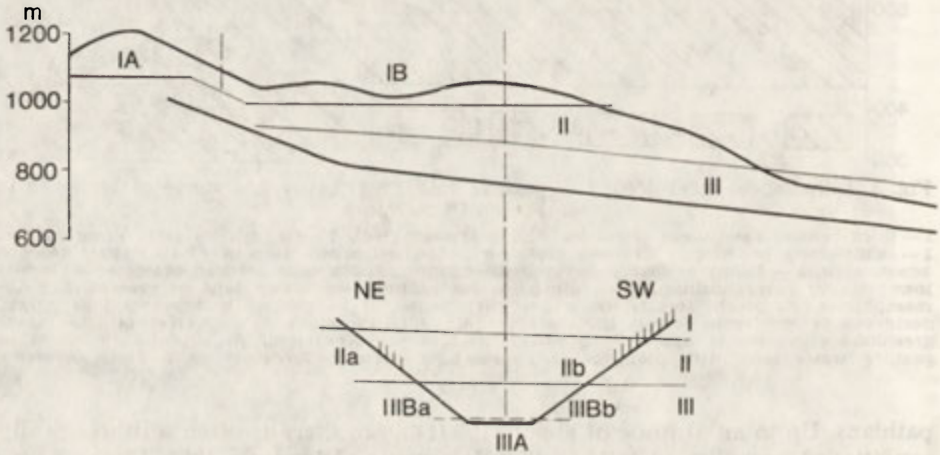

Fig. 4. Schematic distribution of mesoclimatic regions and subregions as well as microclimatic regions in valleys on the southern slopes of the Gorce Mts. — in a transverse and longitudinal section (after Obrębska-Starkel 1969)
Explanation of mesoclimatic units in the text

of valleys and basins are characterized by considerable contrasts of thermic conditions as well as those of air moisture owing to inversion-type stratification developing in the night and strong heating during the day. From investigations in model areas, the following typological units of mesoclimate were observed in the Carpathians (Obrębska-Starkel 1969, 1973):

I. The mesoclimate of valley depressions with the greatest temperature-humidity gradients. In the foothills and the low mountains the vertical range of this unit is 40–60 m above the valley bottom, in medium high mountains up to 80 m. The mean annual difference in minimum temperature amounts to 2° in this layer, which corresponds to differentiation in the number of days with slight frost of the order of 25 days, and in the length of the frostless period 30–50 days. This is the place of the most frequent occurrence of radiational fogs. The following types of mesoclimate were discerned:

Ia — the coolest valley bottoms up to relative altitude of 5 m in the foothills and 20 m in the mountains, with the greatest contrast in character of temperature-humidity conditions;

Ib — terraces in the medium high and lower parts of slopes with relative altitude between 5 and 20 m;

Ic — valley slopes, distinctly warmer and drier in the night, in an interval of relative altitude between 20 and 80 m in medium high mountains.

II. Mesoclimate of slopes and hill tops with optima temperature-humidity conditions, mostly at altitudes exceeding 40–60 m above the bottom of valleys in foothills, plateaux and low mountains, also between about 80 and 300–400 m above valley bottoms in medium high mountains. In the range of this mesoclimatic unit there occurs most often the upper limit of inversion of minimum temperature.

III. Cooler mesoclimate of ridges and summits as well as slopes in low and medium high mountains, situated more than 300–400 m above the valley bottoms and out of range of the influence of local circulation of air in the valleys. The values of temperature and humidity of air change here are depend on the altitude.

The most advantageous conditions for the vegetation of crop plants exist in the range of mesoclimate type II, i.e. in the so-called warm belt on the slope. However, the capability value of a given type of mesoclimate should be considered against a background of zonal macroclimatic differentiation. For instance, on valley bottoms in the moderately warm zone (altitude 250–400 m) it is still possible to grow frost-resistant plant species, while in the moderately cool zone (above 400 m) the valley bottoms are suitable only for meadows and pastures.

TABLE 5. Relations between mean yearly temperature (*tr*) and yearly values of some elements and indices of the climate in the Polish Carpathians on convex (1) and concave (2) surface forms as well as on slopes with northern (3) and southern (4) exposition

tr (°C)	Lenght of vegetation period, days				Length of period without slight-frost days				Number of days with snow cover			
	1	2	3	4	1	2	3	4	1	2	3	4
2°	147	145	145	153	111	103	109	114	189	196	192	185
4°	169	169	167	174	135	116	126	133	148	154	151	142
6°	192	191	190	195	159	128	144	144	106	112	110	99
8°	215	217	212	216	183	141	161	161	65	71	68	56

Notice: The above values were calculated after the equations of linear regression drawn up by M. Hess (1969) The vegetation period represents a period with a mean daily temperature >5°C.

The differentiation of microclimatic conditions connected with a different time and intensity of insolation on slopes varying in exposition and inclination as well as the differentiated morphometric and morphographic features of valleys (e.g., the width and depth of valley incision, conditioning the degree of shadiness) have effect on considerable local differences in the length of the frostless period, the frequency of slight frost, and the duration of the thermic seasons. This differentiation should be taken into account when determining the agriculture–forest limit in concrete field conditions (Table 5).

CONCLUSIONS

A review of the natural elements which in the mountains determine the vertical and spatial range of agricultural land use, and separately arable land and greenland, indicates that there exists in the Carpathians a general zonal system, conditioned by the climate and stressed by the zonality of the surface relief, but at the same time the boundary of a zone of utilization may be so much modified by azonal elements (slope angle, stoniness, soil water regime, and meso- and microclimate), that an altitudinal inversion of types of land use is a frequent phenomenon — and this makes it nearly impossible to draw a linear agriculture–forest limit.

The zonality of the climate determines an approximate range of rentability of arable land which on slopes and hill tops may reach about 650–700 m altitude (locally somewhat higher) on southern slopes, and only up to 450–500 m altitude (Fig. 1) in valley bottoms with a shorter ground-frost-less period. Greenland may range even higher than the forest limit.

The boundaries of the relief types (Figs. 1, 2) — because of a prevalent proportion of steep slopes and the fact that mountain areas reach into the cooler climatic zones — determine the essential limits of areas with prevailing forestry (the mountain relief types) and prevailing agriculture (foothill and valley bottom relief types).

The steepness of slopes, the quality of soils, and the intensity of soil erosion connected with it determine the possibility and rentability of tillage and cropping. Arable land in the mountains should be on slopes not exceeding an angle of 11° (20%) which is in accord with the range of tractor-traction. Again, greenland may be cultivated on slopes up to an angle of 20–22°. At the same time, flat areas with a retention type of water regime, with gleyed soils on slope flattenings and in the bottom of depressions should be excluded from arable utilization.

The protection from soil erosion and from floods in the Carpathians, as well as the latter's function as a water reservoir, compels one to observe not only the rules indicated above but even to lower the postulated limits of agricultural land, and especially those of arable land (Starkel 1972). This is why areas at altitudes exceeding 700 m and inclined at more than 10° (and not 11°) should be devoted exclusively to forests and greenland. At the same time, melioration measures consisting of an acceleration of water flow-off should be abandoned.

Thus, the problem of the agriculture–forest limit cannot be solved by determining a hypsometric limit between agricultural and forestal land use, but by a rational management of areas situated at altitudes about 500–800 m. The variation of environments as to soils, climate, and hydrology in this zone is determined by the conditions of lithology and surface relief. The productivity value of environments therefore determines the local course of the agriculture–forest limit in the mountains, creating most often a mosaic-like pattern.

The spatial distribution of environments in a particular Carpathian region is determined by the type of surface relief and its components: the steepness of slopes, the depth and density of their dismembering, a compact or isolated system of mountain ridges. Therefore, when postulating a change in land use in the mountains and a general lowering of the vertical range of arable land, it is necessary to remember that there are two stages of assessing the problem: on a general scale (based on the relief type and climatic zonality) and in detail (considering azonal elements and their effect on the occurrence of enclaves on both sides of the theoretical boundary).

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THE INFLUENCE OF THE VERTICAL AND LONGITUDINAL CLIMATIC DIFFERENCES IN SOUTH POLAND UPON THE REGIONAL PATTERN OF PHENOLOGICAL UNITS

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INTRODUCTION. AIM OF THE STUDY

It is well-known that plants respond to their environment and some species are particularly susceptible to the influence of climate. The question arises, what kind of conditions should be fulfilled by phenological data in order for them to provide a quantitative and qualitative evaluation of the climate.

The plants observed by phenologists belong to species commonly known and wide-spread, but not much diversified as to sub-species. For macro- and mesoclimatic purposes phenology investigates the recurrence of some periods in the plants' evolution cycle (e.g., leafing, flowering, earing etc.). These phases sometimes reveal a selectivity in the plants' reaction to the intensity of some climatic element, which facilitates the specification of quantitative relations between the phenological and climatic phenomena. The dates of the beginning of stages and the duration of cycles in the wild and cultivated plants' development are numerical indicators of the seasonal climatic structure. They appear in an unvarying succession in the course of each year in a given locality and determine the phenological structure typical of the same. Thus the measures of scatter of dates of the phenological stages are indicators of the climate's variability over a period of many years. In order to assess the climate's influence on phenological phenomena in a given region an estimate of the phenological régime's * characteristics is made from a knowledge of regularities in the formation of relations between natural phenomena recurring in a rhythmic and cyclic manner.

The aim of this paper is to find connections between the climatic conditions and the rhythm of the seasonal plant development in the upper Vistula basin. Owing to the vastness of this area stretching from west to east, and to its varied relief, the dominating feature of the phenological phenomena is its differentiation in the west-east cross-section and, above all, in the vertical profile. Therefore particular stress has been laid in this paper on specifying the role of the geographical coordinates (altitude, latitude and longitude) and of climatic elements in shaping the phenological régime of the particular physiographical units.

* The phenological régime is the entity of phenological phenomena in a given place or region, characterized by particular dynamics of development in the growing season and by periodicity exhibited over a period of years.

EARLIER ATTEMPTS AT THE APPLICATION OF PHENOLOGICAL AND PHENODYNAMICAL INDICES IN REGIONAL CLIMATIC RESEARCH

The majority of macroscale climatic studies based on phenological methods have referred to lowlands, for which the spatial variability of the phenological régime is less marked, as compared with highlands. Typological criteria in these regional studies include the dates of the beginning of phenological stages of chosen plants, e.g. apple-trees, ciltivated corns (Schnelle 1949, 1955), or of groups of plants (Pfau 1964; Dickel 1966; Kurpelowá 1969, 1976; Seyfert 1970), making use of synchronization of dates of the same stage of a given plant in various places, or of several plants in the same locality. The extent to which the main typological species are representative of the variation in the macroclimate is determined on the basis of the results of macroscale ecological studies (e.g., Ellenberg's paper 1974).

The most recent papers which aim at constructing models describe the dependence of the dates of phenological stages on the geographical latitude and longitude and on the height above sea level, by the help of equations of linear and multiple regression (Lausi and Pignatti 1973; Anderson 1974; Flint 1974; Kurpelová 1976; Bednarek and Lech 1975; Obrębska-Starklowa 1977). Simple methods of mathematical statistics are also applied in the determination of relations between phenological phenomena and climatic elements (Caprio 1974; Molga 1967; Pieslak 1967; Reader et al. 1974; Kielchevskaya 1975; Kurpelová 1976; Obrębska-Starklowa 1977). The aim of such a modelling is to explain the control mechanism affecting the endogeneous temporal rhythm in the development of plants.

The results of investigations by both these methods are applied in phenological and agroclimatic forecasting. This is based on the existence of links between the times of the plants' development in the early stages of vegetation and the beginning of events in later seasons (Shigolev 1957; Pfau 1964; Anderson 1974; Kielchevskaya 1975; Obrębska-Starklowa 1977), which links can also be described by correlation methods. All the methods referred to above for showing the dependence of phenological phenomena on abiotic factors, as well as the temporal relations between the phenological phases should be taken into account in the characterization of the phenological régimes of mountains and uplands.

CHARACTERISTICS OF THE AREA EXAMINED

The river basin of the upper Vistula is typical of the climatic and phenological conditions of highlands in the zone of moderate transitional climate. Its area amounts to about 50,000 km² and its altitude ranges from 160 to 2663 m. The distribution of morphological provinces runs west-east. Furthest advanced to the north are the Uplands of Silesia and Małopolska (from 200 to 500 m a.s.l.) and Lublin-Wołyń Uplands (from 200 to 400 m a.s.l.). They are separated from the Carpathian chain by the zone of Subcarpathian Basins comprising the Racibórz-Oświęcim Basin and the Sandomierz Basin (from 160 to 250–320 m a.s.l.). The region in the Polish Carpathians dealt with in the present paper only reaches a height of 1100 m a.s.l., i.e. it consists of Carpathian Foothills of an upland relief (height of ridges 300–500 m a.s.l.) and of the Beskids ranges with a medium-and low mountain relief (ridges at a height of 900–1700 m). The higher groups of the Beskids are concentrated to the west of the meridian 21° λE.

According to M. Hess (1965) the climate of the part of the Vistula basin under review is a pluvio-nival one within the moderately warm and moderately cold climatic vertical zones. The yearly mean air temperature ranges from over 8° to 4° C. The position of the limiting yearly isotherm of 6° between the said climatic vertical zones becomes lower by about 50 m, when progressing from the western to the eastern end of the river basin.

The soils of the upper Vistula basin possess a sufficient amount of water usable for plants (Molga 1969). The changes in length of day and in light intensity resulting from differences in geographical latitude are minimal here. Therefore it is heat that constitutes the main ecological factor conditioning the development of wild and cultivated plants. It undergoes large quantitative changes in the vertical profile depending on the height a.s.l. This became obvious in the typology of climate conditions of Polish West Carpathians elaborated by Hess (1965, 1969). The latter author has shown that the variability of climate in the vertical profile can be represented by means of changes in the yearly mean air temperature with height a.s.l., because it is just this element which is connected by simple statistical correlations with many values of the elements and indices of the climate.

Also in this paper much attention has been paid to the role of thermal conditions in the shaping of phenological phenomena. In zones with a moderate climate and sufficient humidity, it is the heat which forms the factor deciding upon the rate of development and the amount of plant crops (Schnelle 1955; Heyer 1975).

MATERIAL AND METHOD

The material used in the present study consisted of phenological records of the state meteorological service for the years 1946–1965 concerning 63 stages from 26 species of native and cultivated plants. In all, the records at 268 locations for a twenty-year period were collected. The initial data required careful checking and it was necessary to fill in gaps, by using correlation graphs. Observations made at locations in similar relief categories were compared with one another.

Considering that in the region discussed the dispersion of dates in the particular series is affected not only by the climate, but also by other factors of the geographical environment, the independence test χ^2 was applied to the frequency distribution of dates of the particular events. The test was applied to samples of equal size from locations belonging to various morphological mesoregions. It was found that in the vast majority of cases the data discussed belonged to populations possessing a distribution similar to the standard one.

The series with highly skewed distributions, where the dispersion of dates could have arisen from variety differences, local environmental differentiation or observation errors were ignored in later stages of the study. The application of the independence test χ^2 proves that the mean dates of phenological events, the standard deviations from the means and the extreme dates computed for the particular localities are representative of the peculiarities of phenological régime in these sites.

Using the mean values the coefficients of correlation between the dates of the beginning of the individual events and the height above sea level, the annual mean temperature, the temperatures of spring months, as well as the dates of the daily mean temperature's crossing the one-degree thresholds were calculated. Special attention was paid to intercorrelations between the dates of beginning of phenological phases in the time interval from the beginning of hazel blossoming up to completion of the leaves falling from the trees. On the whole, 49 events were analysed in this manner. In the analysis also timing of meteorological phenomena of importance to vegetation, such as for example the disappearance of snow cover, were taken into account. Absolute values of correlation coefficients exceeding 0.55 were accepted as being significant according to Student's *t* distribution.

As the last stage of the work a typology and regionalization of phenological-climatic conditions was carried out on the basis of leading indicators and phenological periods revealing the greatest number of statistically significant relations with the parameters of situation, with climatic elements and with the dates of other phenological events. This regionalization is represented in a map with a working scale 1:500,000.

REGIONAL VARIATION OF THE PHENOLOGICAL RÉGIME IN THE UPPER VISTULA BASIN RESULTING FROM PARAMETERS OF GEOGRAPHICAL SITUATION

The intricate relations in the climate–plant system require a specification of the role of the primary climatic factors in the regional variation of phenological régime. This problem can be illustrated by means of shifting of the mean dates of events per 1° of the geographical latitude and longitude and per 100 m of height a.s.l.

An attempt to define the correlation between phenological phases and geographical latitude in the upper Vistula basin failed, because of the small extension of the basin from south to north and of the configuration of the relief's basic units. In the Polish Carpathians more vast basins possessing a climate of a more extreme character are found in the southern part, at the foot of high or medium-high mountains. As we pass northward the basins become more and more shallow, revealing a lesser contrast of values of elements of the climate. Thus, the dates of the individual events in cross-section from north to south display a considerable variability and irregularity (in spite of their being reduced to a fixed altitude).

However, the data concerning plant development proved that the character of the atmospheric circulation in the particular seasons changes with geographical longitude. This is illustrated by the following indices: duration of growing season and of vegetative periods and intervals between individual stages for basic corns, for which gradients per 1° of geographical longitude λ were calculated at a specified mean height a.s.l. on a given parallel (Table 1). These values represent foothills, basins and uplands. Thus, for example, the shortening of the whole growing season is most rapid in subcarpathian basins (−4.4 days/1° λ).

Figure 1 illustrates the differences in the duration of growing seasons in the vertical profile of the Carpathians in locations situated along 19° and 22°30′ λE. In eastern part of the Carpathians it is striking that — besides a general shortening of the growing season — the several development stages (i.e. from the beginning of winter-rye flowering) occur earlier, as compared with the western part. This may be explained by seasonal changes in the dominating direction of air-masses advection, which is decisive for the differentiation of thermal conditions and, in turn, exerts its influence upon the direction of the progress of phenological seasons.

TABLE 1. Mean horizontal gradients of the duration of some chosen phenological periods and the scope of changes in the dates of the phenological phenomena per unit of the geographical longitude (1°λ)

Phenological phenomenon or period	Phenological gradients in days		
	49°30′ φ N 400 m a.s.l.	50°00′ φ N 200 m s.a.l.	50°45′ φ N 250 m a.s.l.
Period from germination to earing of oats	−0.8	−2.7	−2.4
Period from earing to harvest of oats	−4.3	−3.8	−2.0
Period from germination to earing of spring barley	−3.3	−2.4	−1.8
Period from earing to harvest of spring barley	−3.5	−2.1	−1.4
Vegetative period of spring barley	−4.4	−5.0	−3.4
Start of sowing of winter-rye	−3.2	−2.1	−0.4
Beginning of blossoming of winter-rye	−1.8	−1.8	0.0
Beginning of harvest of winter-rye	−2.0	−2.9	−2.3
Vegetative period of winter-rye	−1.9	−2.8	−3.9
Duration of phenological growing season	−3.6	−4.4	−3.0

Note: The sign "−" denotes the shortening of the period with the increasing geographical longitude, i.e. the earlier course of the phenomena in the eastern than in the western part of the upper Vistula river basin.

The west-east pattern of morphological units in the river basin examined facilitates the air flow along the parallel axis. However, in the course of a year the influence of the maritime and continental climate is exerted with varying intensity. Thus, the average gradients of air temperature in particular months of the growing season reveal considerable differences. This gradient assumes its maximum value $-0.3°/1° \lambda$ in March and, as a result, there is a difference in the dates of the beginning of the growing season amounting to 15 days between the western and eastern ends of the river basin. In April and May there occurs a change in the dominating direction of the air-masses advection from SW and W to NW and N (Niedźwiedź 1976). The continental and maritime influences of the climate upon the area discussed are then in equilibrium. This is shown by the fact that the increase of the mean monthly temperatures amounts almost to zero ($0.02°/1° \lambda$ for April and $0.04°/1° \lambda$ May) and in the whole west-east cross-section the phases of full spring and early summer, such as, e.g., leafing and blossoming of blackthorn *Prunus spinosa*, of horse chestnut *Aesculus hippocastanum*, earing of winter-rye *Secale cereale*, occur simultaneously.

The mean air temperatures in July and August are higher in the eastern part than in the western (gradients: $0.1°/1° \lambda$ and $0.06°/1° \lambda$ respectively), and the monthly precipitation totals are lower. This results in decreased cloudiness, higher frequency of clear days, and higher totals of the duration of sunshine. All these factors bring about an earlier ripening of winter- and spring corns by 2–2.5 days per 1° of geographical longitude when moving from west to east.

The above features of the phenological régime in the west-east cross-section of the upper Vistula basin give evidence of an opposition between oceanic- and continental influences in this area. In defining the border between the regions under oceanic influence and those under increasing continental influences it may be helpful to use the phenomenon of interception of the average dates of blossoming of locust *Robinia pseudacacia* and elder *Sambucus nigra* (Fig. 1).

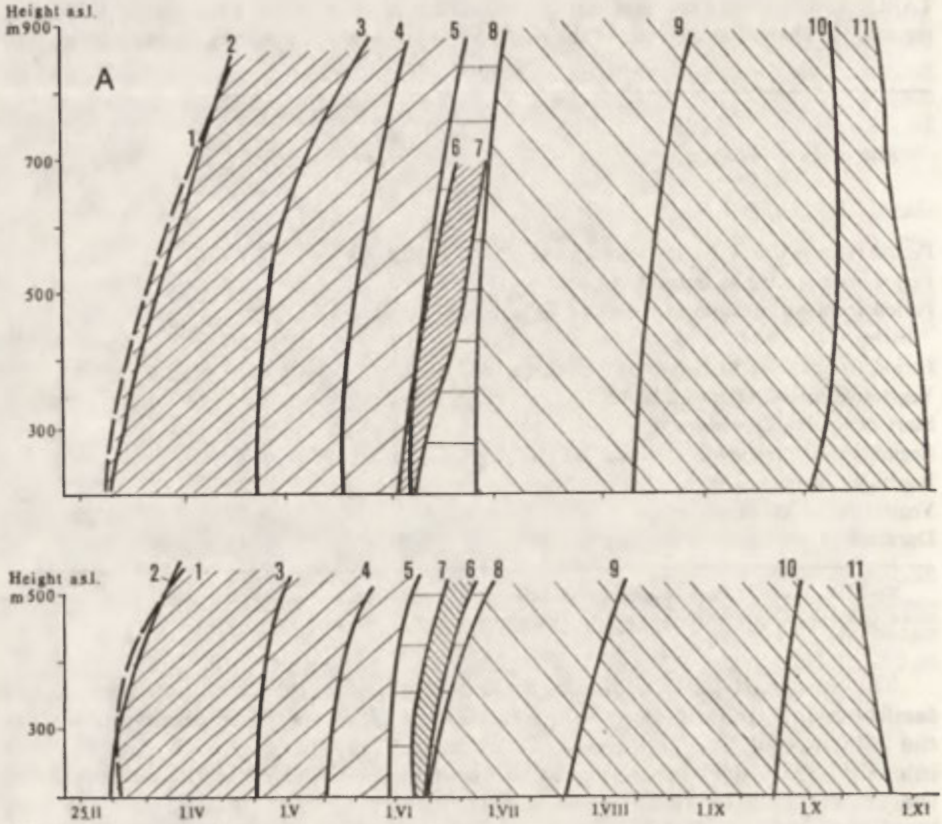

Fig. 1. Characteristics of the phenological growing season in the upper Vistula river basin: A — at meridian of 19° λE, B — at meridian 22°30′ λE

Lines show following stages: 1 — full disappearing of snow cover, 2 — beginning of blossoming of hazel *Corylus avellana*, 3 — beginning of germination of spring barley *Hordeum distichum*, 4 — beginning of blossoming of horse chestnut *Aesculus hippocastanum*, 5 — beginning of blossoming of winter-rye *Secale cereale*, 6 — beginning of blossoming of elder *Sambucus nigra*, 7 — beginning of blossoming of locust *Robinia pseudacacia*, 8 — beginning of earing of spring barley, 9 — beginning of harvesting of spring barley, 10 — beginning of germination of winter-rye, 11 — end of phenological growing season

Note: Beginning of the phenological growing season has been calculated as arithmetic means of the dates on which the first female flowers of the hazel appear and of the beginning of the first spring field works. The end of this season has been determined as the mean arithmetic date of the full leaves falling of the horse chestnut and birch *Betula verrucosa*

N. P. Smirnov has shown (cf. Schnelle 1955) that an earlier blossoming of locust in comparison to elder betrays a more continental climate. This was confirmed by Ellenberg (1974), who has found that locust is connected with a more continental climate. The reverse order of blossoming is a proof of influence of an oceanic character. The isoline of simultaneous beginning of the two events divides the upper Vistula basin into two phenological-climatic scopes within the transitional type of moderate climate (Fig. 2). This border line is consistent with the results of earlier researches concerning the thermal continentality in Poland (Zinkiewicz 1962; Okołowicz 1968; Lesko 1971; Huculak 1973). It runs along the western border of the transversal lowering in the Carpathian chain represented by Low Beskids, which favours more frequent advection of air masses from the south.

The most important factor differentiating the phenological conditions in the area discussed is the height above sea level. The vertical zonality of the phenological régime depends on the vertical climatic differentiation and it is typical of the both western and eastern scope. Table 2 gives examples of the correlation coefficients *r* for the dependence of timing of chosen phenological phases and of the duration of phenological periods at a height above sea level in the central portion of the river basin. These coefficients are particularly high for plants in the flowering- and leafing stages and for corns in those of flowering and earing. The average upward shifting of dates of the phenological stages' beginning ranges from 2 to 3 days/100 m. Thus, for example, knowing the height a.s.l. (*H*) of a given place, one can compute the mean date of leafing of small-leaved lime--tree *Tilia parvifolia* (*y*) with an accuracy ± days using the following equation of straight-line regression:

$$y = 0.03\ H + 113.3 \qquad r = 0.755.$$

The correlation is significant at the level of 0.1% according to Student's *t* test. The value of the unknown (*y*) is determined by the number of the consecutive day from the beginning of the year.

There is also an essential relation between the altitude and the duration of the phenological growing season ($r = -0.704$), of the winter-rye's vegetative period ($r = 0.853$) or of that of spring barley ($r = 0.670$). The duration of the growing season varies in the river basin's vertical profile from 220 days in subcarpathian basins to below 190 days at the altitude of 1100 m.

RELATION BETWEEN PHENOLOGICAL CHARACTERISTICS AND ELEMENTS OF THE CLIMATE

The relation between phenological phenomena and thermal characteristics is most marked in the vertical profile of the area discussed. The matrix of correlation (Table 2) reveals a high significance of this relation for the mean dates of many phenological stages and for the duration of phenological periods. This fact can be useful in practice in a twofold manner. Namely, if the yearly mean temperature of a given place is known, the characteristics of the phenological régime can be represented on the basis of equations of straight-line regression such as given in Table 3. Or else, if the mean date of a phenological event is known, the yearly mean air temperature of the given place in the river-basin's vertical profile can be determined and, in this manner, the position of that place in the pattern of vertical climatic zones can be estimated, referring to Hess' typology of the Carpathian climate. As can be seen from the correlation coefficients in Table 2, the phenological data can also serve as a basis for computing the monthly mean temperatures from March to June and the duration of thermal seasons, in which the daily mean temperature exceeds 5° and 10°.

The relationships described above permit the acceptance of the yearly mean air temperature as a criterion showing the limits also for the vertical phenological zones of the river basin. Moreover, strict interdependencies between phenological conditions and climate justify the introduction of the conception of a phenological-climatic régime. Because the periodical course of events with plants illustrates the character of climatic conditions in a given region, the mean dates of the particular phenological stages reveal most essential relations with the crossing of one-degree thesholds by the daily mean air temperature (correlation coefficients higher than 0.8). This enables the differentiation of thermal conditions in the vertical profiles of mountains and uplands to be reproduced with high accuracy in the period of vernal increase of the air temperature. The most useful for this purpose are the stages with wild and cultivated plants occuring in the period from early spring up to high summer.

TABLE 2. Correlation matrix of some mean phenological dates and periods with the height a.s.l. and some climatic elements in the central part of the Polish Carpathian Mts.

Phenological phenomena		Altitude (m)	a *Secale cereale*	b *Secale cereale*	b *Avena sativa*	b *Aesculus hippocastanum*	b *Syringa vulgaris*	b *Prunus spinosa*	b *Robinia pseudacacia*	Phenological growing season	a–b interval *Secale cereale*	a–h interval *Secale cereale*	Vegetative period *Secale cereale*	g–a interval *Avena sativa*	a–h interval *Avena sativa*	Vegetative period *Avena sativa*	g–a *Hordeum distichum*	a–h *Hordeum distichum*	Vegetative period *Hordeum distichum*	Mean temperature of March	Mean temperature of April	Mean temperature of May	Mean temperature of June	Mean annual air temperature	Period with daily temp. ≥ 5°	Period with daily temp. ≥ 10°
Altitude (m)			93	94	91	91	82	85	92	−70	50	54	85	33	12	55	17	52	67	−94	−98	−99	−99	−98	−86	−97
Secale cereale	a			93	88	89	79	83	96	−67	35	45	82	22	14	42	26	51	65	−92	−91	−90	−92	−93	−84	−94
Secale cereale	b				80	89	76	88	90	−67	48	48	84	18	30	56	89	60	69	−90	−93	−93	−93	−93	−86	−93
Avena sativa	b					88	79	74	89	−72	38	48	77	51	−14	39	32	35	52	−84	−90	−90	−90	−88	−81	−91
Aesculus hippocastanum	b						79	87	90	−60	40	45	82	29	12	52	24	41	61	−85	−89	−89	−90	−90	−78	−88
Syringa vulgaris	b							80	87	−58	46	70	83	25	22	33	19	41	59	−82	−88	−88	−88	−88	−82	−88
Prunus spinosa	b								83	−53	44	50	83	12	21	45	10	45	61	−85	−87	−87	−87	−88	−70	−82
Robinia pseudacacia	b									−64	48	60	86	23	16	47	20	57	70	−87	−93	−92	−94	−94	−86	−96
Phenological growing season											−44	−47	−63	−19	01	−23	04	−40	−37	69	70	70	69	69	83	68
Secale cereale — interval	a–b											59	57	10	27	41	−26	55	15	59	−50	−52	−51	−46	−26	−47
Secale cereale — interval	a–h												76	17	25	47	−14	66	59	−59	−70	−67	−60	−59	−51	−59
Secale cereale vegetative period														21	31	57	33	64	66	−89	−87	−87	−87	−89	−73	−84
Avena sativa — interval	g–a														−54	32	56	−14	19	−27	−30	−31	−32	−28	−25	−35

Avena sativa — interval a–h		52	−27	77	53	−10	−11	−11	−10	−11	−95	−91
Avena sativa vegetative period			11	66	74	−44	−51	−54	−52	−51	−44	−51
Hordeum distichum — interval g–a				−17	29	−14	−14	−14	−14	−14	−17	−23
Hordeum distichum — interval a–h					82	−46	−52	−52	−51	−48	−48	−54
Hordeum distichum vegetative period						−59	−67	−69	−66	−65	−61	−70
Mean temperature of March							93	93	93	97	82	90
Mean temperature of April								99	99	99	89	97
Mean temperature of May									99	99	89	97
Mean temperature of June										99	90	98
Mean annual air temperature											88	97
Period with daily temperature ≥5°												93
Period with daily temperature ≥10°												

Note 1. Abbreviations: a — heading, b — blossoming, h — harvest, g — germination, interval — interval of time between two phenological stages.

Note 2. The correlation coefficients are given in the form of r × 100. The coefficients, the absolute values of which exceed 0.55, are significant at the level 0.1% according to Student's *t* — distribution.

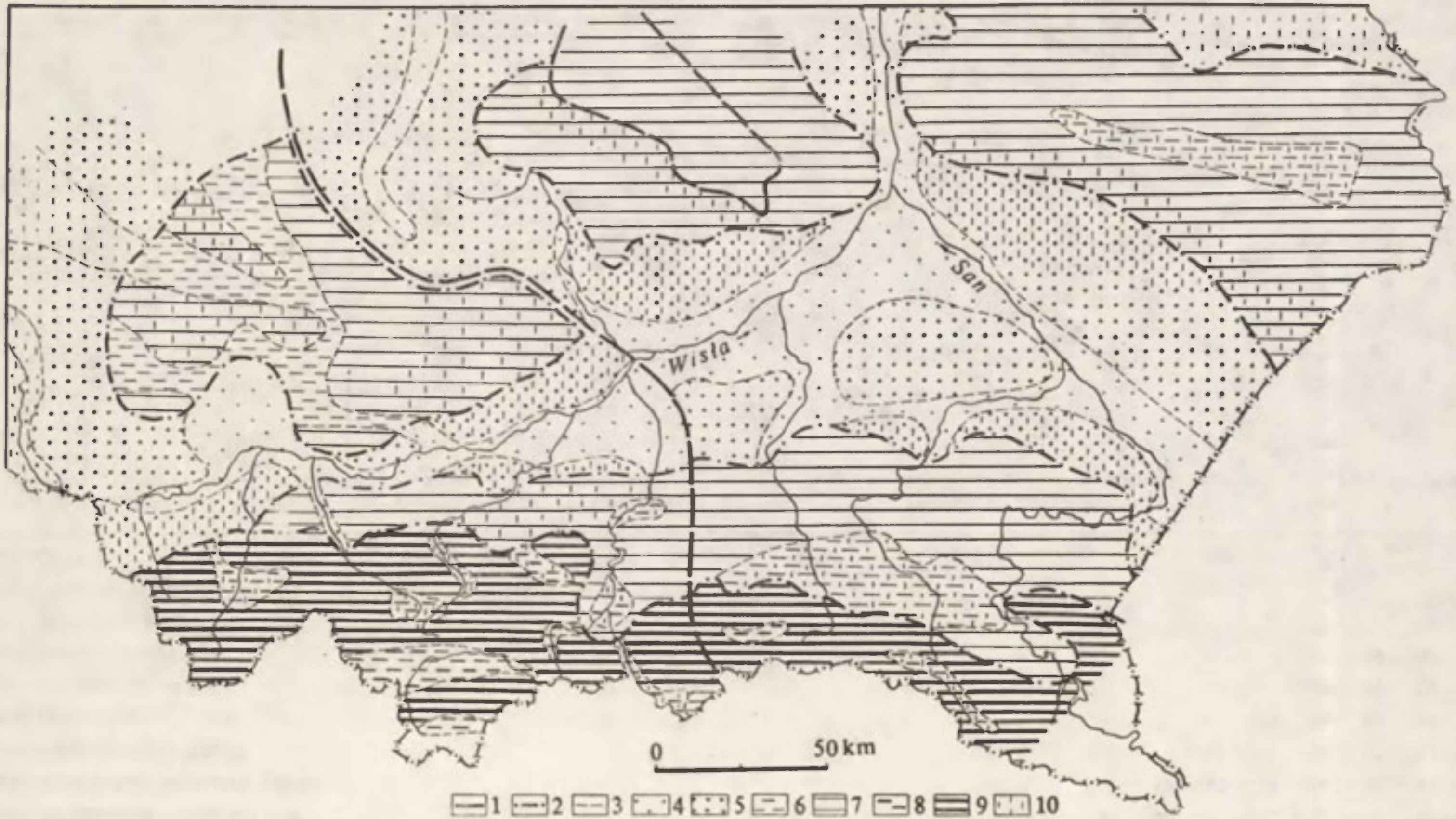

Fig. 2. Differentiation of the phenological climatic conditions in the upper Vistula river basin

1 — boundary between the area influenced by the maritime climate and that with an increasing influence of the continental climate, 2 — limits of phenological-climatic vertical zones, 3 — boundaries between the regions with different phenological-climatic régimes within the phenological-climatic vertical zones; 4-9 — types of phenological mesoclimatic régimes in: 4 — valley bottoms, within cold reservoirs in the warm vertical zone, 5 — small ridges within the subcarpathian basins in the warm vertical zone, showing differences in the course of plant development, depending on the thermal and water conditions of soils, 6 — lowerings and basins in the temperate warm vertical zone, 7 — upland regions in the temperate warm vertical zone, 8 — lowerings and basins in the temperate cool vertical zone, 9 — low and medium-high mountains in the temperate cool vertical zone; 10 — regions with an accelerated course of plant development within the given vertical zone

TABLE 3. Dependence of the beginning of phenological stages in wild and cultivated plants (y) and duration of some chosen phenological periods (y') on mean annual air temperature (t) in upper Vistula river basin

Parameter y (y')	Equation of linear regression	r	$\pm S$ (in days)	Significance level of correlation (%)
Earing of winter-rye	$y = 177.7-5.78\ t_r$	−0.934	1.1	0.1
Blossoming of winter-rye	$y = 195.3-5.94\ t_r$	−0.933	1.2	0.1
Earing of oats	$y = 216.9-5.20\ t_r$	−0.888	2.1	0.1
Blossoming of horse chestnut	$y = 159.2-3.60\ t_r$	−0.901	1.1	0.1
Blossoming of lilac	$y = 170.2-5.20\ t_r$	−0.876	2.0	0.1
Blossoming of blackthorn	$y = 151.8-4.51\ t_r$	−0.879	1.7	0.1
Blossoming of locust	$y = 200.6-6.20\ t_r$	−0.933	1.2	0.1
Phenological growing season	$y' = 170.7+5.39\ t_r$	0.687	5.9	0.1
Winter-rye — interval a–h	$y' = 89.1-2.88\ t_r$	−0.591	4.5	0.1
Vegetative period of winter-rye	$y' = 358.6-6.94\ t_r$	−0.889	2.3	0.1
Vegetative period of oats	$y' = 138.0-1.85\ t_r$	−0.510	3.8	1.0
Spring barley — interval a–h	$y' = 70.0-3.07\ t_r$	−0.510	6.3	1.0
Vegetative period of spring barley	$y' = 140.6-3.54\ t_r$	−0.652	4.4	0.1

Note: Abbreviations as in the Table 2.
s — standard error of the estimation of unknown value (y)

TEMPORAL RELATIONS BETWEEN PHENOLOGICAL PHASES IN THE GROWING SEASON

The above considerations show that in the dates of beginning and in the duration of phenological phenomena the influence of climatic factors is coded, differentiating them in time and space. In years with a retarded beginning of vegetative activity and in places situated higher above sea level, or in those more advanced to the east the rate of plant development is accelerated and the duration of many intervals between the particular phases becomes shorter. In other years, earlier dates of the beginning of the growing season caused by some types of weather conditions produce reverse reactions in the rate of progress of the plants' development stages. Thus on the basis of the intercorrelation of many-year mean dates of events we may speak of a temporal connection between the occurrence of different phenological stages and the phenological periods. This is illustrated by the matrix of correlation for the central profile in the river basin (Table 2). The highest correlation coefficients were obtained for the beginning of phenological stages with small dispersion of dates occuring from early spring up to high summer. These are, first of all, the dates of beginning of leafing and blossoming of: blackthorn *Prunus spinosa*, horse chestnut *Aesculus hippocastanum*, small-leaved linden *Tilia parvifolia*, and of blossoming of lilac *Syringa vulgaris* and locust *Robinia pseudacacia*, of flowering and earing of winter-rye *Secale cereale*, as well as of earing of oats *Avena sativa* and spring barley *Hordeum distichum*. Somewhat lower correlation coefficients (0.55–0.7) with other phenological phases were obtained for the beginning of blossoming of maple *Acer platanoides* and elder *Sambucus nigra*.

They also have a smaller number of correlations with phenological phases of other species. The timing of the majority of stages here referred to coincides with the mean daily temperature included within an interval of the width of 1–1.5°. This confirmed the results obtained by Pfau (1964) and by Kielchevskaya (1975). Whereas the results of correlation of, for example, the beginning of hazel blossoming, or of sowing and germination of spring corns turned out to be insignificant ($r = 0.1–0.4$). The data of Table 2 show that on the basis of the mean dates of wild plants' blossoming it is possible to determine with high probability the duration of the phenological growing season, of the winter-rye's or spring barley's vegetation period, or else of some intervals between the individual stages in years not too much departing from the average weather conditions.

CHARACTERISTICS OF REGIONAL DIFFERENTIATION OF PHENOLOGICAL-CLIMATIC CONDITIONS IN SOUTH POLAND

In the determination of the phenological régime's characteristic such events with wild and cultivated plants were used as typological indicators, as revealed a great number of simple correlations with the geographical situation's parameters, with thermal features and with other plant development stages.

Taking into account the differentiation of the phenological régime's characteristics the area discussed (up to the altitude of 1100 m) was divided into a western and eastern phenological-climatic scope within the transitional climate of pluvionival type. The western scope bears the features of a more oceanic character, the eastern one in subject to increasing continental influence. Within these scopes three vertical climatic zones were distinguished, in which the phenological régime varies with height above sea level. These are: the warm vertical zone of lowlands and submontane basins, the moderately warm zone comprising Carpathian foothills and uplands of Middle Poland, and the moderately cool zone with a relief type of low and medium high mountains (Table 4, Fig. 2).

The phenological régime of the particular climatic vertical zones is inwardly differentiated in connection with the existence of large complexes of convex and concave forms. The influence of relief forms permitted the establishment of types of phenological-mesoclimatic régimes, e.g. escarpments of upland areas with an accelerated rate of vernal vegetative activity (Fig. 2).

CONCLUSIONS

1. The analysis of correlations between the dates of beginning of phenological phenomena and the parameters of geographical situation and elements of the climate has proved the existence of strict quantitative relations between the climatic conditions in highland and upland areas, and the rate of plant development. In areas with a diversified relief the phenological conditions are shaped under the influence of fundamental climate forming factors.

2. Phenological data have for climatologic researches not only a complementary character, i.e. they not only allow the missing values of the climatic elements to be inserted by the help of equations of regression linking the leading phenological indicators with the values of climatic elements. A great number of statistically significant relations with climatic elements makes it possible to elaborate a structurally uniform typology and phenological-climatic regionalization of areas with a diversified relief.

TABLE 4. Characteristics of some elements of the phenological-climatic regime in the upper Vistula river basin up to the height of 1100 m a.s.l. in two scopes: I — with more oceanic features, II — with increasing continental influence

Climatic vertical zone	Altitude (m)	Mean annual temperature (°C)	Phenological growing season (in days)	Phenological aspects
Temperate cool	from 600–700 up to 1100 m	6–4	below 200	Beginning of phenological growing season: 1 = 25 III–31 III; II = 25 III–5 IV Vegetative period of spring barley: I = above 120 days; II = 110–120 days Mean dates of winter-rye's harvesting: I = 5 VIII–12 VIII; II = 31 VII–7 VIII
Temperate warm	from 250–300 up to 600–700	8–6	210–200	Beginning of phenological growing season: I = 25 III–31 III (C,! U); II = before 31 III (C); 31 III–5 IV (U) Vegetative period of spring barley: I = 110–120 days (C), about 110 days (U); II = 110 days (C), locally 105–110 days (C); 100–110 days (U) Mean dates of winter-rye's harvesting: I = 20 VII–5 VIII (C); 20 VII–28 VII (U); II = 20 VII–31 VII (C); 15–25 VII (U)
Warm	up to 250–300	above 8	220–210	Beginning of phenological growing season: I = 20 III–31 III; II = about 31 III Vegetative period of spring barley: I = 110–120 days; II = 100–110 days Mean dates of winter-rye's harvesting: I = 15 VII–28 VII; II = 10 VII–15 VII

Abbreviations: C — Carpathians, U — Middle Polish Uplands.

3. As the guiding criteria in phenological-climatic typology such phenological stages were chosen, as reveal, besides the relations with parameters of geographical situation and climate, essential temporal relations with the timing of other phenological phases with wild and cultivated plants. They also have a prognostic significance because they allow one to forecast the duration of various phenological and thermal periods. These conditions are best fulfilled by species of tress and shrubs in the stages of leafing and blossoming and corns in their flowering and earing stages.

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GEOMORPHOLOGICAL EVIDENCE OF HOLOCENE CLIMATIC CHANGES IN NORTHERN MONGOLIA *

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Changes of climate which occurred in Central Asia during the Upper Quaternary, and the resultant geomorphological and sedimentological effects are only briefly mentioned in publications (Murzayeva et al., 1971; Ravskiy 1972; Gravis and Lisun 1974; Murzayeva et al. 1973). In the detailed consideration of events in both their regional distribution and their chronological order (paleogeographical aspect) many unresolved questions still remain. One of the problems is that of the changes of Holocene climate.

This paper provides a paleoclimatic interpretation of the results of both geomorphological and sedimentological research made in Northern Mongolia during three summers, 1976–1978. The areas of study were in the major valleys of the Selenga-Orkhon mountains of intermediate height.

THE STUDY AREA

The Selenga-Orkhon Mts lying in the borderland between the mountains of East Siberia and the plains of Central Asia (Aleksandrovskaya et al. 1964) join the higher Khentei Mts (2800 m a.s.l) with the Khubsugul Mts (3500 m a.s.l.; Fig. 1). During the Upper Tertiary and the Quaternary the Selenga-Orkhon Mts were affected by block-faulting (Schmidt 1974) which produced isolated mountain ranges (1400–2000 m a.s.l.) and wide intermontane depressions with floors lying at between 1000 m and 1200 m a.s.l. Because of the nearby base level, which is the level of Lake Baikal, the valleys of the rivers Selenga, Egiin-gol, Orkhon-gol and Khara-gol are deeply incised. Consequently, the relative relief is 500–700 m.

The area investigated experiences extreme continentality of climate and severe winters (Badarch 1971). The annual temperature averages from 0° to −2° C. The mean January temperature drops below −22° C, and the mean July temperature is between 16° and 18° C. In winter the anticyclone developed over interior Asia causes temperatures to fall below −50° C in the mountain-enclosed inland basins, but in summer air temperatures can rise above +30°C. Temperatures also vary widely between day and night. The area discussed receives 250–300 mm of precipitation per year. The maximum precipitation occurs in the summer, (June–August). The intense winter cold and the lack of a firm snow cover result in the development of discontinuous permafrost

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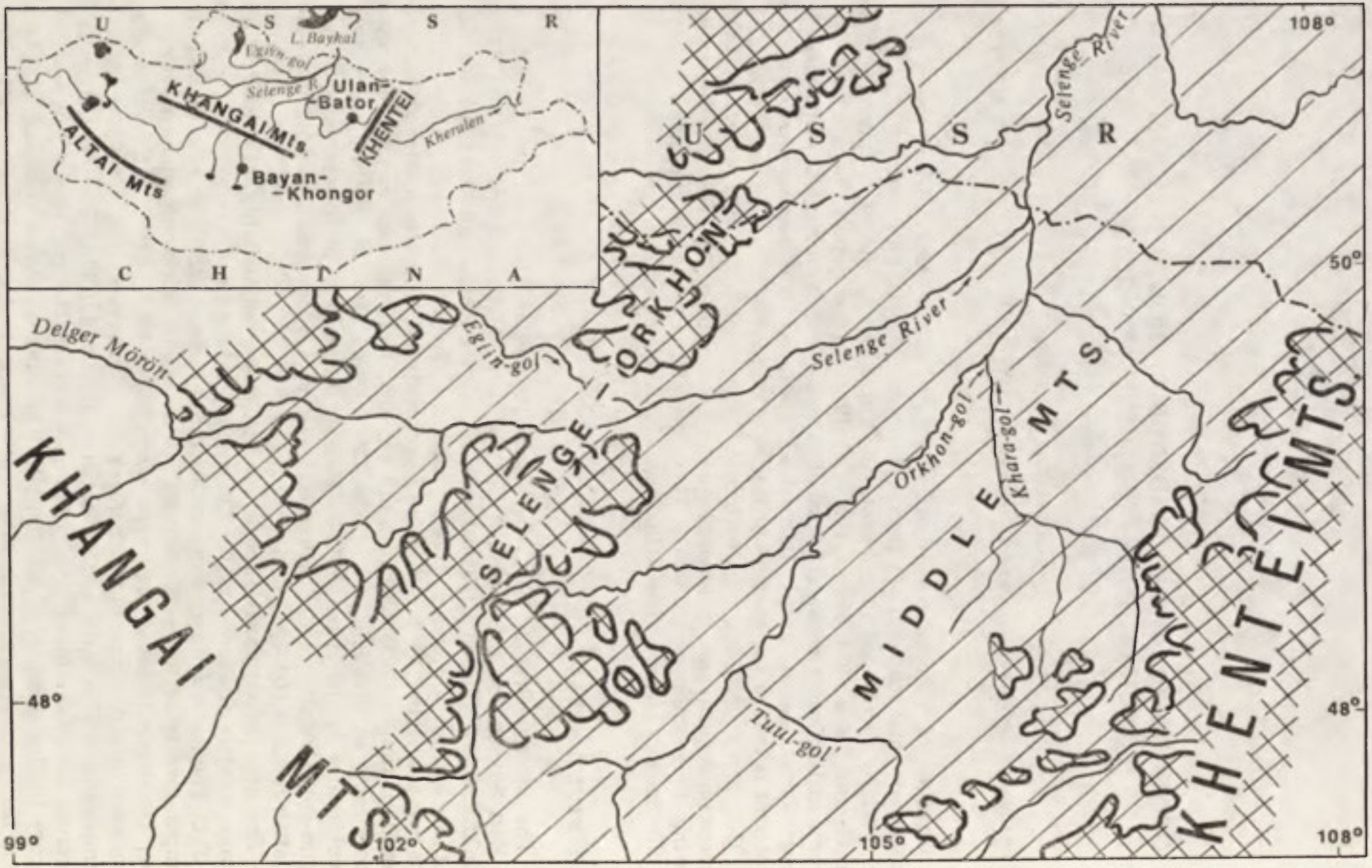

Fig. 1. Locality map of the study area

which usually underlies the wet basin floors. Wherever conditions are favourable permafrost also occurs on north-facing mountain-sides (Gravis 1974).

The Selenga-Orkhon Mts lie at the boundaries between the South Siberian taiga and the Mongolian steppes. This transitional zone, which is several hundred kilometres wide, is known as the forest-steppe. On north-facing slopes forest with *Larix sibirica* is growing at lower levels, while *Pinus sibirica* occurs at higher levels. The south-facing slopes are occupied by steppe communities, and *Artemisia* is widespread.

LANDFORMS AND DEPOSITS AS EVIDENCE OF CLIMATIC CHANGES

Much of the Selenga-Orkhon Mts are mountain-sides. The configuration of slopes and the overburden occurring on both lower slope portions and footslopes shows that climate has changed there in the immediate past.

The majority of slopes display a similarity of form independent of geological structure and height. The upper slope is usually a cliff or steep face. There may be a thin veneer of waste overlying the bedrock. As the gradients decrease gradually downslope to 10°–15°, the sheets of clay and angular rock fragments increase in thickness. Consequently, a smooth sloping surface (2–5°) is produced at the bases of mountain-sides. This surface is wholly depositional (Fig. 2).

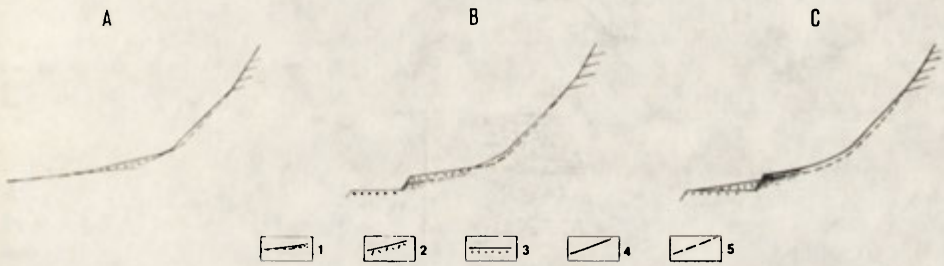

Fig. 2. Relation of the footslope-forming deposits (depositional glacis) to bottoms of the intermontane depressions (A) and to river valleys (B and C)

1 — older (Pleistocene) sandy-silty alluvial fan deposits forming the depositional glacis, 2 — younger (Holocene) scree bouldary alluvial fan deposits, 3 — gravelly-sandy alluvial valley fills, 4 — long-profile of older (Pleistocene) V-shaped valleys cutting both valley-sides and footslopes, 5 — long-profile of younger (Holocene) small valleys cutting both valley-sides and footslopes

Within the intermontane rift depressions the smooth sloping surfaces pass into the floors of basins (Fig. 2A). In the major river valleys these surfaces are usually undermined, and both inactive and fresh river cliffs occur (Fig. 2B and C). A striking feature of the area are the rather poorly dissected and uniform slopes, neither slope profiles nor modes of slope dissection are changing over large distances.

Into the high upper slopes minor V-shaped valleys are carved locally and alluvial fans lie at their mouths. Below the well dissected valley-sides, numerous alluvial fans tend to coalesce on the mid-slopes to form a continuous surface — the depositional glacis on the lower slopes.

In the Khara-gol, Egiin-gol and Selenga valleys, river-bank exposures reveal the composition of the glacis. This consists of sand and silt layers, several metres thick, which are interbedded with thin layers of angular rock fragments, 3–5 cm in diameter. Smaller particles, a few millimetres in diameter, occur frequently (Fig. 3). In some places (e.g., in the Egiin-gol valley) the deeply incised footslopes display thick layers of rock debris. Alluvial fan deposits are considerably thicker and stony at the mounths of the greater V-shaped valleys which are not active now. Rock fragments here are better rounded.

Such a character of deposits favours the concept of climatic control of both weste production and sedimentation on the slopes. A cold and relatively dry climate allowed physical weathering (frost action) of the bedrock. Because of moisture and running water shortages only fine waste products were displaced downslope. Coarse-grained deposits are restricted to the central points of alluvial fans. The thicker gravelly intercalations may indicate wetter phases, and even single rainshowers or single snowmelt seasons in a former cool climate. Fossil permafrost structures recorded from the fine-grained sediments suggest a Pleistocene date. It seems that the above described deposits were laid down largely in a cool mountain steppe or mountain tundra environment which prevailed here during the Last Glacial. On the basis of simplified analyses of sporadic pollen from the discussed deposits, G. F. Gravis and A. M. Lisun (1974) have come to a similar conclusion. However, the suggested time available for the formation of such sediments seems to be too long.

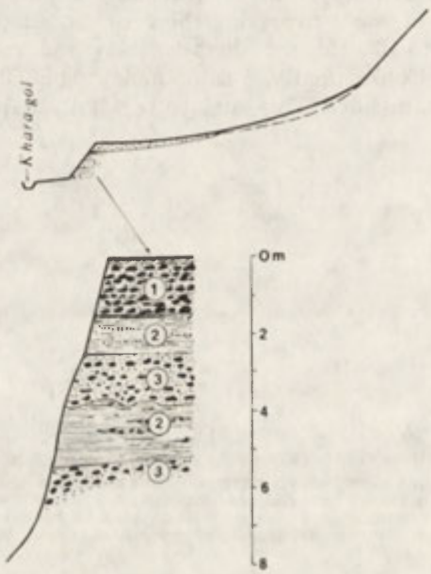

Fig. 3. Structure of deposits forming the bases of the steep Khara-gol valley-sides

1 — angular rock debris, 30 cm in diameter — Holocene alluvial fan deposits bearing a chestnut soil, 2 — silty-sandy older (Pleistocene) alluvial-proluvial deposits with fine gravel intercalations: this series bears a buried soil, 3 — rock debris, 10-15 cm in diameter, being embedded in a metrix of clay lying between sandy-silty deposits

Good examples are the landforms of deposits preserved in the Khara-gol valley. Within the Batsumber Basin, near its head end, the footslopes are formed of a wind-deposited loess-like silt. R. Malarz and K. Pękala (1978) reported that this sedimentary series contains two layers of solifluction deposits explicable only as the result of wetter conditions prevailing during the Pleistocene.

In the Khara-gol valley (285–304 km on the railway track joining Ulan Ude with Ulan Bator) great earth-flow tongues rest at the bases of steep slopes at elevations of 1000–1200 m a.s.l. The earth-flows range from 100 m to 200 m in length and display steep bulging toes, 30 m high (Fig. 4). These consist of 3 m blocks which are embedded in a matrix of sand and clay. Earth-flows spread out upon the depositional glacis extending at the bases of valley-sides. Both the geomorphological situation of the earth-flows and their composition indicate that in past times conditions were favourable for the supersaturation of waste that was swept out of the small valley heads occurring in the mid-slope portions above 1000 m a.s.l. This event can be attributed to a wetter phase which post-dates the formation of the alluvial-proluvial glacis.

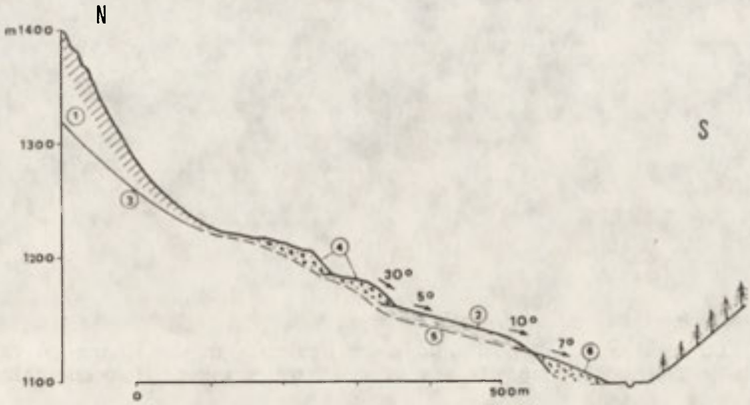

Fig. 4. Profile of the Khara-gol valley-side with earth-flow occurrences
1 — rocky valley-side, 2 — older (Pleistocene) footslope, 3 — bottom of the older V-shapped valley cutting the valley-side, 4 — earth-flow tongues, 5 — bottom of the younger (Holocene) small valley cutting the valley-side, 6 — younger (Holocene) alluvial fan extending into the valley floor

The bottoms of the V-shaped valleys are dissected by younger, dry ravines which extend downslope and continue on the upper parts of the older alluvial fans (Fig. 2). On the mid-slopes the younger ravines are 5–12 m deep and become shallower further downslope. At their outlets younger alluvial fans rest on the earlier depositional glacis (Fig. 2A) extending into intermontane basins. The younger ravines which cut into the short and steep valley-sides reach the bases of slopes. The younger fan deposits either overlie the older fan deposits (Fig. 2B) or extend into the valley floors (Fig. 2C). The younger ravines also dissect the earth-flow tongues.

The younger alluvial fan deposits are clearly distinguished from the older (Pleistocene) alluvial sheets by the predominance of angular rock fragments up to 30 cm in diameter. Sand and silt is of minor importance there. Such a composition of the younger fans indicates both moister conditions and increased force of water running down the slopes.

The ravines and alluvial fans described above are relic forms. The evidence for this is that: (1) the younger alluvial deposits have well developed chestnut soils, (2) on the fan surfaces both tumuli dating from the Turkish period and Chinese irrigation systems dating from the 17th and 18th centuries are preserved.

The composition of sediments and the geomorphological situation of both younger ravines and younger alluvial fans are obviously the result of a change of climate which occurred in the area investigated in post-Pleistocene times. The streams were then able to carry larger rock fragments than those under cool conditions. It seems probable that the prime cause was the increase in both total precipitation amount and rainfall intensity. Thus the conclusion can be drawn that the Pleistocene depositional glacis were partly eroded and partly built up by Holocene fan deposits during a more humid phase than at present.

Phot. 1. Composition of a depositional glacis occurring in the Khara-gol valley. The sandy-dusty Pleistocene deposits are overlain by younger (Holocene) alluvial fan scree

Phot. 2. An earth-flow tongue spreading out upon the older depositional glacis, incised by a younger (Holocene) ravine

Phot. 3. A younger (Holocene) small valley cut into the older depositional glacis

Phot. 4. Younger scree and bouldary alluvial fan deposits rest on the older fine-grained sediments forming the footslope (on the right of the photograph)

THE CHRONOLOGY OF EVENTS DURING THE HOLOCENE

In the valleys of the rivers Khara-gol, Egiin-gol and Selenga all the available arguments do not allow the exact age of the above described landforms and deposits to be established. For this reason attention in drawn to type horizons that have been found in the neighbourhood (a distance of 200–300 km!) of the area investigated. Dated Holocene sedimentary sequences are recorded from (a) the Kotakel lake occurring on the northern slope of the Chamar-Daban range not far off the southern shore of Lake Baikal (Vipper 1976; Khotinsky 1977), (b) the Terkhin-Tsagan-nuur lake situated on the northern slope of the Khangai Mts at 2060 m a.s.l., and (c) the Ugin-nuur lake which lies in the Orkhon valley at 1335 m a.s.l. (Vipper et al. 1976). The sequence of the Kotakel lacustrine sediments points to a rapid climatic warming in the continental mountainous region of southern Siberia. Its date is 9500–8000 a B. P. (Khotinsky 1977). The sequences of lacustrine sediments recorded from Lakes Terkhin-Tsagan-nuur in the Khangai Mts and Achit-nuur in the distant Mongolian Altai indicate a humid phase dated at 5000 a B. P. This was accompanied by rising lake-levels and confirmed by the high frequencies of AP (*Pinus sibirica, Pinus silvestris* and *Betula*). It appears that in the Selenga-Orkhon Mts including the study area the climate of that period was warmer and more humid than that of today. Pollen spectra from the above mentioned lacustrine sediments show that about 2000 a B. P. the frequencies of NAP marked by the presence of *Artemisia* and other steppe plants were significantly high and similar to the present day. At the same time the frequencies of AP were low. This change in plant communities indicates both aridisation and, probably, climatic cooling in northern Mongolia (Fig. 5).

The climatic deterioration and aridisation which occurred during the last 2000 years is also documented by other findings in the southern foreland of the

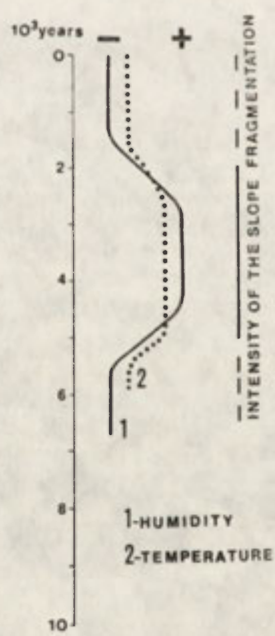

Fig. 5. Holocene changes in air temperature and temperature and humidity in northern Mongolia (based on data by Vipper et al. 1976 Khotinsky 1977)

Khangai Mts, i.e. on the northern fringe of the plains of Central Asia (Kowalkowski et al. 1977).

The formation of the above described younger ravines and younger fans should be related to the wettest phase of the Holocene with significantly high temperatures. The period before 5000 a B. P. — in Siberia known to be one of clearly warmer conditions (Ravskiy 1972) — was rather dry in northern Mongolia.

Thus it appears that the complex of younger ravines and younger alluvial fans developed 5000–2000 a B. P.

CONCLUSION

The climatic cooling some 5000 a B. P. (= the AT/SB transition), which has been recorded from west Europe (vide Starkel 1977), from the Russian Plain and Siberia (Ravskiy 1972), brought about clearly wetter conditions on the northern, mountainous border of Central Asia. This humid phase lasted for some 3000 years and favoured the formation of younger ravines. These relic landforms survived without much modification because of arid conditions now prevailing in this part of Asia.

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THE STRUCTURE OF ALTITUDINAL ZONATION OF SOILS IN THE DONOIN DZUN-NURUU MASSIF, KHANGAI MTS (MONGOLIA)*

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THE PROBLEM

The specific vertical zonation of soils within the soil-geographic zones in Mongolia is determined by the hydrothermal conditions there, which are modified by the mountain chains. In addition to altitude above sea level, exposure, slope inclination, geographic situation and meso- and microclimatic conditions, the structure of vertical soil-zones is determined by the width, openness, and depth of the valleys separating the mountains as well as individual crests. In consequence of the combined action of various factors, the soil-zones tend to become asymmetric and undergo inversion (Dorzhgotov 1975; Dorzhgotov and Kowalkowski 1981). First, solifluction, fluvial and eolian processes as well as zoogenic erosion of varying intensity yield in effect a specific structure of the soil cover within each individual zone. The actual effect of each such process in soil formation depends on the geographic situation of any given mountain complex. The granodioritic crest of the Donoin Dzun-nuruu in the central part of the Khangai Mts is an example of this dependence. The crest is situated in the horizontal zone of forest permafrost brown soils with a semihumid variant of the Khangai vertical zonation structure (Dorzhgotov and Kowalkowski 1981) within a very cool wet climatic zone (Badarch 1975).

THE OBJECT AND AREA OF THE STUDY

The Donoin Dzun-nuruu massif, which stretches over an area of 24 km^2, with a cryogenically smoothed-out 1–3 km wide plateau situated at an altitude of 3100–3352 m a.s.l., is bounded by the valley of the river Olon Nuurin-gol from the NE and by that of the Modotin-gol from the SW (Fig. 1). These are glacial U-shaped valleys cutting 300–500 m deep with broad (about 1 km) even bottoms filled with alluvial material. In the upper part they are closed by glacier kars, while in the lower one by series of end- and lateral moraines that encircle the south-eastern and southern edge of the massif. There, at altitudes between 2600 and 2700 m a.s.l. they form a wide hilly bog-lake plateau (Klimek 1976).

* Contribution No. 39 to the Mongolian-Polish Physical-Geographic Expedition to the Khangai Mts.

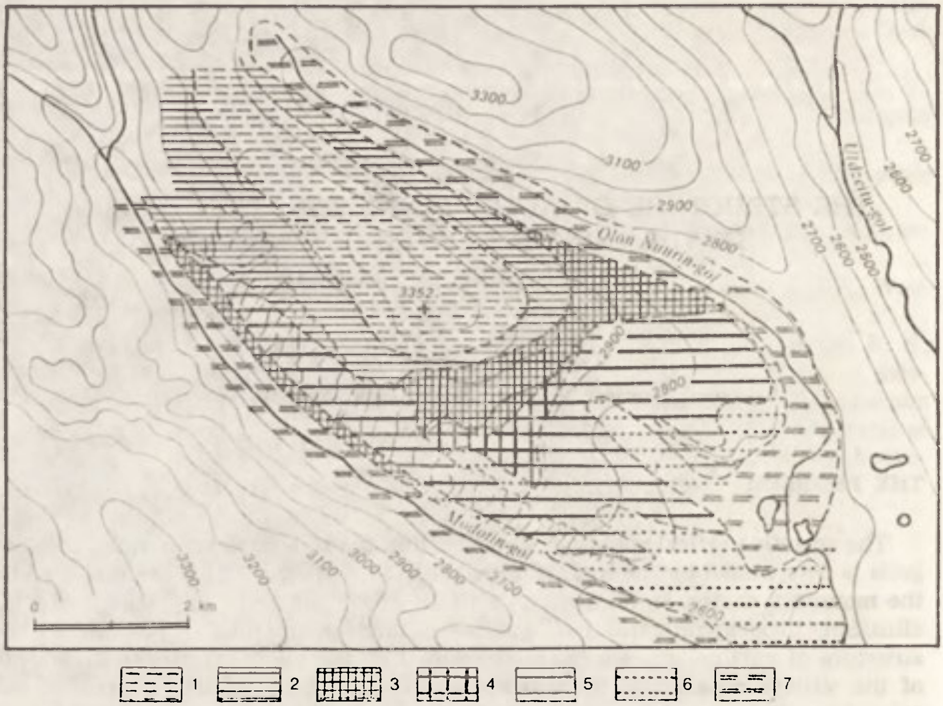

Fig. 1. Map of altitudinal zonation of soils in the Donoin Dzun-nuruu in central Khangai

1 — weakly developed and brown weakly developed tundra soils, 2 — mountain brown soils, 3 — grey-brown mountain soils, 4 — mountain hydrogenic chernozems, 5 — mountain brown chernozems, 6 — meadow-steppe dark-chestnut mountain soils, 7 — turf, turfy and gley mountain hydrogenic permafrost soils

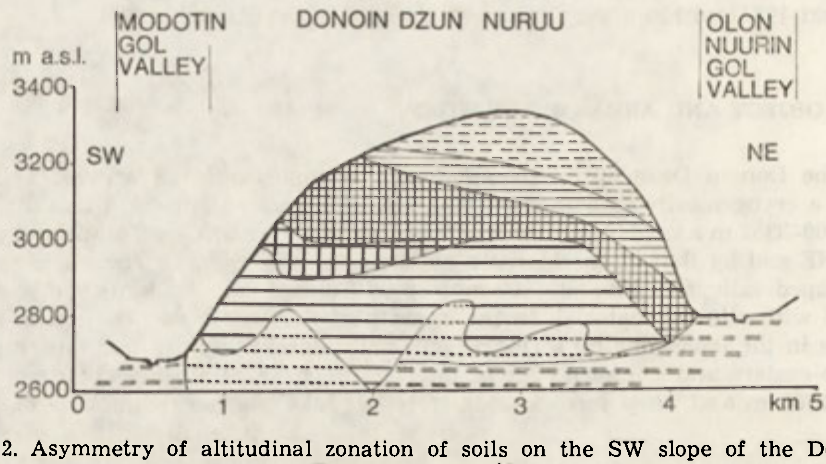

Fig. 2. Asymmetry of altitudinal zonation of soils on the SW slope of the Donoin Dzunnuruu massif

For explanation of symbols see Fig. 1

TABLE 1. Distribution of soil-vertical zones depending on exposure

Soil-vertical zone	Exposure		
	NE	SE	SW
	m a.s.l.		
Mountain brown soils at initial stage of development, and weakly developed mountain polygonal, solifluctional and permafrost brown soils	>3040	>3210(3240)	>3210
Polygonal, solifluctional, permafrost mountain brown soils	2820–3040	3180–3210	2780–3210
Polygonal, solifluctional, permafrost mountain grey-brown soils	2770-2820	2700-3180	2780-2800
Hydrogenic, polygonal, solifluctional mountain chernozems	—	2920–3180	—
Solifluctional, permafrost mountain brown chernozems	—	2650–2920	2800–3100
Polygonal and permafrost mountain dark-chestnut soils	—	2600–2980	2680–2700

A map of the soils of the area was made in the June of 1974 and 1975 on the ground of a 1:100,000 topographic map enlarged to 1:10,000. The vertical soil zones, which had been localized by means of an altimeter, were then examined for their morphology and samples taken for laboratory analysis. Some of the results have been already published (cf. Kowalkowski 1976, 1977) while others will be published later.

THE DISTRIBUTION OF THE SOIL VERTICAL ZONES

The asymmetric pattern of soils is illustrated in Figs 1 and 2 and in Table 1. The central part of a convex cryoplanation, with a general inclination of 2–3° toward the SW, as well as the upper and middle parts of the NE-slope with an inclination of 30–40° are covered by an asymmetric contour of stony polygonal (Phot. 1) and strip solifluctional mountain tundra soils. These are surrounded asymmetrically by mountain solifluction brown soils whose contour stretches over 250–1000 m. On the even cryoplanations they take the form of stone polygons. On slopes with inclination exceeding 2–3° there are solifluctional stone strips (Phot. 2) and block-seas (on the edges of the cryoplanation terraces: Phot. 3). The contour of those soils becomes narrower on the NE-slope overhanging the upper Olon Nuurin-gol. On the SW-slope, in the upper part of the Modotin-gol, those soils reach down as far as to the bottom of the valley forming a more than 1.5 km wide zone there. A wedge of mountain cryogenic stony chernozems intrudes along the lower part of this latter river. Those soils crop up in the form of sod islets from among the surrounding block tongues and seas that creep down the slope inclining more than 40°. The permafrost-turf soils in the Modotin-gol valley contact a narrow strip of grey-brown permafrost soils. The high humidity and the low dept of the permafrost there account for the gleyic features that occur in them. Locally those soils are covered by stony and clayey proluvia.

The vertical soil-zone structure on the SE-slope is diversified. The broad (500 to more than 1000 m) vertical zone of grey-brown soil is characterized by large solifluctional tongues and rock strips (Phot. 4) with small spots of hydrogenic chernozems. This contour widens downward the wet NE-slope till it

Phot. 1. Stone rings with tundra soils on the cryoplanation

Phot. 2. Stone rings and strips in the mountain brown soil-zone. A cryoplanation terrace built of granodioritic rocks visible at the top

Phot. 3. Fragment of a wall of a cryoplanation terrace with rocks pressed upwards in the mountain brown soil-zone

Phot. 4. Large solifluction lobes in the zone on mountain grey-brown soils with distinct rock strips

reaches the bottom of the Olon Nuurin-gol valley and the well-drained glacial edge of the Modotin-gol valley.

On the cryoplanation at an altitude of 2920–2980 m a.s.l. in this part of the SE-slope there is a contour of hydrogenic permafrost chernozems and thufur permafrost-turf soils which declines toward the NE. It is diversified by a number of cryogenic 'eyes' of open waters. Between the stone polygons and strips those soils are often underlaid by granodioritic plates at the depth of 40–60 cm. The mountain cryogenic brown chernozems in the wide contour in the middle and lower parts of the SE-slope have locally no brown fossils in their base, either. Their landscape is diversified by systems of old cryoplanation terraces (Fig. 3) and solifluctional sod and turf lobes, especially in the depressions on the slope.

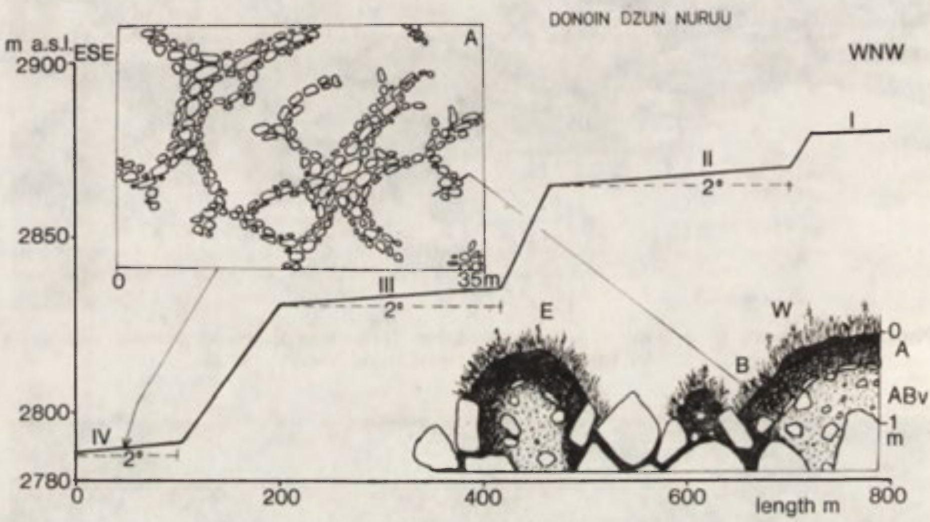

Fig. 3. Scheme of the system of cryoplanation terraces in the zone of brown chernozems on the SE slope, with an example of stony polygons on terrace IV (A) and a fragment of the vertical cross-section (B) with cryogenic brown chernozem

Narrow tongues or elongated isles of cryogenic dark-chestnut soils intrude from the SE into this zone from the elevated part of the morainic valley. Those tongues and isles emerged on local S-exposures. The neighbouring chernozems have a chestnut hue. Those soils are blown-over by dry winds from the south that arrive through the wide valley of the Tsagan Turutuin-gol (Avirmid, Niedźwiedź 1975).

WATER CONDITIONS IN THE SOIL-VERTICAL ZONES

That the soil-zones have distinct boundaries is also seen in the species composition and the density of the plant cover. Water is among the factor that both distinguish and integrate the vertical soil-zones. Surface precipitation waters and water from permafrost are prevalent there. Precipitation waters and waters from the snow and ice accumulated in the systems of stone polygons and strips of depths occasionally exceeding 2 m in the tundra soil-zone flow down the slopes in all directions. In the brown and grey-brown soil-zone those waters flow in erosional channels (up to 6 m deep) filled with rocks or in fresh carvings of depths up to 1.5 m. Microalluvia composed mainly of fine sand and dust emerge locally, at places of lesser inclination (Kowalkowski 1977).

The effect of surface waters is more pronounced in the zones of grey-brown soils and of hydrogenic and brown chernozems. At the turn of June and July 1975, many water streams were found (Phot. 5), some of them in elevated

Phot. 5. Stream in the chernozem zone amidst abundant soddy plant cover. Its course coincides with the network of cryogenic polygons

dike-shaped beds, and occasionally in tunnels of 50–80 cm in depth on the permafrost. Microalluvia of several to several score square meters often emerge in those zones, on a solifluction and cryogenic base (Fig. 4). Waters coming down from the higher-up zones flow broadly over the surface of those alluvia, thus creating bog-type conditions there. Those waters are rich in mineral and organic suspensions of silty and colloidal grain (Table 2, profile 042), which are deposited amidst the abundant plant cover. The terraces and dikes contain up to 35% of organic substances. The bulk density of the organic-mineral material that builds them is low — it amounts to 0.47 g/ml. The strongly porous material is sometimes fully water-saturated, under favourable conditions inducing solifluction processes. Frost processes are active too, as evidenced both by the sharp-edged rocks protruding from the front of the terraces and by the uneven fuzzy sod. The surface waters do not form cascades but penetrate the terraces to reemerge at the foot as streams.

On the cryoplanation terraces (Fig. 3), waters accumulate in the stone polygon form local levels on different altitudes. They rarely overflow in cascades onto the lower terraces (Fig. 5). As a rule they are stagnant waters, warmer than the flowing ones. On July 6 and 7, 1975, for instance, the clean waters flowing out of the stone strips at 2890–3000 m a.s.l. were found to have temperatures of 3–5.2 °C or 6–7 °C in the Olon Nuurin-gol river (at 2650 m a.s.l.), whereas the temperature of the suspension-rich stagnant waters in the stone polygons

TABLE 2. Soil granulation in different vertical zones on the SE-slopes

Soil-level / Altitude a.s.l. (m)	Profile No.	Depth of sampling (cm)	Skeletal parts, %			Earth parts, %						
			> 20	20–10	10–2	2–1	1–0.5	0.5–0.25	0.25–0.10	0.10–0.02	0.02–0.002	< 0.002
			mm									
Tundra soils at initial stage of development	037	0–5	2.2	2.2	5.5	8.3	13.4	7.0	6.5	22.4	24.4	8.2
3340		20–25	3.3	0.8	4.6	8.4	23.0	9.1	8.5	17.4	17.4	7.5
Mountain brown soils	038	0–5	0	0.9	5.1	11.7	32.2	10.8	7.2	24.6	4.1	3.3
3340		10–15	0.6	1.1	6.2	7.7	19.2	12.2	9.9	20.3	18.6	4.2
		25–35	2.4	4.3	7.0	6.4	21.5	10.5	8.1	18.3	19.9	0.8
Mountain grey-brown soils	039	0–5	0	0	0	0	22.0	11.2	11.8	43.0	15.0	7.0
3110		25–30	0	0	0.5	6.3	12.3	13.3	14.4	26.1	19.6	7.5
		60–70	0	0	3.4	6.8	15.9	12.8	12.6	19.2	19.8	9.9
		50–60	0.8	2.0	12.4	10.5	15.7	12.8	10.7	17.9	9.2	6.0
Mountain brown chernozems	041	0–5	0	0	0	1.3	11.3	11.8	14.3	38.6	17.6	5.9
2810		35–40	0	1.9	4.2	7.6	12.9	10.0	11.6	29.3	17.3	5.2
		50–55	5.5	0.6	8.4	9.7	9.6	10.1	13.0	24.3	15.2	3.8
		70–75	0	0	8.6	13.0	16.1	10.0	9.9	21.9	14.9	5.5
Mountain hydrogenic chernozems	042	20–30	0	0	0	0	0.3	0.3	0.5	33.0	35.0	31.0
2770		70–80	0	0	0	0	0.6	0.7	1.7	33.0	35.0	29.0
High mountain dark-chestnut soils	043	5–10	0	0	0	1.4	8.4	7.4	6.9	42.4	23.7	9.9
2740		30–40	0	0	0.5	4.2	9.5	8.1	13.8	26.7	28.6	8.6
		50–60	11.2	3.1	10.4	7.8	8.8	7.9	11.0	24.3	11.5	4.1

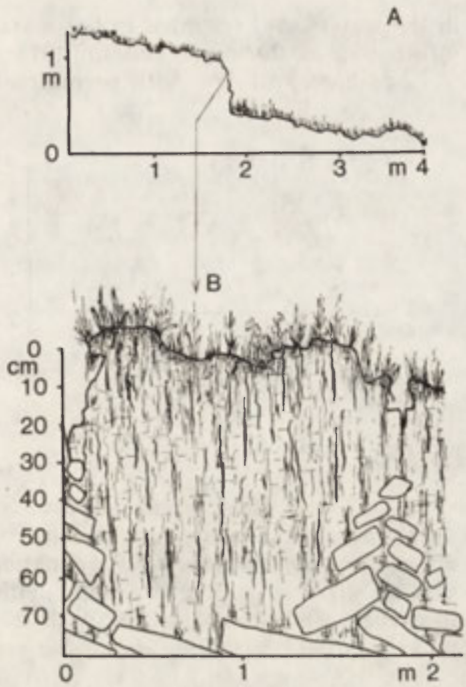

Fig. 4. Microalluvial terrace on solifluctional and cryogenic base at 2770 m a.s.l. (profile 042) in the zone of mountain brown chernozems (A) and its front devoid of sod due to cryogenic processes (B). In the sod there are ditches forming polygonal systems corresponding to the stony structures

and that of the waters flowing over the microalluvia (at 2790–2880 m a.s.l.) was 18.1–14,5°C.

The temperature differences of the waters flowing from the zones of weakly developed tundra and brown soils or waters overflowing the zone of hydrogenic and brown chernozems are responsible for their alluvial, transit and accumulative effects. This factor is of significance in the formation of the soils of the various zones and their fertility.

Yet the occurrence of dark-chestnut soils suggests that the seasonal dynamics of waters should display some features of continentalism. One example of this is

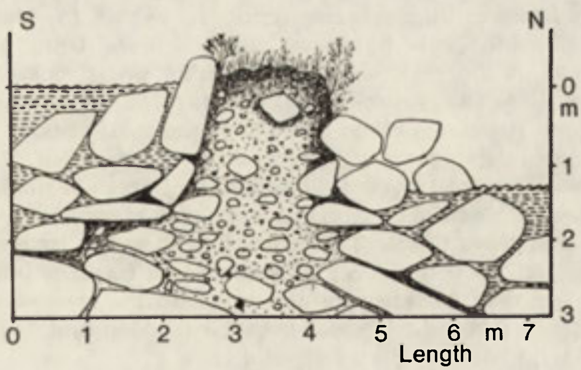

Fig. 5. Differences in water-level in systems of old stony polygons in the zone of dark-chestnut soils at 2690 m a.s.l.

the 2.8 m difference in the water-level recorded in the morainic valley between 1974 and 1965 (Fig. 6); another is the emergence in 1975 of shallow lakes in depressions that in 1974 had been still dry, with permafrost to a depth of 2.8–3.0 m.

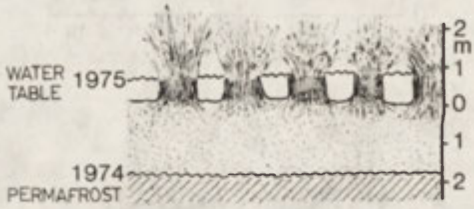

Fig. 6. Fluctuation in surface and ground waters on hydrogenic meadows

PEDOMORPHOGENETIC PROCESSES

Cryogenic features are the most outstanding characteristics of various past and present morphogenetic processes. In the tundra zone, stone polygons, most of them irregular in shape, occur on surfaces with inclinations of 2–3° (Phot. 1), while stone strips occur on surfaces with greater inclinations. The strips are composed of sharp-edged rocks and granitic plates with their edges facing the central parts of the polygons filled with fine cryogenic waste. At places that remain wet for a long time the stones and rocks are positioned vertically, with their longitudinal axes parallel to the slope's inclination. The fine-grained yellow-brown waste also includes sharp-edged rocks.

The surface on the active polygons is as a rule convex and crusted, with a fine gravel deflational cover. The sod plants on the edges of the polygons are a factor stabilizing the surface as well as an indicator of the physical stability of the soil environment (Kowalkowski 1977).

The vary-grained waste with a predominance of dust and floatable fractions strongly water-saturated (Table 2, profile 037), displays features of thixotropicity. Under the impact of outer physical impulses, this feature on slopes with more than 3° inclination may induce solifluction and lead to the emergence of stone-waste strips.

The zone of mountain cryogenic brown soils is characterized by inclinations of the slopes as a rule exceeding 3°. Large blocky solifluction lobes dominate this zone (Phot. 2). At inclinations up to 20° they are cryogenically pressed upward to form 10–20 m high terraces (Phot. 3). Within the stony lobes there are small plots of sodded soils. Since sod has been found being pressed upward 1.5–2.0 m in front of the rock walls and pushing upon rocks or lower-lying solifluction lobes, it can be assumed that they are in the process of creeping. At this level, block structures claim 80–90% of the total area.

Similarly active slope processes have been observed in the grey-brown soil-zone. Yet there it more frequently happens that areas of thicker dust-clayey pressed-up wastes with distinct segregation in the surface layers occur between the stone strips and lobes (Table 2, profile 030). They are covered by well-developed sod creeping upon the rocks. Cryoplanation terraces built of rocks on slopes inclining less than 20° are rare and small. In the creep-accumulation lobes, surface waters carved ditches down to 1.5 m deep and 3–4 m wide with bottoms littered with rocks or plates of solid rock.

The mountain chernozem soil-zones are characterized by numerous large soddy solifluction lobes. In local depressions they become alluvial terraces with features of bogging on their surface and at their feet. Turf-sod lobes sometimes creep upon old polygons and stone polygons forming 2–4 m high suspended hillocks. The physiognomy of those levels is diversified by systems of 10–20 cm wide and 40–60 cm deep partly dry beds (Phot. 5). They are overgrown with an abundant sod and herb vegetation, often on 40–60 cm high ramparts of phytoalluvial origin. Also numerous are fragments of stone polygons, especially on the cryoplanation terraces (Fig. 4). Yet these are non-active sodded forms, generally lying 1–2.5 m below the surrounding chernozem soils.

At the foot of the SE-slope, at 2760–2680 m a.s.l., close to the passage into the bog-lake plateau, there stretch 3–4 parallel elongated slide ramparts of 2–4.5 m height, which are indicative of a great slope slide. It reaches an altitude of 2950 m a.s.l. where 40–50 cm thick humus chernozems were found lying directly on a base of solid rock.

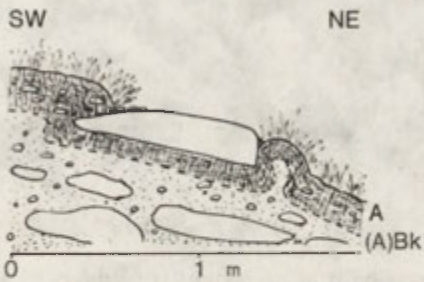

Fig. 7. Deformations in the profile of dark-chestnut soil induced by cryogenic mass movements on the slope

In the dark-chestnut and hydrogenic-permafrost soil-zone, there are old cryoplanation shelves with networks of irregular polygons of rounded-off boulders reaching diameters even of 1–2 m which occur on the elevated glacial moraines of the bog–lake plateau (Phot. 6). The rock and soil mass continues to move down the slopes inclining more than 3° (Fig. 7). Those movements are, however, relatively weak, especially in wet years. At inclination exceeding 20°, soil slides may call forth soil degradation and the rock base underlying them may get uncovered. The terrace-like structure of that area accounts for the precipitation waters and melting permafrost waters forming NE-facing drain systems with water-level differences up to 100 m.

The dominant effect of the water factor is pronounced in the bottom of the river valleys, with their shallow layer of active permafrost, thufur fields and hydrogenic meadows. Polygonal structures are ubiquitous there. Depending on the granulation of the materials deposited, they are either stony (normally at the slope-foot) or turfy (in the central parts). At the slope-foot they form proluvial rock or stone or, less frequently, fine-grained fans. The narrow and deeply cutting meandering rivers, with their bottoms littered with rocks, deposit mineral alluvia in the meanders. These are largely coarse-grained sharp-edged materials deriving from thermal weathering.

The course of the pedomorphogenetic processes is reflected in the granulation of the studied soils (Table 2). What is characteristic is the increasing proportion of vary-grained material from the dark-chestnut soil-level to that of tundra. The proportion of dust fractions in the upper soil-levels, which decreases in the same order, and the declining features of silt transport are two results of the rising significance of cryogenic processes in the formation of the profile of

Phot. 6. Old stone polygons built of granodioritic boulders of a lateral moraine in the mountain dark-chestnut soil-zone

granulation With decreasing altitude pedogenetic processes are gaining in importance as factors in the transformation of wastes into soil.

CONCLUSION

The Donoin Dzun-nuruu massif, which is built of granodiorite, displays a climatically determined asymmetry of soil vertical zones. Local microclimates and the effects of the macroclimate both are important factors there. One manifestation of the latter is the replacement of the zone of forest and the concomitant soils by the steppe dark-chestnut soil-zone on the SE-slope.

Each slope has its own autonomous vertical soil-zone structure. However, exposure is not always the decisive autonomous factor responsible for the formation of the soil cover structure in the zones. Stepanov's contention (1975) that the factors that are determined by the vertical zones structure affect soils but slightly and therefore result in secondary differences only is not confirmed by the findings reported here. Apart from the undisputable microclimatic differences betwen the individual zones within the same type of climate, we can state far-reaching effects of the northern and southern macroclimates. The latter are due to the orography of the area and the types of air circulation on the continental scale. In addition, the water and frost factors in the different soil-zones display different patterns of influence, depending on exposure. Their effects and up in the formation of soil-zones with characteristic autonomous features with distinctly drawn boundaries. Though they are active all over the studied area, these factors display clearly different characteristics in their soil-forming and morphogenetic action. For instance, water is responsible for the frost-induced disintegration and chemical decomposition of rocks with a continuous eluvial process in the soils of the tundra zone, grooving erosion and solifluction processes in the brown and grey-brown soil-zones as well as for solifluction and chemical and biochemical accumulation in that of the chernozems. The simultaneous action of groups of factors of the geographic environment accounts for the specific autonomous pedomorphogenesis that takes place on each zone as well as for the integrated pedomorphogenesis on each slope. The vertical zonality is doubtlessly at variance with the geographic regularities valid for soil zones in general (Bykov 1954; Dorzhgotow 1975), yet it is a persistent geographic regularity in the mountain group studied here.

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A HIERARCHY OF WORLD TYPES OF AGRICULTURE

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The first, preliminary scheme of world types of agriculture, based on a broad discussion of the principles, criteria, methods and techniques of agricultural typology,[1] was presented by the IGU Commission on Agricultural Typology to the IGU Regional Conference, held in Hungary in 1971,[2] and then to the XXIII International Geographical Congress in Canada.[3] A new, improved version of the scheme, in which the discussion at the 5th Commission meeting, held in Hamilton, Canada,[4] was taken into account was elaborated and published in 1974.[5] The discussion at the 7th Commission Meeting at Fontenay-aux-Roses, France, led to the elaboration of a further improved version of the scheme of world types of agriculture which was published in 1976.[6] The application of that version in several countries was presented and discussed at the 8th and last meeting of the Commission held in Odessa[7] in 1976.

Following all those discussions and many testing studies it has been decided to base agricultural typology on the four principal groups (social, operational, production and structural) of agricultural attributes. In the 1974 version each of those groups was represented by 6–7 variables with the exception of the group of production attributes, which was described by 4 variables only. In order to balance the importance of each group the three variables representing production attributes were then doubled. That made the total number of variables characterizing each case rise from 24 to 27.

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[1] Cf. the proceedings of the meetings of the IGU Commission on Agricultural Typology: J. Kostrowicki and W. Tyszkiewicz (eds), Essays on agricultural typology and land utilization, *Geogr. Pol.*, 19, 1970, 290 p.; C. Vanzetti (ed), *Agricultural typology and land utilization*, Verona 1972, 448 p.; L. G. Reeds (ed), *Agricultural typology and land use,* Hamilton Ontario 1975, 350 p.; C. Vanzetti (ed), *Agricultural typology and land utilization*, Verona 1975, 498 p.; J. Kostrowicki and W. Tyszkiewicz (eds), Agricultural Typology, *Geogr. Pol.*, 40, 1979, 260 p. — as well as J. Kostrowicki, Agricultural Typology. Concept and method, *Agricultural Systems*, 2, 1977, pp. 33–45.

[2] J. Kostrowicki, The methodological bases for the typology of world agriculture, in: G. Krajko et al. (eds), *Symposium on agricultural typology and agricultural settlements*, Szeged-Pecs 1971, pp. 141–173.

[3] J. Kostrowicki, A preliminary attempt at a typology of world agriculture, in: W. P. Adams and F. M. Helleiner (eds), *International Geography,* 2, Montreal 1972, pp. 1097–1100 as well as J. Kostrowicki, The typology of world agriculture. A preliminary scheme, in: L. G. Reeds, *op. cit.*

[4] L. G. Reeds, *op. cit.*

[5] J. Kostrowicki, *The typology of world agriculture. Principles, methods and model types*, Warsaw 1974, 74 p. (mimeographed). Reprinted in: C. Vanzetti (ed), *Agricultural typology*... 1975, *op. cit.*, pp. 429–479.

[6] J. Kostrowicki, *World types of agriculture*, Warsaw 1976, 49 p., (mimeographed).

[7] J. Kostrowicki, W. Tyszkiewicz (eds), Agricultural typology, *Geogr. Pol.*, 40, 1979, 260 pp.

To make the variables fully comparable they had to be normalized. That was done by reducing the value of each of them to 5 classes, representing the world ranges of given phenomena. The 27 figures, representing those classes, were arranged in codes. Then, it was arbitrarily decided that codes which did not differ from each other by more than one-tenth of the total variance possible, i.e. by more than 10 variables (27×4 maximum distance between classes 1 and 5 = 108) could still be treated as representing the same type, i.e. that the types ought to differ from one another by at least 11 variables.

The codes based on this assumption for over 1000 investigated cases — whether agricultural holdings or such aggregates as administrative or other units — were established and grouped into 61 model types for which codes were also elaborated.

As the attempt to group those types into types of a higher order was found not fully successful, the types of a higher order were not characterized by similar sets of variables, i.e. by the codes.

Such a characteristic became only possible after testing a number of methods of grouping the established model types into the types of a higher order.

At the same time few minor changes were introduced to the set of the variables accepted as a basis of the codes. First of all, the three doubled variables, representing the production attributes, were substituted by three new variables.

Finally it was decided that agricultural types were to be identified on the basis of the following attributes.

A. Social attributes

(1) The percentage rate of agricultural land which is owned, controlled, or held in common by a group of people under traditional customary rights of tenure.

(2) The percentage rate of agricultural land operated under a labour or share tenancy, or any other form of landed bondage.

(3) The percentage rate of agricultural land, owned or held in ownerlike possession as an individual, joint or corporate private property.

(4) The percentage rate of agricultural land operated by a consciously planned collective or state enterprises.

(5) The size of holdings in terms of a number of actively employed people per one agricultural holding.

(6) The size of holdings in terms of a total amount of agricultural land (under temporary and perennial crops, cultivated and rough grassland, fallow land) in hectares per one holding.

(7) The size of holdings in terms of gross agricultural output in conventional units[8] per one holding.

B. Operational attributes

(8) Inputs of labour in terms of the number of people actively employed in agriculture per 100 hectares of agricultural land.

(9) Inputs of animal power in terms of the number of conventional (horse) draught units.[9]

[8] For the list of conventional units see footnote 6, Appendix No. 1, pp. 44–47. 100 kg of wheat is accepted as *one* conventional unit.

[9] As above, Appendix No. 2, p. 48.

(10) Inputs of mechanical power in terms of the number of HP of tractors and other self-propelling machinery (combines, etc.) per 100 hectares of cultivated land (cropland, gardens, cultivated meadows and pastures).

(11) Chemical fertilizing in terms of the amount of chemical fertilizers in kilograms used per one hectare of cultivated land.

(12) Irrigation measured by the percentage rate of irrigatied land (all systems of irrigation and entrapment) to the total of cultivated land.

(13) Intensity of cropland use in terms of the percentage rate of harvested to the total land under temporary crops (including fallow).

(14) Livestock population in the number of conventional (large) animal units[10] per 100 hectares of agricultural land.

C. Production attributes

(15) Land productivity in terms of gross agricultural output in conventional units per one hectare of agricultural land.

(16) (new). Productivity of cultivated land in terms of gross agricultural output from cultivated land per one hectare of actually cultivated land.

(17) Labour productivity in terms of gross agricultural output in conventional units per one person actively employed in agriculture.

(18) (new). Commercial labour productivity in terms of commercial (sold or delivered off farm) production in conventional units per one person actively employed in agriculture.

(19) The degree of commercialization as the percentage rate of commercial to gross agricultural output.

(20) Commercial production of land as the amount of commercial production in conventional units per one hectare of agricultural land.

(21) (new). The degree of specialization expressed as a coefficient of the degree to which the commercial part of agricultural production of an agricultural holding is concentrated on the least number of items.[11]

D. Structural attributes

(22) Land under perennial (trees, shrubs, vines) and semi-perennial crops (covering land without rotation for several years) as the percentage of the total agricultural land.

(23) Permanent grasslands (including leys within field-grass systems and current fallows if used for grazing) as the percentage of the total agricultural land.

(24) Land under primary food crops (edible grains, tuber, root and bulb crops, vegetables, fruits) as the percentage of the total agricultural land.

(25) General gross production emphasis (orientation) as the percentage rate of animal products in the total agricultural output (in conventional units).

(26) General commercial emphasis (orientation) as the percentage rate of commercialized animal products to the total commercial production of agriculture (in conventional units).

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[10] As above, Appendix No. 3, p. 49.

[11] Cf. J. Szyrmer, Stopień specjalizacji rolnictwa (Sum: The degree of agricultural specialization), *Prz. Geogr.*, 47, 1975, 1, pp. 117–135. See also J. Kostrowicki, *The typology...* 1974, *op. cit.*, Appendix No. 4, p. 74.

TABLE 1. Classes of world ranges of individual attributes

No. of the variable	Classes				
	1	2	3	4	5
	very low	low	medium	high	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	1000-10000	10000-100000	100000-
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	80-120	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-

(27) Production of industrial crops (to be used only or chiefly after industrial processing) as the percentage of gross agricultural output (in conventional units).

The classes resulting from the normalization of indices representing individual attributes were not changed, but new classes were elaborated for 3 new attributes (Table 1).

When analysing the selected variables and their classes one has to take into account that most of them do not characterize only one attribute and that taken either individually or combined they express many more attributes,[12] which was overlooked by some authors.[13]

Such a deliberate selection made it possible to reduce the number of variables to the manageable quantity, below which it would be difficult to express all the important attributes of agriculture. On the other hand, with more variables, possible errors in their calculation lessen their importance.

[12] See J. Kostrowicki, *The typology*... 1976, pp. 20–22.

[13] E.g., I. M. Kuzina, L. F. Yanvaryova, Types of world agriculture map for higher schools, *Geogr. Pol.*, 40, 1979, pp. 17–22.

To arrive at a proper method of grouping such multifeature units a number of taxonomic methods, whether graphic or mathematical ones, have been tested by the IGU Commission on Agricultural Typology or afterwards.

Among the graphic methods the following could be mentioned here:

— the Czekanowski diagram which, for quite a long time [14] has been widely used in physical anthropology and, subsequently, in plant sociology, agricultural economics, etc.;

— the Wrocław dendrite;[15]

— the typogram method, i.e. a kind of a star diagram introduced to agricultural typology;[16]

— the diagram proposed by J. Szyrmer.[17]

All of those methods have certain advantages and disadvantages. The first two methods, based on the assumption that distances between objects under study are linear, have been discarded as considerably distorting the reality.[18]

The typogram technique which became quite popular in some countries,[19] though very instructive and fairly effective when one has to deal with clear-cut differences between objects under study, requires too many arbitrary decisions when the differences are less evident.

The Szyrmer diagram is quite effective when units which are to be compared are not too numerous, otherwise it produces a too complicated picture.

Out of numerous mathematical methods used in numerical taxonomy the following ones have been tested by a group of Polish mathematicians and geographers:[20]

— R and Q techniques of the factor analysis,

— the principal component analysis,

— the Berry grouping, based on either initial characteristics, or on the Hotteling components,

— the single linkage method,

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[14] J. Czekanowski, Zur Differentialdiagnose der Neandertalgruppe, *Korrespondenz-Blatt der Deutschen Gesellschaft für Anthropologie, Ethnographie und Uhrgeschichte*, XL, 1909, pp. 44–47, as well as numerous other publications.

[15] J. Perkal, Taksonomia wrocławska (Wrocław taxonomy), *Prz. Antrop.*, 19, 1953, pp. 82–96; *idem*, On the analysis of a set of characteristics, *Zast. Mat.*, 5, 1960, pp. 35–45.

[16] J. Kostrowicki, Types of agriculture in Poland. A preliminary attempt at a typological classification, *Geogr. Pol.*, 19, 1970, pp. 99–110; *idem*, A preliminary attempt... *op. cit.; idem*, A typology of world agriculture. A preliminary scheme, in: L. G. Reeds (ed), *Agricultural typology and Land Use*, Hamilton, Ontario 1972, pp. 2–52.

[17] J. Szyrmer, Propozycja zastosowania nowej metody taksonomicznej do typologii rolnictwa (Sum: The proposal of the new taxonomic method to be applied in agricultural typology), *Prz. Geogr.*, 45, 1973, 4, pp. 739–756. See also: J. Kostrowicki, *The typology*... 1974, Fig. 1.

[18] For the discussion see above.

[19] Cf. J. Bonnamour, Y. Guermond, Ch. Gillette, Typologie des systèmes d'exploitation agricole utilisés en France, *Annales de Geographie*, 438, 1971, Mars, Avril, pp. 144–166; The same authors: Les systèmes regionaux d'exploitation agricole en France. Methodes d'analyse typologique, *Etudes rurales* 1971, 43–44, pp. 78–169; J. Bonnamour, *Geographie rurale. Methodes et perspectives*, Paris 1973, pp. 44–48; M. Chabaud, A. Champalbert, Methode d'analyse de l'espace agricole: typogramme et matrice ordonnable. Exemples du Minervois et de la valleé du Rhône, *Bulletin de la Societé Languedocienne de Geographie*, 7, 2, Montpellier 1973; J. L. Dongmo, Typologie de l'agriculture camerounaise. Essai d'application à l'Afrique Noire de la methode statistico-geographique du professeur Kostrowicki, Université de Yaounde, *Annales de la Faculté des Lettres et Sciences Humaines*, 5, 1973, pp. 19–40; A. H. Kampp, Et forslag til landbrugstypologi, Geografisk Orientering, 3, 1973, pp. 134–137.

[20] See: K. Bielecka, M. Paprzycki, Z. Piasecki, Applicability of numeric taxonomy methods in agricultural typology. Problems, criteria and methods of evaluation — published in the present volume, pp. 149–162.

— the paired group method,
— the Hubert divisive methods A and B,
— the McQuitty elementary and restricted linkage analyses,
— the McQuitty maximum distance replacement,
— the Farell method, and
— the Ward method.

In addition, the following new taxonomic methods have been proposed by the same group:[21]

— the ORLINE method, elaborated by Z. Piasecki,
— the GRAVITY method, elaborated by M. Paprzycki,
— the modification of the FARELL method by M. Paprzycki,
— the IDVER method, elaborated by Z. Piasecki.

The consecutive stages of their studies and methods described in more detail in their papers were presented to the meetings of the IGU Commission on Agricultural Typology in Verona, Fontenay-aux-Roses, and Odessa.[22]

One of the results of these investigations was the conclusion that while some methods could be quite correct from the formal, mathematical point of view and successfully used in various classifications, they could at the same time be little effective in the other. Therefore, the testing of formal effectiveness of the methods concerned should be supplemented by testing its cognitional (practical) effectiveness for a given purpose. While the first ought to be done by mathematicians, the second is a duty of the specialists in the subject in which the method is to be used, and should be based on certain empirical material.

As all the mathematical methods listed above are effective only for a given set of objects and any addition, or withdrawal of any object could change the whole grouping, therefore none of those methods meets in full one of the principal requirements of agricultural typology and a number of other classifications that their results should be comparable, both in time and space.

Such a requirement could only be met by the IDVER method which, similarly to the deviation method used to date in the typology of world agriculture, is effective only in comparison with model types established in advance.

In order to test both formal and practical effectiveness of the proposed methods for agricultural typology 61 types of world agriculture described by codes (Table 2) were grouped into types of a higher order by means of the following methods, selected as the most effective by the group mentioned above:

— the Ward method representing a group of dendrite (linkage tree) methods,
— the ORLINE method as a mathematical expression of the typogram method representing diagraphic methods,
— the FARELL method in its modified version representing pattern recognition methods,
— the GRAVITY method representing centroidal methods,
— the IDVER method representing methods applying a frame of reference.

The formal (mathematical) effectiveness was tested by means of 14 criteria.[23]

In the light of the criteria adopted the sequence of effectiveness from the most to the least effective ones was established as follows: (1) GRAVITY, (2) FARELL-mod, (3) Ward, (4) ORLINE, and (5) IDVER.

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[21] References as above.
[22] See footnote 1.
[23] See footnote 20.

TABLE 2

No.	Old symbols	New symbols	No.	Old symbols	New symbols
1	Tsf	Eff	32	Mmn	Mmn
2	Tsb	Efb	33	Mml	Mma
3	Toc	Eth	34	Mxm	Mml
4	Ton	Enc	35	Mxg	—
5	Tnn	Enn	36	Mxc	Mem
6	Tem	Etm	37	Mxl	Mmb
7	Tec	Etc	38	Mcc	Mec
8	Tds	Tir	39	Mvm	Mlc
9	Tdh	Tmh	40	Mvh	Mlh
10	Tia	Tio	41	Mvn	Mln
11	Tin	Tin	42	Mpp	Mlp
12	Tii	Tii	43	Mrr	Arr
13	Tjn	—	44	Muu	Add
14	Tji	Tij	45	Mgg	Mig
15	Tjm	Tiu	46	Sec	Sec
16	Tsv	Tss	47	Sem	Sem
17	Tse	Tse	48	Smc	Smc
18	Tsc	Tsd	49	Smm	Smm
19	Tmk	—	50	Scc	Scc
20	Tmc	Tmc	51	Sll	Sme
21	Tmm	Tmm	52	Srr	Aro
22	Tml	Mmt	53	Stc	—
23	Lcc	Tlc	54	Sth	—
24	Lll	Tla	55	Shv	Shv
25	Lpp	Tlp	56	Shf	Shf
26	Mii	Mii	57	Soo	Smi
27	Mss	—	58	Sin	Sin
28	Mhg	Miv	59	Sii	Sii
29	Mhf	Mif	60	Sgg	Shg
30	Mmc	Mmc	61	Suu	Ads
31	Mmm	Mmm			

To test the practical effectiveness of the above mentioned method for agricultural typology the results of grouping of the 61 types of world agriculture were compared with one another by a graphic method. On the figures representing the distribution of those types obtained by means of the Szyrmer graphic method (Fig. 1) groupings obtained by each of those five methods were marked by lines (Figs. 2–6).

Three out of those methods produced groupings into a certain number of types of one higher order only:

ORLINE — into 17 types,

FARELL-mod — into 16 types,

IDVER — into 13 types

while the advantage of both the GRAVITY and Ward methods is that they make it possible to group the same types into several higher orders of types.

The GRAVITY method (Fig. 5), for example, grouped 61 units into 8 types of the highest order, which could be subdivided into the types of the 2nd order and some of them into those of the 3rd order.

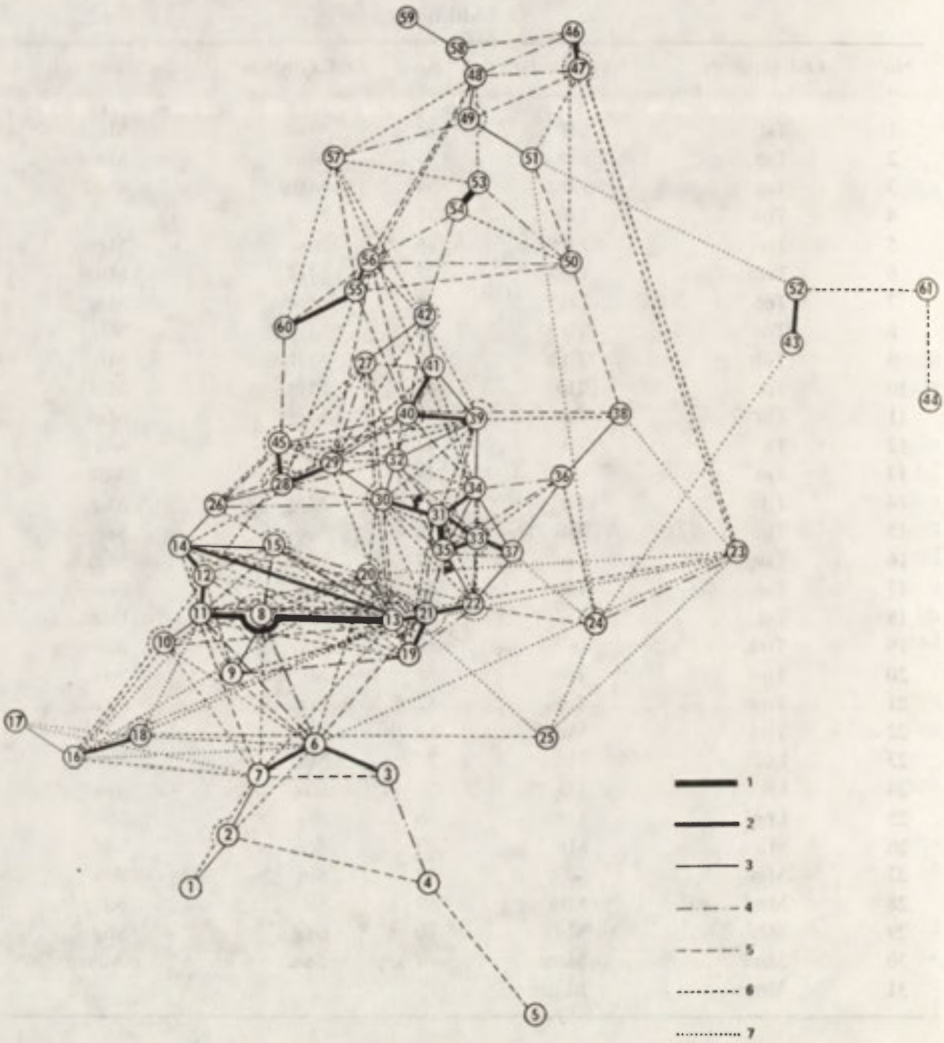

Fig. 1. Szyrmer diagram. Differences between types
1 — below 10, 2 — 11-12, 3 — 13-14, 4 — 15-16, 5 — 17-18, 6 — 19-21, 7 — some selected 22-24

The diagram resulting from the Ward method could be used for the identification of any number of such orders depending on an arbitrary decision as to how many times and where exactly the diagram could be crossed, i.e. what degree of similarity is to be accepted for each order. In the present study it was arbitrarily decided to cross the diagram three times: first at the level of the ESS (Error Sum of Squares) equal 200, the second time at the level of ESS = = 1000, and the third time at the level of ESS = 5000.

The comparison of Figures 2–6 reveals that the results of some of those groupings are more similar to one another, while the other produced more divergent results. The similarity of groupings and their consistence with empirical knowledge of the dfferentiation of world agriculture were used as the criteria of the practical effectiveness of those methods for agricultural typology.

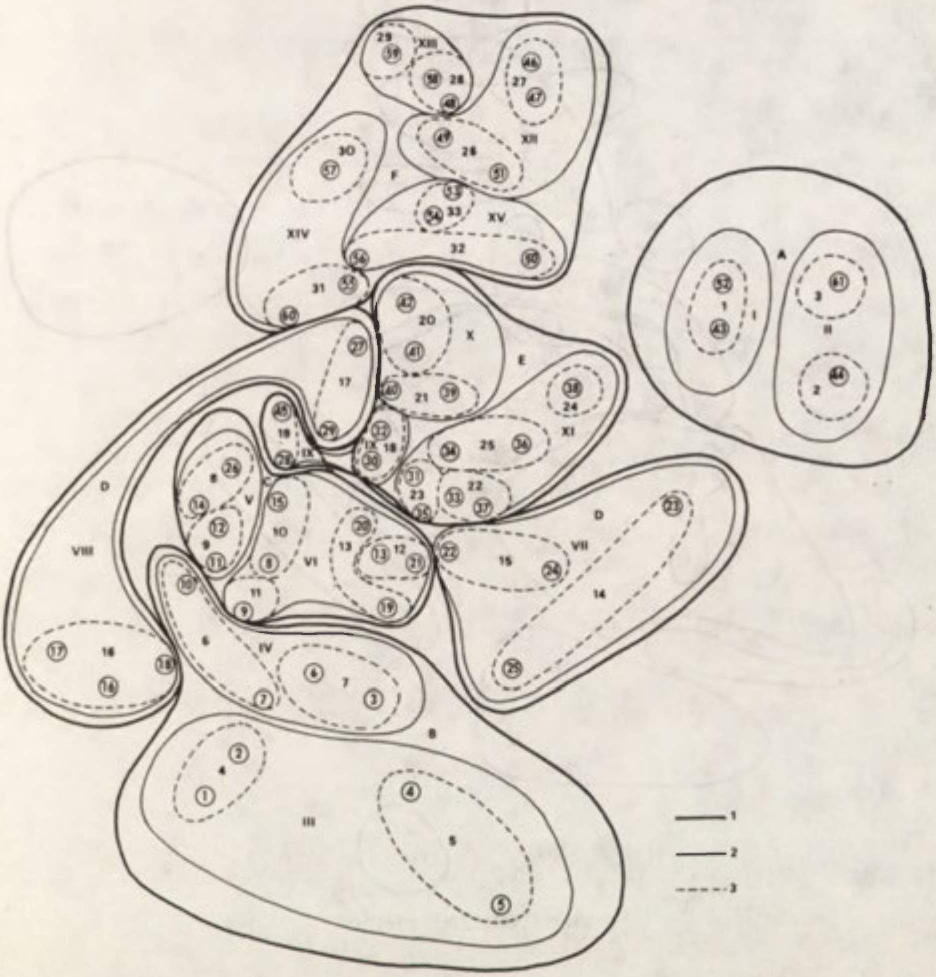

Fig. 2. Ward method
1 — first order, 2 — second order, 3 — third order

As agricultural typology is by assumption a hierarchical concept those methods that made such a hierarchization possible were considered to be more effective.

By use of such criteria the effectiveness for agricultural typology of the methods tested could be arranged in the following sequence: (1) GRAVITY, (2) Ward, (3) Farell-mod, (4) ORLINE, (5) IDVER.

In the grouping of the 61 types considered as the types of the 3rd order into types of the 2nd and 1st order the results of all groupings were consulted while priority in the decision was given to those groupings that were corroborated by more methods.

Following the former assumption that the types of the 3rd order ought to differ from one another by more than 10 per cent of the total variance, i.e. by at least 11 deviations, it was decided that the types of the 2nd order should differ by more than 20 per cent of the total variance, i.e. by at least 22 de-

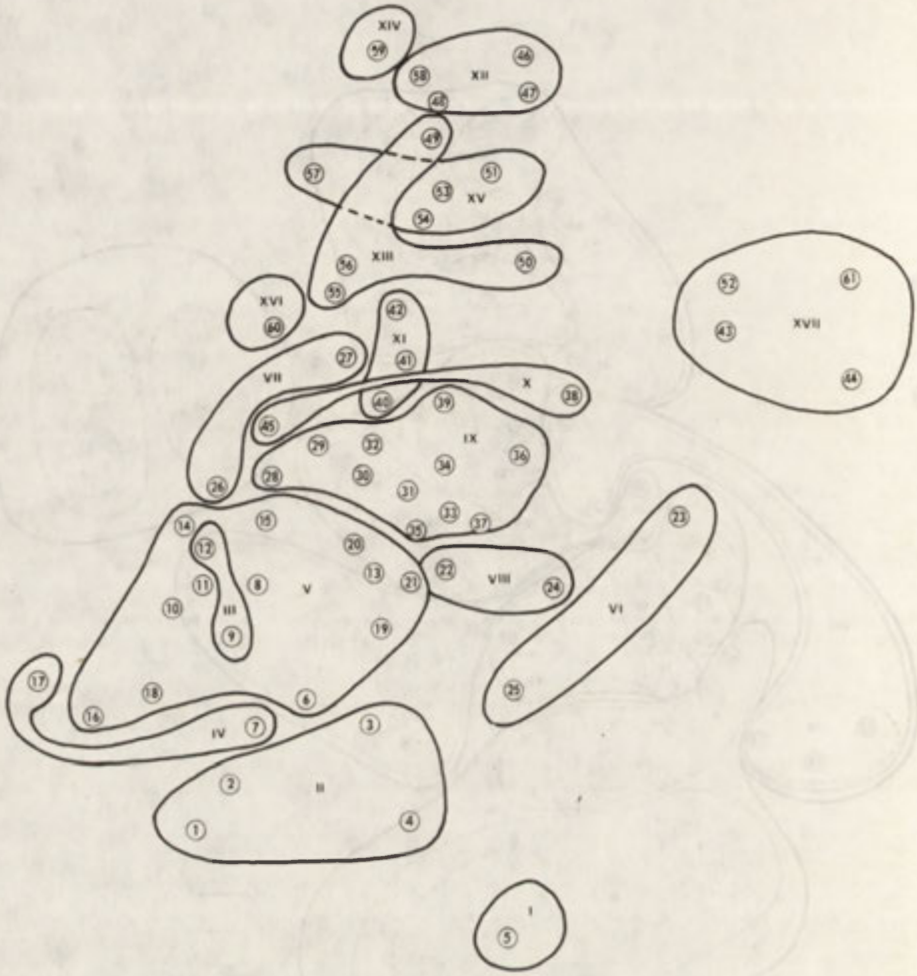

Fig. 3. ORLINE method

viations, and the types of the 1st order by more than 30 per cent of the total variance, i.e. by at least 33 deviations.

The differences between each of the 61 types of the 3rd order and every other were calculated by use of a computer according to the following program, elaborated by M. Kopyt.

"Let us assume that we have *m* items, each of them described by *n* integer numbers, and that these numbers are in a $(m \times n)$ matrix (called ITEMS).

We must compute coefficients $V_{i,j}$ $1 \leqslant i,j \leqslant m$

$$V_{i,j} = \sum_{k=1}^{n} |\text{ITEMS}(i, k) - \text{ITEMS}(j, k)|$$

Our alghoritm, in Fortran, has the form of a subroutine with parameters: ITEMS, IHELP, M, N.

```
SUBRØUTINE TRANS (ITEMS, IHELP, M, N)
DIMENSION ITEMS (M, N), IHELP (M)
```

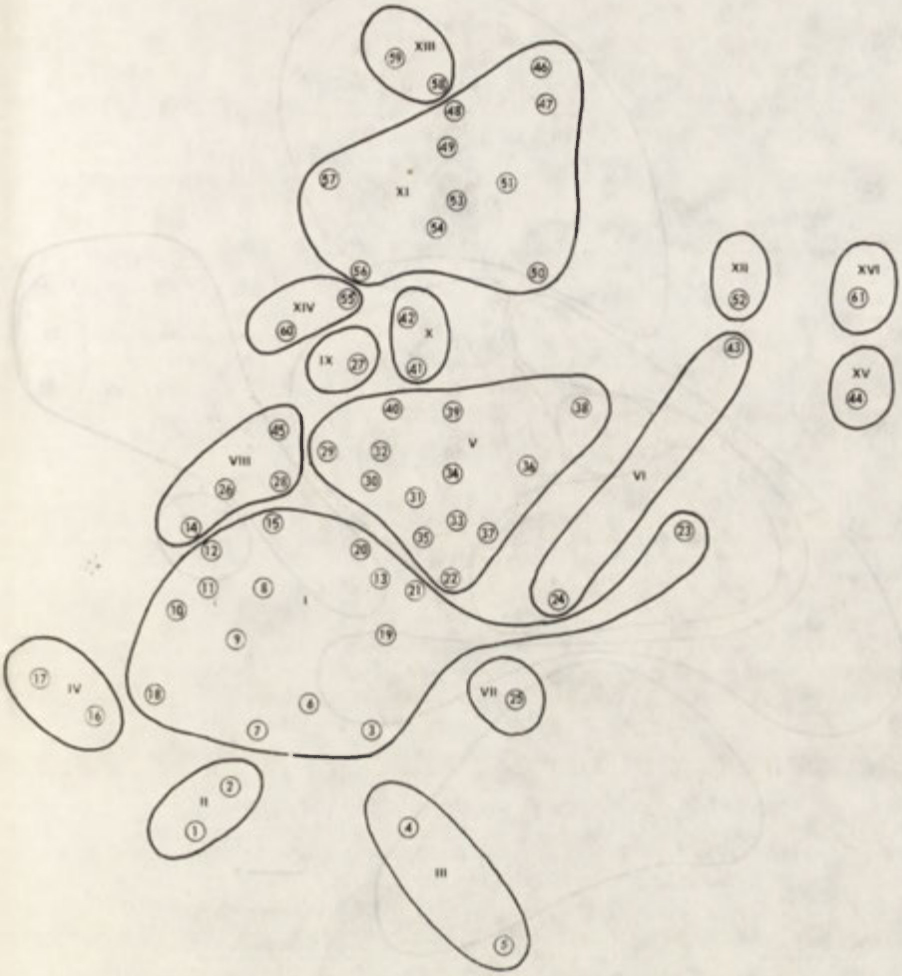

Fig. 4. FARELL-mod method

```
      DØ 100 II = 2, M
      III = M-II+2
      IEND = III-1
      DØ 200 IJ = 1, IEND
      ISIGM = 0
      DØ 300 IK = 1, N
      ISIGM = ISIGM+IABS (ITEMS (III, IK) — ITEMS (IJ, IK))
300   CØNTINUE
      IHELP (IJ) = ISIGM
200   CØNTINUE
C***  the auxiliary vector IHELP (I), 1 ⩽ I ⩽ IEND
C***  ought to be printed here
100   CØNTINUE
      RETURN
      END"
```

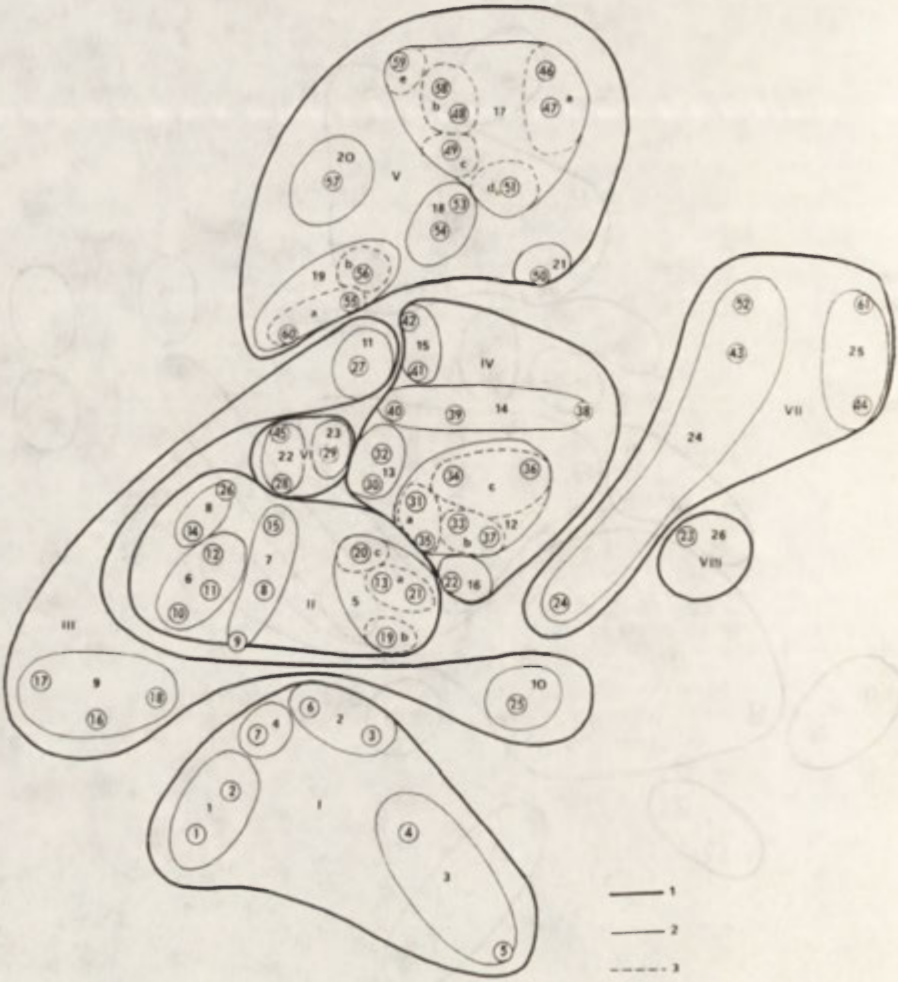

Fig. 5. Gravity method
1 — first order, 2 — second order, 3 — third order

In cases when most of the methods applied produced similar groupings such a group was identified as the core of a given type of the 2^{nd} order. By use of the mediana method a code for each type was elaborated. In the same way based mainly on the GRAVITY and Ward methods as well as the Szyrmer diagram the types of the 2^{nd} order were grouped into the types of the 1^{st} order, for which codes were established in a similar way as for the types of the 2^{nd} order.

Then the codes for each type of the 1^{st}, 2^{nd} and the 3^{rd} order were compared with one another once more by means of a computer according to the same program as the types of the 3^{rd} order, first to find out whether the accepted thresholds of differences for the types of the 2^{nd} and 3^{rd} order were maintained, and secondly, to decide what to do with the types where similarities to the types of a higher order varied considerably when different methods of grouping were applied.

As the 61 types of the 3^{rd} order certainly did not represent all possible types of that order, as the number of the types of the 2^{nd} order could also be increased

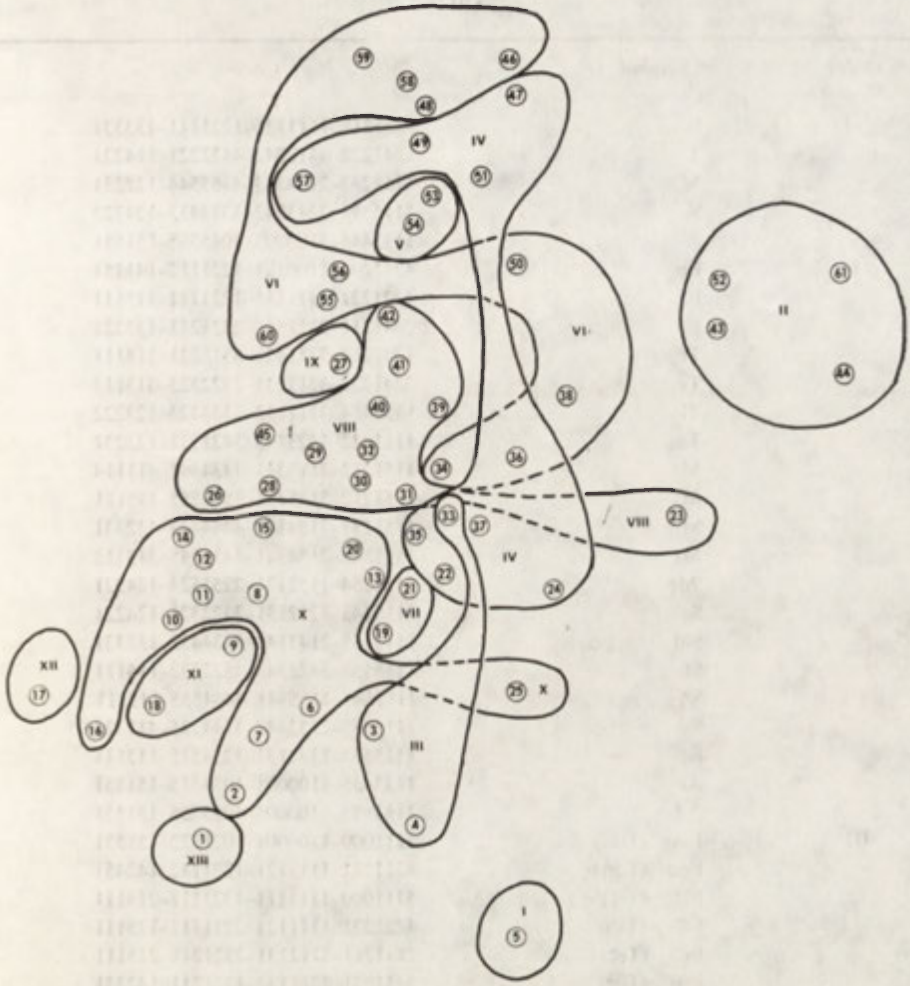

Fig. 6. IDVER method

with new investigations, and as individual types of any order did not represent the same number of cases, the codes obtained by means of the mediana method were slightly modified with both the comparative weights of individual types of the lower orders and possible additions to each of the types of the higher order taken into account.

At the same time, the codes for the types of a lower order differing from those which were considered as the core types of various groups — were compared with the codes established for the types of the higher order. Some of them turned out to be of transitional character between the types of a higher order, while the others represented individually, at least for the time being, separate types of a higher order. It was particularly true for the types representing poorly investigated territories.

In the result, the following hierarchy of world types of agriculture was obtained. For their codes see Table 3 for their distribution on a diagram and deviations, see Fig. 7, and for their final grouping — Fig. 8.

TABLE 3

Order	Symbol	Code
I	E	5321211-1111121-1221111-133331
	T	1241222-4412242-4422221-114221
	M	1151233-2154343-4455544-122231
	S	1115555-3243242-3333433-124221
	A	1133445-3100003-3045535-151551
II	En	4211201-1100121-1221112-141451
	Ef	5221221-1111111-1221111-115111
	Et	2441211-2211132-2321211-133221
	Ti	1241212-5311452-5511221-114111
	Ts	2241222-3212231-2222325-313113
	Tl	1351454-3311132-2333323-123222
	Tm	1151222-4423143-3421321-123231
	Ms	1151212-3113341-4434444-411114
	Mi	1151212-5145451-5545555-115111
	Mm	1151233-3154143-4444443-132331
	Ml	1151345-2154341-4455545-313113
	Me	1151254-1152131-2255524-124221
	Se	1115443-3232131-2322321-124221
	Sm	1115555-2143143-3434432-132331
	Si	1115555-5422343-4522232-114111
	Sh	1115545-4155341-4444555-115111
	Ss	1115555-2133442-3344535-411224
	Sc	1115555-1142131-1234515-115111
	Ar	1133455-1100001-1034515-151551
	Ad	1133455-5100005-5055555-151551
III	Enn (Tnn)	5111000-1100001-1021122-151551
	Enc (Ton)	4211211-1111121-1221112-142451
	Eff (Tsf)	5111000-1111111-1321111-214111
	Efb (Tsb)	4221221-1111121-2211111-115111
	Etc (Tec)	2441211-2111131-2321211-215111
	Eth (Toc)	3431221-2211132-1321211-142331
	Etm (Tem)	2341211-3311132-2321211-123221
	Tir (Tds)	1151211-4411244-2211211-114211
	Tio (Tia)	2231212-4211441-3312222-214111
	Tin (Tin)	1241212-4311142-4411121-214111
	Tii (Tii)	1251212-5411452-5511121-115111
	Tij (Tji)	1151212-5323452-5522332-114111
	Tiu (Tjm)	1151112-4422454-3322321-214111
	Tse (Tse)	2241131-1111131-1123315-312114
	Tsd (Tsc)	1351221-3311332-2312325-323113
	Tss (Tsv)	2241222-3112241-2222325-313113
	Tlp (Lpp)	1351444-4411142-3423435-333213
	Tlc (Lcc)	1351454-2222132-2333322-124211
	Tla (Lll)	1251354-2211132-2333424-141341
	Tmh (Tdh)	1251211-4511343-2411111-122341
	Tmc (Tmc)	2241212-4422243-3423332-224221
	Tmm (Tmm)	1151222-3323143-3423321-123231
	Mii (Mii)	1151211-4234551-5534443-114111

TABLE 3 cont.

Order	Symbol	Code
III	Mif (Mhf)	1151222–4134241–4444545–415111
	Miv (Mhg)	1151222–4145352–5534555–115111
	Mih (Mgg)	1151313–5155551–5555555–115111
	Mmt (Tml)	1151232–2223143–3433333–131341
	Mmc (Mmc)	1151222–4244242–4434443–213222
	Mmn (Mmn)	1151222–3155342–4445544–112213
	Mmm(Mmm)	1151222–3255144–4444442–123231
	Mma (Mml)	1151232–3154145–4444444–131351
	Mml (Mxm)	1151344–2154143–4455443–123231
	Mmb (Mxl)	1151243–2143143–3455434–131451
	Mlc (Mvm)	1151244–2154441–4455542–113112
	Mlh (Mvh)	1151345–2154341–4445545–315111
	Mln (Mvn)	1151255–2154242–4455545–311114
	Mlp (Mpp)	1151455–3133341–4434545–411115
	Mem (Mxc)	1151254–1152132–3355534–133331
	Mec (Mcc)	1151254–1152131–2255525–115111
	Sec (Sec)	1115443–3232231–2322422–124121
	Sem (Sem)	1115443–3233132–2333321–133331
	Smm (Smm)	1115555–2144143–3434432–132341
	Smc (Smc)	1115555–3233242–3433432–223221
	Smi (Soo)	1115555–2154443–4455543–122222
	Sme (Sll)	1115555–1142132–2244423–142441
	Sin (Sin)	1115555–4322143–4422222–224221
	Sii (Sii)	1115555–5422454–5522232–114111
	Shf (Shf)	1115555–3133241–4444545–415111
	Shv (Shv)	1115545–4154342–4434555–115111
	Shh (Sgg)	1115545–5155551–5555555–115111
	Scc (Scc)	1115555–1143131–2234525–115111
	Arr (Mrr)	1151354–1100001–1044515–151551
	Aro (Srr)	1115555–1100001–1034515–151551
	Add (Muu)	1151323–5150005–5055555–151551
	Ado (Suu)	1115555–5150005–5055555–151551

The total number of the types of the 3rd order in the Table 3 is less than 61 since with additional new attributes some types no longer differed by at least 11 deviations one from the other. It was also decided to eliminate a few types of the 3rd order for which the codes were based on insufficient number of cases, and to leave the further subdivision of the types of the 2nd order open.

E.[24] Traditional extensive agriculture[25]

Land held in common or under servile or share tenancy. Small scale agriculture with low inputs of labour, very low (if any) capital inputs, extensive use of

[24] In the present version of typology, the symbols have been changed in such a way that they symbolize certain characteristics — e.g., A,a — animal, c — crop, E,e — extensive, i — intensive, l — large-scale, M — market-oriented, m — mixed, S — socialized, s — specialized, T — traditional etc. The codes from the former version are presented in the parantheses.

[25] As it is impossible for the names of types to represent all the 27 characteristics, only some of those characteristics, that best differentiate a given type from the other, have been used to form a name.

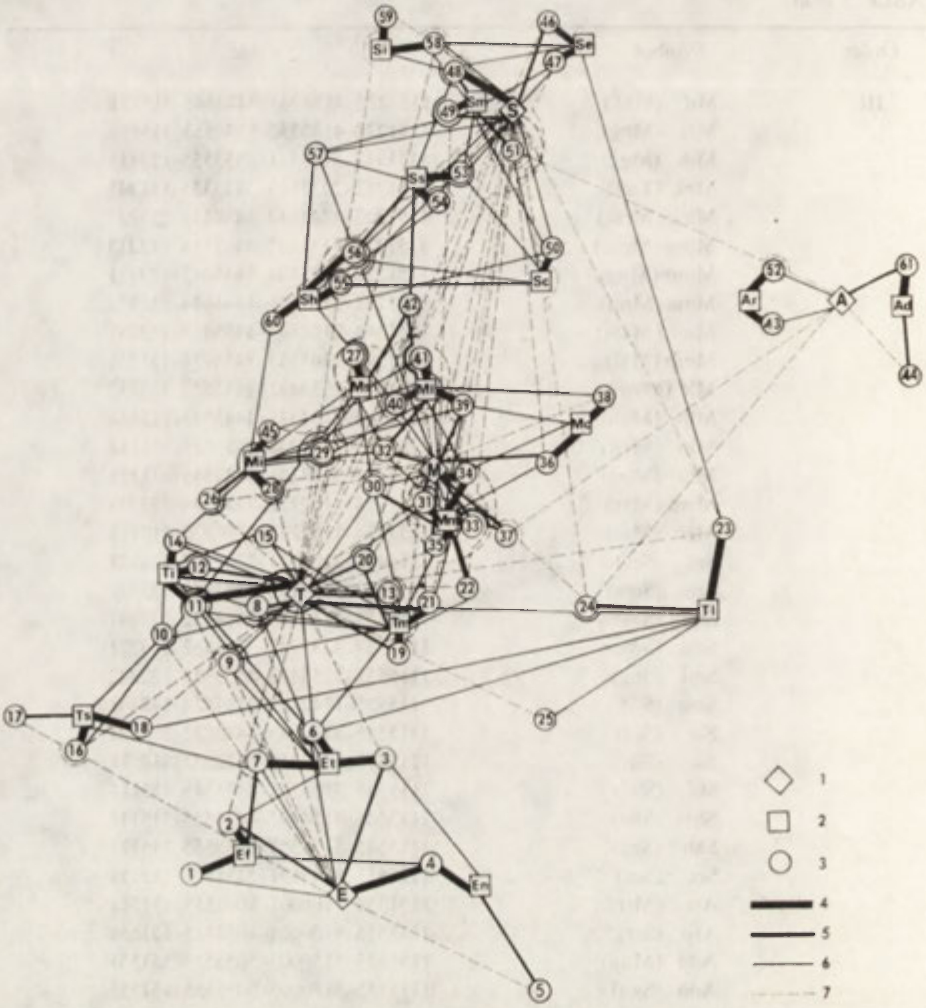

Fig. 7. Hierarchy of world types of agriculture
1 — first order, 2 — second order, 3 — third order; 4 — 10 deviations or less, 5 — 11-15 deviations, 6 — 16-21 deviations, 7 — 22-32 deviations

land, very low to low land and labour productivity, very low commercialization and specialization, oriented chiefly toward food production whether vegetal or animal.

En. Nomadic herding

Land held in common. Small to medium scale migratory herding, with or without supplementary crop growing. Very low labour and (if any) capital inputs, extensive use of land, very low to low productivity and commercialization, livestock products dominant.

Enn (Tnn)	Nomadic herding North Africa, Middle East

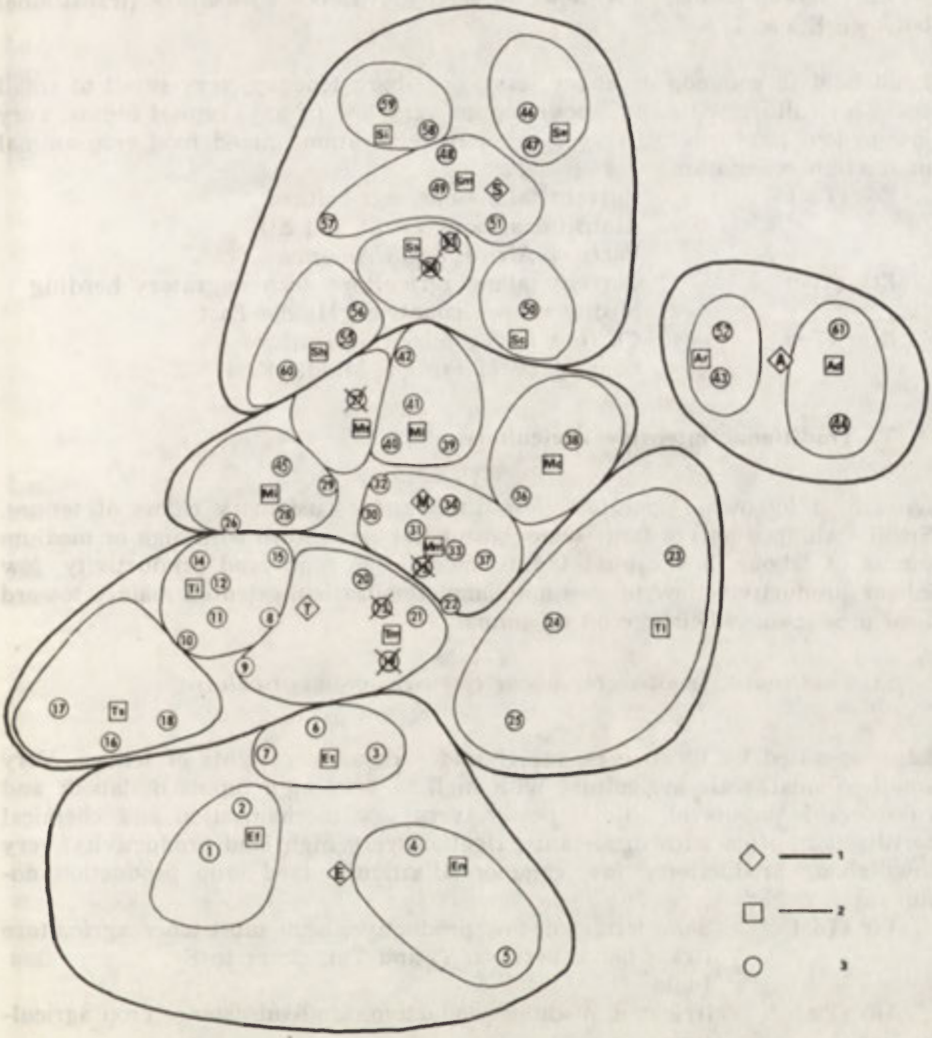

Fig. 8. Hierarchy of world types of agriculture
Grouping: 1 — first order, 2 — second order, 3 — third order

Enc (Ton)	Nomadic herding with subsidiary crop growing North Africa, Middle East

Ef. Shifting cultivation

Land held in common, very small to small scale agriculture with very low inputs of labour and (if any) capital inputs, very low to low productivity, very low commercialization, mixed food crop production dominant.

Eff (Tsf)	Shifting, forest fallow, agriculture Central Africa, South-East Asia, Amazonia
Efb (Tsb)	Rotational, bush fallow, agriculture West Africa, South East Asia, Latin America

Et. Current fallow, subsistence to semi-subsistence agriculture (transitional between E and T)

Land held in common or under servile or share tenancy, very small to small scale agriculture with low labour inputs, very low (if any) capital inputs, very low to low productivity, very low commercialization, mixed food crop-animal production orientation.

Etc (Tec)	Current fallow crop agriculture (transitional between Ef and Et) Parts of Africa, Latin America
Eth (Toc)	Current fallow agriculture with migratory herding Mediterranean countries, Middle East
Etm (Tem)	Current fallow mixed agriculture Some parts of Europe, Middle East

T. Traditional intensive agriculture

Land held by owner-operators, less often under customary rights of tenure. Small scale (peasant) or large scale (latifundia) agriculture with high or medium inputs of labour, low capital inputs, medium to high land productivity, low labour productivity low to medium commercialization, oriented mainly toward food production whether crop or animal.

Ti. Traditional, small-scale, labour intensive crop agriculture

Land operated by its owners, rarely under customary rights of tenure. Very small to small-scale agriculture with high to very high inputs of labour and considerable inputs of animal power, very low mechanization and chemical fertilization, often with important irrigation, very high land productivity, very low labour productivity, low commercialization, mixed crop production dominant.

Tir (Tds)	Semi-irrigated, low productive, semi-subsistence agriculture (transitional between Ti and Tm, closer to E) India
Tio (Tia)	Irrigated, medium productive, semi-subsistence crop agriculture Arid lands of North Africa and the Middle East oases, inundated river valleys
Tin (Tin)	Non-irrigated, highly productive, subsistence to semi-subsistence crop agriculture South and East Asia
Tii (Tii)	Highly intensive, irrigated, highly productive, subsistence to semi-subsistence crop agriculture South and East Asia
Tij (Tji)	Highly intensive, irrigated, highly productive, semi-commercial crop agriculture Parts of South and East Asia, Japan
Tiu (Tjm)	Irrigated, medium productive, semi-subsistence to semi-commercial crop agriculture (transitional between Ti and Tm) Northern India

Ts. Traditional small-scale, semi-commercial specialized crop agriculture

Land operated by its owners, less often under various customary rights of tenure. Small scale agriculture with low to medium inputs of labour, low to medium capital inputs, low land and labour productivity, medium commercialization, mixed food-cash crop orientation, very high specialization mostly in perennial industrial crops.

Tse (Tse)	Extensive, semi-commercial, specialized crop agriculture Semi-arid countries of Latin America and Africa
Tss (Tsv)	Semi-commercial, specialized crop agriculture West and East Africa, South-East Asia, Oceania, Latin America
Tsd (Tsc)	Semi-commercial, semi-irrigated, specialized crop agriculture Semi-arid and arid lands of North West India, Pakistan, Sudan

Tl. Traditional, large-scale agriculture (latifundia)

Land privately owned, often operated under servile tenancy. Large scale agriculture with medium inputs of labour and animal power, very low capital inputs, extensive use of land, with low to medium land productivity, medium labour productivity and commercialization, medium specialization in various crop or animal products.

Tlp (Lpp)	Traditional plantations Latin America, some other tropical countries.
Tlc (Lcc)	Traditional latifundia with crop growing prevalent Southern Europe, Latin America
Tll (Lla)	Traditional latifundia with livestock breeding prevalent Southern Europe, Latin America

Tm. Traditional, small-scale, mixed agriculture

Land operated by its owners. Small scale agriculture with high inputs of labour and animal power, low to medium capital inputs medium to high land productivity, low labour productivity, low to medium commercialization, mixed crop and animal orientation.

Tmh (Tdh)	Semi-irrigated, medium productive, subsistence agriculture with livestock grazing developed (transitional between Tm and Ti, closer to E) South Asian Mountains
Tmm (Tmm)	Semi-subsistence to semi-commercial mixed agriculture Parts of Europe, Latin America
Tmc (Tmc)	Semi-subsistence to semi-commercial mixed agriculture, with crop growing prevalent Parts of Europe, Latin America

M. Market-oriented agriculture

Private ownership of land, low inputs of labour, high capital inputs, high land and labour productivity, high degree of commercialization.

Ms. Small-scale, specialized, industrial crop agriculture

Very small to small scale agriculture with medium inputs of labour, very low mechanization, low to medium chemical fertilization, often with irrigation, high productivity of land and medium labour productivity, high commercialization and specialization, mainly in perennial industrial crops.

For a time being no subdivision made because of insufficient information.
Japan, Taiwan, Malaysia, parts of Africa and Latin America.

Mi. Small-scale, highly intensive, crop agriculture

Very small to small scale agriculture with very high inputs of labour, high to very high capital inputs, very high land productivity, high to very high labour productivity, very high specialization in the production of various food crops.

Mii (Mii)	Labour intensive, irrigated, highly productive food crop agriculture (transitional between Mi and Ms) Japan, Taiwan
Mif (Mhf)	Specialized fruit tree growing (transitional between Ma and Ms) Europe, Latin America
Miv (Mhg)	Specialized vegetable growing (market gardening) Europe
Mih (Mgg)	Highly industrialized horticulture (greenhouses important) Europe, North America

Mm. Mixed agriculture

Small to medium scale agriculture with medium labour and high to very high capital inputs, high land and labour productivity, high commercialization with mixed crop and animal orientation.

Mmt (Tml)	Medium-scale, semi-commercial, mixed agriculture with livestock breeding prevalent (transitional between Tm and Mm) Mountains of North and West Europe
Mmc (Mmc)	Small-scale mixed agriculture with crop growing prevalent Southern Europe, Latin America
Mmn (Mmn)	Small-scale mixed agriculture with industrial crops prevalent (transitional between Mm, Ms and Ml) Parts of Europe
Mmm (Mmm)	Small-scale mixed agriculture Central and Western Europe
Mma (Mml)	Medium-scale, mixed, commercial agriculture with livestock breeding prevalent West Europe
Mml (Mxm)	Large-scale mixed agriculture (commercial landed estates) West Europe
Mmb (Mxl)	Large-scale, mixed agriculture with livestock breeding prevalent North America (Dairy and Corn Belts), Australia, New Zealand

Ml. Large-scale intensive crop agriculture

Large-scale agriculture with low inputs of labour and high capital inputs, high land and very high labour productivity, very high commercialization and very high crop production specialization.

Mlc (Mvm)	Large-scale, irrigated, mixed crop agriculture USA, South USA, South Africa
Mlh (Mvh)	Large-scale horticulture (fruit and vegetable) USA, Latin America, South Africa, Australia
Mln (Mvn)	Large-scale industrial crop agriculture USA, Australia, South Africa
Mlp (Mpp)	Modern plantations (transitional between Ml and Ms) Latin America, parts of Africa, South Asia, Oceania

Me. Large-scale, extensive, specialized, grain crop agriculture

Large-scale agriculture with very low inputs of labour, very high mechanization, low land productivity, very high labour productivity, very high specialization in grain crop products, sometimes with subsidiary livestock breeding.

Mem (Mxc)	Extensive grain crop growing and livestock breeding (transitional between Me and Mm) Australia
Mec (Mec)	Extensive grain crop growing USA, Canada, Australia, South Africa

S. Socialized agriculture

Socialized (collective or state) land ownership and operation. Large-scale agriculture of varying intensity and productivity with high degree and prevailing redistributive system of commercialization.

Se. Incipient socialized agriculture

Large-scale agriculture with medium inputs of labour, low inputs of animal power, medium mechanization, low chemical fertilization, extensive use of land, low to medium land productivity, low labour productivity, low to medium commercialization, mixed crop animal orientation.

Sec (Sec)	Incipient, socialized mixed agriculture with crop growing prevalent South-East Europe
Sem (Sem)	Incipient, socialized mixed agriculture East-Central Europe

Sm. Socialized mixed agriculture

Very large-scale agriculture with low inputs of labour, high mechanization and low chemical fertilization, medium to high land and labour productivity, mixed crop-animal orientation.

Smm (Smm)	Mixed agriculture East Central Europe, USSR
Smc (Smc)	Mixed agriculture with crop growing prevalent South Eastern Europe
Smi (Soo)	Capital intensive, irrigated mixed agriculture (transitional between Sm and Sh) South Eastern Europe, southern parts of USSR
Sme (Sll)	Extensive livestock breeding with subsidiary crop growing USSR

Si. Socialized labour intensive agriculture with crop growing prevalent

Very large-scale agriculture, with high to very high inputs of labour, high inputs of animal power, low mechanization and chemical fertilization, important irrigation, high to very high land productivity, low labour productivity, low to medium commercialization, and crop orientation.

Sin (Sin)	Labour intensive non-irrigated agriculture Northern China
Sii (Sii)	Labour intensive irrigated agriculture China, North Vietnam

Sh. Socialized horticulture

Large to very large-scale agriculture with high inputs of labour, very high capital inputs, high land and labour productivity, very high commercialization, high specialization in various food crops.

Shf (Shf)	Specialized fruit tree agriculture (transitional between Sh and Ss) USSR and East-Central Europe
Shv (Shv)	Specialized vegetable agriculture USSR and East Central Europe
Shh (Sgg)	Highly industrialized horticulture (greenhouses important) Various socialist countries

Ss. Socialized, specialized industrial crop agriculture

Very large-scale agriculture with low to medium inputs of labour, medium to high capital inputs, medium land productivity, high productivity of labour, high to very high commercialization and very high specialization in perennial, industrial crop growing.

No subdivision made for the time being, because of insufficient information
USSR (cotton, tea), Cuba (sugar cane etc.)

Sc. Socialized, extensive, specialized grain crop agriculture

Very large-scale agriculture with very low inputs of labour, high mechanization, low chemical fertilization, extensive use of land, very low to low land productivity, medium to high labour productivity, high commercialization and very high specialization in grain crops.

Scc (Scc)	Extensive specialized grain crop growing Southern parts of the USSR

A. Highly specialized livestock breeding

Types of agriculture in which common technological characteristics combined with a large scale of operation and a high degree of specialization in livestock breeding prevail over other agricultural attributes.

Ar. Extensive commercial herding

Market-oriented or socialized, large to very large-scale agriculture, with very low inputs of labour and capital, very low land productivity, medium to high labour productivity, high commercialization and very high specialization in animal products.

Arr. Market-oriented livestock grazing (ranching)
Western USA, Australia, South Africa
Aro. Socialized livestock grazing (otgon)
Southern parts of the USSR, Mongolia

Ad. Highly industrialized (feed-lot), livestock breeding

Market-oriented or socialized large-scale agriculture with very high inputs of labour and capital, very high land and labour productivity, very high commercialization and specialization in various animal products.
Add. Market-oriented, highly industrialized livestock breeding
Various West European Countries, North America
Ado. Socialized highly industrialized livestock breeding
Various socialist countries

The present hierarchy deals with the three highest orders of the types only. If needed, it is possible to subdivide each type of the 3rd order into types of still lower orders. To do so ten classes instead of five as proposed in the 1974 version of the agricultural typology[26] could be used some additional variables relevant for a given territory could be introduced, such as, for example, irrigation systems, the role of part-time farmers, the number and average size of crop fields per one holding, proportion of agricultural production delivered off farm but not sold etc., under the condition that the balance between four groups of attributes is maintained, or else by using 5 per cent differences, i.e. at least 6 deviations from the model types.

The first attempt to present such a subdivision without introducing any additional variables or more classes was made by W. Tyszkiewicz [27] in her study of agriculture of the Thracian Basin, Bulgaria, which appeared to be very monotonous. Two methods were tested in that study: the Szyrmer diagram and the deviation method with the conclusion that the second one was more effective for that purpose.

Transitional cases are another problem. Here, the technique of successive products — somewhat reciprocal to successive quotients technique [28] — was applied successfully to measure the distances between various transitional cases and two or more model types of agriculture,[29] particularly when larger aggregates were used as basic units of investigation.

In case when differences between two or more cases and the model code are around 10, but one is slightly below 11 and another 11 or slightly more,

[26] J. Kostrowicki, *The typology*... 1974.

[27] W. Tyszkiewicz, Agricultural typology of the Thracian Basin, Bulgaria, as a case of the typology of world agriculture, *Geogr. Pol.*, 40, 1979, pp. 171–186.

[28] J. Kostrowicki, Some methods of determining land use and agricultural 'orientations' as used in the Polish land utilization and typological studies, *Geogr. Pol.*, 18, 1970, pp. 93–110; *Idem*, On the methods of determing land use, crop and livestock combinations as used in the Polish studies, in: *Essays in Applied Geography. In memory of the late Professor S. M. Ali, Sagar M. P., India* 1976, pp. 111–120, as well as J. Szyrmer, Przemiany w strukturze przestrzennej produktywności i specjalizacji w rolnictwie indywidualnym w Polsce w latach 1960–1970 (Sum: The spatial changes of the productivity and specialization of individual farming in Poland in 1960–1970), *Dok. Geogr.*, 4–5, 1976, pp. 50–61.

[29] W. Stola, Essai d'application des méthodes typologiques à l'étude comparée sur developpement des agricultures belge et polonaise, *Geogr. Pol.*, (in print); W. Tyszkiewicz, Types of agriculture in Macedonia as a sample of the typology of world agriculture — in the same volume, pp. 163–185.

a 25 per cent clause was proposed to eliminate possible identification of the first case as a pure type, and the repudiation of the other. Such clause states that in such a situation, besides the case which falls within the accepted limit, those that are up to 25 per cent higher should also be taken into account. Practically it applies only to the cases with 9 and 10 deviations from the model codes, which, plus 25 per cent, are respectively 11.25 and 12.5 deviations.

The scheme of the world agricultural types is an open system. While it is doubtful that more types of the 1st order, differing sufficiently from the five listed above, could be identified at least nowadays, it is quite certain that many more types of the 2nd and particularly of the 3rd order could still be discovered, particularly for the countries or periods for which data or literature are scarce. Described in the same way they could supplement the present scheme.

In fact, numerous new types were already described in a number of studies carried on, or encouraged by the Commission. Most of those descriptions, however, were based on the former versions of the typology, differing in some variables, with codes elaborated only for the types of the 3rd order. Rearranged in a proper way they could be included into the present scheme.

At the same time a great number of other studies have recently appeared that bring quantative data characterizing agriculture of various areas or holdings. If expressed by codes, they could also be used for the extension of the present scheme to cover agricultures for which no sufficient data had earlier been available. Another problem is a temporal extension of the scheme to cover agricultures of the past. Many data for their characterization could be found in numerous countries, both in statistics as well as in some historical studies.

Their use and presentation in a comparable way could greatly contribute to the knowledge of the processes and directions of transformation of agriculture in time, endowing the agricultural typology with a more dynamic character. Some studies of that kind have already been completed, none of them, however, covers a period longer than 1–3 decades.[30] Besides a cognitional interest such comparative dynamic studies could be of practical importance for forecasting or programming agricultural development.[31]

[30] W. Stola, Changements dans les types de l'agriculture belge dans les années 1950–1970, in: C. Vanzetti (ed), *Agricultural Typology and Land Utilization*, Verona 1975, pp. 336–339; R. Szczęsny, Changing types of Austrian agriculture 1960–1970, *Geogr. Pol.*, 40, 1979, pp. 161–169.

[31] J. Kostrowicki, An attempt to apply typological methods for forecasting and/or programming further changes in a spatial organization of agriculture, in: C. Vanzetti ... as above, pp. 229–256; *idem*, Agricultural typology as a tool in planning spatial organization of agriculture, *Geoforum*, 7, 1976, pp. 234–259; idem, Agricultural typology. Concept and method, *Agricultural Systems* 2, 1977, pp. 35–45; W. Stola, Essai ..., *op. cit.*

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APPLICABILITY OF NUMERIC TAXONOMY METHODS IN AGRICULTURAL TYPOLOGY PROBLEMS, CRITERIA AND METHODS OF EVALUATION

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INTRODUCTION

The utilization of the apparatus of quantitative methods in certain research areas in nontechnological sciences where they have never been employed before is, as a rule, a hard and intricate task. To obtain effects positive from the cognitive point of view when applying the quantitative methods certain defined requirements should be fulfilled. The interdisciplinary method of work, i.e. the co-operation of mathematician with a branch specialist, is of vital significance in setting and solving a given research problem. The specialist should determine the subject and goal of research, as well as to formulate questions which should be answered. The mathematician should match adequate quantitative methods or even submit a new one which would ensure correct answers to the questions put by the specialist. The mathematician is therefore obliged to analyse throughly the subject and goal of research, formulated by the specialist, and to verify information as to its being adequate for the subject and goal of research.

In matching the quantitative method it should be remembered that usually one must select the most efficient method among the adequate ones for solution of the given research problem. To this end it is, of course, necessary to be well aware of the degree of efficiency of each separate method.

However, our knowledge of the efficiency of quantitative methods is rather poor, and as regards current needs it must be more profound. This opinion is also true as far as the applicability of quantitative methods in geography of agriculture is concerned.

The authors of this paper have taken up research which could provide an answer to the question put by the geographers of agriculture — which quantitative method is the most adequate for typology of agriculture.

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Quantitative methods which we had to evaluate in our research were determined by the principal methodological problems with which typology of agriculture[1] was concerned, namely:

[1] Cf.: J. Kostrowicki, *The typology of world agriculture. Principles, methods and model types*, Warszawa 1974, 74 pp. International Geographical Union, Commission on Agricultural Typology (mimeographed); *World types of agriculture*, Warsaw 1976, 49 pp.+1. Fig. International Geographical Union, Commission on Agricultural Typology (mimeographed).

(1) the selection and appropriate expression of diagnostic characteristics (features) of type of agriculture, and

(2) the method of dividing (classifying, grouping) the sets of objects (spatial units), which may ensure the comparability of the results of grouping in both space and time.

Potentially adequate methods which can be used to solve problems associated with those listed above, are:

(1) factor analysis methods which make it possible

— to pass from the system of non-comparable characteristics to one of statistically comparable common factors,

— to analyse dependences between diagnostic characteristics,

— to reduce the set of diagnostic characteristics to the minimum set of common factors without losing information contained in the set of initial characteristics,

— to analyse similarities between objects;

(2) numeric taxonomy methods which deal with:

— the classification, i.e. the division of a non-homogeneous set of multicharacteristic objects into groups of objects similar — on the ground of investigated characteristics,

— the (subordination) ordering of objects, i.e. a formalized presentation of the structure of similarity between the objects of the analysed set.

At the moment we started our work the world literature on the subject was characterized by great heterogeneity as regards the grouping procedures and — at the same time — no clarity existed as to which method was the best.[2] In consequence the opinion prevailed that the most appropriate procedure from the practical point of view was to make methodical experiments taking into consideration the requirements of the given discipline. In such conditions the selection of the best quantitative method which could be applied in typology of agriculture required that many methods had to be tested on an empiric material.

First of all, we tested a group of 'popular' methods, i.e. multivariate analysis methods (cf. Annex 1), known and popularized in Polish and other literatures. We tried to explain:

(1) whether and with what effect 'popular' methods could be utilized in typology of agriculture;

(2) which of the methodical solutions for typology of agriculture or regionalization, proposed in the world literature, could be adopted without any modification for use in the method of typology of agriculture, which is being worked out in Poland.

When it appeared that there was no effective way in which 'ready' methods could be applied, the centre of gravity was shifted in our research towards a search for our own methods, better than the previous ones.

The following four new taxonomic methods are the outcome of our investigations:

(1) the ORLINE method, worked out by Z. Piasecki,

(2) the GRAVITY method, worked out by M. Paprzycki,

(3) the FARELL-mod method, which is a modification by M. Paprzycki of the FARELL method,

(4) the IDVER method, worked out by Z. Piasecki.

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[2] Cf.: J. W. Aitchison, The farming systems of Wales, in: C. Vanzetti (ed.), *Agricultural typology and land utilization,* Verona 1975, pp. 109–146.

The consecutive stages of our research have been presented i.a. at the meetings of the IGU Commission of Agricultural Typology in Verona,[3] Paris,[4] and Odessa.[5]

One of the conclusions we have drawn so far is that numeric taxonomy methods, quite correct from the point of view of mathematical formalism (rules of expressing entities and relations according to requirements of mathematical precision) and an efficient classifying instrument in some areas of application, can be entirely useless in typology of agriculture, as was the case with the Wroclaw taxonomy method. There is therefore a need to look for a formal method of evaluation of the applicability of taxonomic methods, which is particularly important since the effectiveness of the applied given method of classification (division) is appraised on the basis of the evaluation of the obtained division of a set.

Hence, the question which appeared on the agenda was how to evaluate classification methods. This issue is as important as it is difficult. The present paper contains our proposals how to solve the problem.

METHODOLOGICAL PREMISES AND METHODS FOR THE EVALUATION OF EFFICIENCY OF CLASSIFICATION METHODS

Specificity of the construction of numeric taxonomy methods causes that each method (they are numerous, as we are well aware) used for classification of a set of multicharacteristic objects brings about a different division of the same given set. We have therefore started research leading to the selection of the most efficient method out of those adequate for the subject of the analysis.

The basic requirement for the classification method of the set of multicharacteristic objects is that the singled out groups contain objects which are as similar as possible and at the same time the groups differ one from an other, again to a highest possible degree.

Besides this basic requirement certain other special requirements can also be put before the method, namely: comparability of grouping results of sets in space and time, hierarchization of the division, arrangement of the objects according to their similarity degrees, and others.

As the efficiency of methods depends on selecting the most efficient one out of all adequate, it is very important that the branch specialist interested in the application of a quantitative method formulates the goal and requirements of the classification, which he proposes to carry out.

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[3] K. Bielecka, M. Paprzycki, Z. Piasecki, An evaluation of the applicability of selected mathematical methods for the typology of agriculture, in: C. Vanzetti (ed.), *Agricultural typology and land utilization*, Verona 1975, pp. 55–70; also Z. Piasecki, A Study of applicability of selected mathematical methods in agricultural typology — Proposal of a new identification-verification method, a paper read in Verona, September 1974, duplicated typescript, pp. 11; next published, Proposal of a new identificatio-verification method to be used in agricultural typology, in: C. Vanzetti (ed.), *Agricultural typology and land utilization*, Verona 1975, pp. 269–276.

[4] Z. Piasecki, *A typology of Poland's agriculture — A study of application of the IDVER method*, a paper read at the Paris Conference, September 1975 Fontenay-aux-Roses, duplicated typescript, pp. 8+1 map, now being in print; The French version: *La typologie de l'agriculture de la Pologne — Etude sur l'application de la methode IDVER.*

[5] K. Bielecka, M. Paprzycki, Evaluation of taxonomic methods from the point of view of comparability of results in space and time — in optimization aspect, a paper read in Odessa, July 1976, duplicated typescript pp. 7, published in: *Geogr. Pol.*, 40, 1979, pp. 187–190.

To evaluate efficiency of numeric taxonomy methods its formal evaluation has to be made by a mathematician and the cognitive evaluation by a branch specialist interested in its application.

The initial formal evaluation is made from the point of view of selecting methods adequate to fulfil the classification requirements. It consists of a logical analysis of the construction of taxonomy methods, i.e. of the analysis of the measure of similarity, of the criterion of the division of a set and of the algorithm. This analysis should be made in full awareness of such assumptions as: that the requirement of the comparability of the results of grouping can only be fulfilled by methods which operate on open sets; that the hierarchization of the division can be obtained when using hierarchical methods; and that objects should be arranged in required positional sequence with methods of ordering.

The best among adequate methods can be specified, as it has been done before, by comparing the division of the given set made by means of several such methods.

The formal evaluation of goodness of the division of a set, which is usually applied, is a logical analysis of the material under observation, combined with autopsy and intuition, and of the divisions obtained.[6] This method makes it possible to evaluate:
(1) the sharpness of the division, i.e. to ascertain by which procedure the groups are most sharply distinguished; (2) the inclination of the method, i.e. to establish the structure of the division, for example: whether there is an inclination to form small numbers of large groups, or to join objects in chains; etc.; (3) the minuteness of the division details; (4) the internal homogeneity of groups but in a highly generalized degree.

This potentially possible — when the logical analysis is combined with autopsy and intuition — reach of cognition and formal evaluation of goodness of the set division is insufficient and therefore the cognitive evaluation by a branch specialist is of great significance. The latter, using all his knowledge of the morphology of the classified object, should decide whether the obtained division of the analysed set is — according to him — acceptable or not. The knowledge of the classified objects plays here an important role and it is possible to rely on this criterion. However, there is a need to be careful in passing the judgement. The specialist evaluates the division of a set through though comparison with the picture, conceived by himself, of the structure of a multicharacteristic phenomenon, which examined so far analitically only as regards its single characteristics makes the picture not necessarily tally with reality. Moreover, it should always be remembered that classification concerns always only the information contained in the adopted descriptive characteristics, and therefore the results of the division of a set are approximate to reality in such a degree in which adopted descriptive characteristics and the manner of their measuring are adequate for the classified object.

The cognitive evaluation of goodness of the division of a set may be correct only in case of a good knowledge of the morphology of the investigated object. It happens however quite often that a little known object is classified, and then the cognitive evaluation of goodness of the division of a set may be based only on intuition, which is not sufficiently satisfactory criterion.

Thus, both the situation in which the object is little known and that when the choice is guessed after certain hesitation, make it necessary to continue

[6] We have also applied this method in our research work.

search for solution among quantitative criteria, which would be objective, very sharp, diagnostic instrument to be used in the division of a set.

Science has not as yet worked out the formal criterion of the evaluation of goodness of division of a set of multicharacteristic objects. Our work in this field is pioneering.

The solution proposed is to adopt a criterion which will minimalize the intragroup differences and maximalize the intergroup differences of the divided set — on account of the variability of descriptive characteristics (features). Such a criterion could be, for example, the maximum of the function which is a ratio of the multidimensional intergroup variance to the multidimensional intragroup variance. Unfortunately, it has not been possible so far to solve numerically the task thus formulated.

An approximate solution of this complicated issue is the system of formal criteria which we have worked out using also the findings obtained by F. A. Szczotka (Annex 2).

FORMAL CRITERIA OF THE EVALUATION

As there is no unequivocal criterion of the evaluation of goodness of the division of a set we have used a system of 14 criteria. The system was formulated on the basis of the principle, stipulating consideration of the various aspects of intuitive premise of taxonomy — minimalization of intragroup differences and maximalization of intergroup differences.

The criteria adopted by us are as follows:

1. Average intergroup distance $K_{10} = d_{sm}$

(1) $$(1) d_{sm} = \frac{2}{n(n-1)} \sum_{i=1}^{n} \sum_{j=i+1}^{n} \min_{\left\{ \substack{k \in N_i \\ l \in N_j} \right\}} (d_{kl})$$

2. Maximal intergroup distance $K_{11} = d_{Mx}$

(2) $$d_{Mx} = \max_{\left\{ \substack{i, j \in N \\ i = j} \right\}} \min_{\left\{ \substack{k \in N_i \\ l \in N_j} \right\}} (d_{kl})$$

3. Minimal intergroup distance $K_{12} = d_{mx}$

(3) $$d_{mx} = \min_{\left\{ \substack{i, j \in N \\ i = j} \right\}} \min_{\left\{ \substack{k \in N_i \\ l \in N_j} \right\}} (d_{kl})$$

4. Proportion of average intergroup distance of average of averages intragroup distances $K_{13} = \frac{d_{sm}}{d_{ws}}$

(4) $$d_{ws} = \frac{1}{n} \sum_{i=1}^{n} \sum_{\left\{ \substack{j \in N_i \\ j \neq k} \right\}} \sum_{k \in N_i} d_{kj} \frac{1}{(n_i - 1) n_i}$$

where:

N — is the set of numbers of groups,

n — is the number of groups,

d_{kj} — is the euclidean distance between the kth and jth objects (spatial units),

N_i — is the set of numbers of objects belonging to the ith group,

n_i — is the frequency of the ith group.

5. Product of maximal intergroup distance and average diameter of groups $K_{14} = d_{Mx} \cdot d_{wm}$

$$d_{wm} = \frac{1}{n} \sum_{i=1}^{n} \max_{\substack{j \in N_i \\ k \in N_i \\ j \neq k}} (d_{kj}) \tag{5}$$

6. Product of maximal intergroup distance and average of averages intragroup distance $K_{15} = d_{Mx} \cdot d_{ws}$

7. Proportion of average diameter of groups to minimal intergroup distance $K_{16} = \frac{d_{wm}}{d_{mx}}$

8. Proportion of average of averages intragroup distances to minimal intergroup distance $K_{17} = \frac{d_{ws}}{d_{mx}}$

9. Average intergroup ratio $K_{18} = d_s$

$$d_s = \frac{2}{n(n-1)} \sum_{i=1}^{n} \sum_{j=i+1}^{n} D_{ij} \tag{6}$$

$$D_{ij} = \max_{\substack{k \in N_i \\ l \in N_j}} (d_{kl}) / \min_{\substack{k \in N_i \\ l \in N_j}} (d_{kl}) \text{ for } \{i,j: l \in N, j \in N, i \neq j\}$$

10. Maximal intergroup ratio $K_{21} = d_M$

$$d_M = \max_{\substack{i,j \in N \\ i \neq j}} (D_{ij}) \tag{7}$$

11. Minimal intergroup ratio $K_{22} = d_m$

$$d_m = \min_{\substack{i,j N \\ i \neq j}} (D_{ij}) \tag{8}$$

12. Product of average intergroup ratio and average of averages intragroup distances $K_{23} = d_s \cdot d_{ws}$

13. Product of maximal intergroup ratio and average diameter of groups $K_{24} = d_M \cdot d_{wm}$

14. Product of maximal intergroup ratio and average of averages intragroup distances $K_{25} = d_M \cdot {}_{ws}$

Criteria K_{10}, K_{11}, K_{12}, K_{20}, K_{21}, and K_{22} are based exclusively on the intergroup and intragroup variance evaluated by means of diverse, contradictory manner.

Criteria K_{13}, K_{14}, K_{15}, K_{16}, K_{17}, K_{23}, K_{24} and K_{25} are based on the intergroup and intragroup variance. This means that these are some of many analytically possible manners of expressing the primary criterion of taxonomy, i.e. they make it possible to obtain as a result of taxonomy (classification) such a division that simultaneously fulfils the following two conditions:

(1) the groups are internally homogeneous, and

(2) the groups differ substantially one from another.

It should, however, be emphasized that all selected criteria are constructed of intraobject distances and are not directly influenced by the values acquired by the objects (spatial units) in their characteristics, which causes that they are not directly associated with the mutual positioning of objects in the space of the characteristics.

In accordance with the given idea of the criterion of goodness of the division of a set, which implies that the most profitable situation is when the intragroup distance is minimal and the intergroup distance is maximal — the division of a set will get better with smaller values of criteria K_{11}, K_{14}, K_{15}, K_{16}, K_{17}, K_{20}, K_{21}, K_{23}, K_{24} and K_{25}, and higher values of criteria K_{10}, K_{12}, K_{13} and K_{22}.

THE APPLICATION

A system of 14 quantitative criteria was used in the formal evaluation dividing results of a set of 61 spatial units of the world described by means of the codes,[7] in this work five following taxonomic methods were used: WARD'S, Z. Piasecki's ORLINE, M. Paprzycki's FARELL-mod, M. Paprzycki's GRAVITY and Z. Piasecki's IDVER. They were selected from among 16 taxonomic methods analysed earlier and matched in such a way that they represented various kinds of taxonomic methods and various areas of potential applications.[8]

WARD'S METHOD IS ONE OF THE DENDRITIC METHODS[9]

This method is based on the principle of division of the set by using the criterion of the minimal growth of intragroup variance.

The dividing results of the analysed set obtained by this method are given in Fig. 1. and in Table 1.

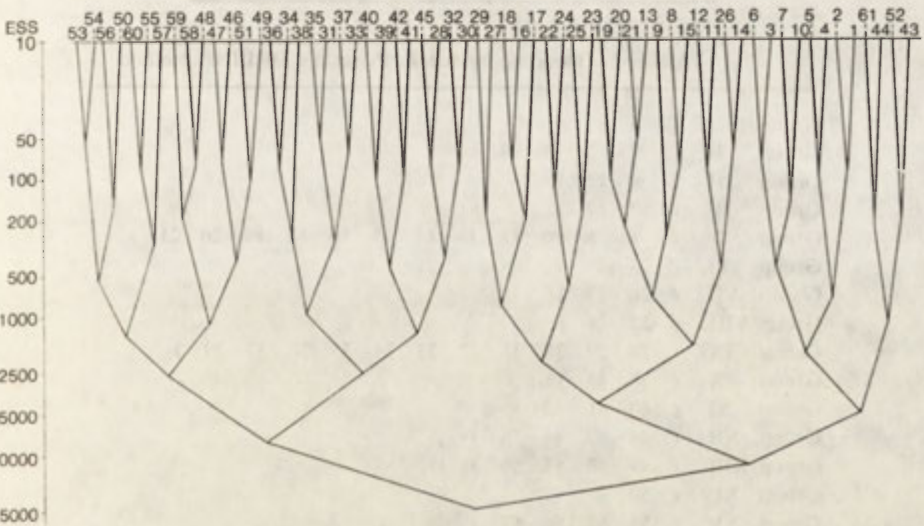

Fig. 1. Linkage tree for grouping by WARD'S method

ESS = Error Sum of Squares

The diagram has been made in logarithmic scale

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[7] The codes worked out by Professor J. Kostrowicki (Annex 3).

[8] Methods: ORLINE; FARELL-mod, GRAVITY and IDVER are described in a paper by K. Bielecka, M. Paprzycki, Z. Piasecki, Proposal of new taxonomic methods for agricultural typology, *Geogr. Pol.*, 40, 1979, pp. 191–200.

[9] WARD'S method is described in: J. H. Ward, Hierarchical grouping to optimize an objective function, *Journal of the American Statistical Association*, 58, pp. 236–244.

THE ORLINE METHOD REPRESENTS DIAGRAPHICAL METHODS

This method, which is a formalization of the idea of Czekanowski's diagraphic method,[10] utilizes distances and orders the objects linearly.

The dividing results of the set by ORLINE method are given in Table 2.

Dividing results of the set of 61 world types of agriculture

TABLE 1. Grouping by the WARD'S method

Group	I.	(50 53 54 56)
Group	II.	(55 57 60)
Group	III.	(48 58 59)
Group	IV.	(46 47 49 51)
Group	V.	(31 33 34 35 36 37 38)
Group	VI.	(39 40 41 42)
Group	VII.	(28 30 32 45)
Group	VIII.	(16 17 18 27 29)
Group	IX.	(22 23 24 25)
Group	X.	(8 9 13 15 19 20 21)
Group	XI.	(11 12 14 26)
Group	XII.	(3 6 7 10)
Group	XIII.	(1 2 4 5)
Group	XIV.	(44 61)
Group	XV.	(43 52)

TABLE 2. Grouping by the Z. Piasecki's ORLINE method

Group	I.	(5)
Group	II.	(1 2 3 4)
Group	III.	(9 12)
Group	IV.	(7 17)
Group	V.	(6 8 10 11 13 14 15 16 18 19 20 21)
Group	VI.	(23 25)
Group	VII.	(26 27)
Group	VIII.	(22 24)
Group	IX.	(28 29 30 31 32 33 34 35 36 37 39)
Group	X.	(38 45)
Group	XI.	(40 41 42)
Group	XII.	(46 47 48 58)
Group	XIII.	(49 50 55 56)
Group	XIV.	(59)
Group	XV.	(51 53 54 57)
Group	XVI.	(60)
Group	XVII.	(43 44 52 61)

[10] J. Czekanowski, Zur Differentialdiagnose der Neandertalgruppe, in: *Korespondenz-Blatt der Deutschen Gesellschaft für Anthropologie, Ethnographie und Urgeschichte*, XL, 1909, pp. 44–47; Zarys metod statystycznych w zastosowaniu do antropologii (An outline of statistical methods applicable in anthropology), in: *Prace Towarzystwa Naukowego Warszawskiego, III Wydział Nauk Matematycznych i Przyrodniczych*, 5, 1913, pp. 167–172.

TABLE 4. Grouping by the M. Paprzycki's GRAVITY method

Group	I.	(1 2 3 4 5 6 7)
	I.1.	(1 2)
	I.2.	(3 6)
	I.3.	(4 5)
	I.4.	(7)
Group	II.	(8 10 11 12 13 14 15 19 20 21 26) + (**9** extreme)
	II.1.	(13 19 20 21)
	II.1.1.	(13 21)
	II.1.2.	(19)
	II.1.3.	(20)
	II.2.	(10 11 12)
	II.3.	(**8 15**) + (9 extreme)
	II.4.	(**14 26**) extreme sub-group
Group	III.	(16 17 18 25 27)
	III.1.	(16 17 18)
	III.2.	(25)
	III.3.	(27)
Group	IV.	(30 31 32 33 34 35 36 37 38 39 40 41 42) + (**22** extreme)
	IV.1.	(31 33 34 35 36 37)
	IV.1.1.	(31 35)
	IV.1.2.	(33 37)
	IV.1.3.	(34 36)
	IV.2.	(30 32)
	IV.3.	(39 40) + (**38** extreme)
	IV.4.	(**41 42**) extreme sub-group
	IV.5.	(22) extreme sub-group
Group	V.	(46 47 48 51 53 54 55 56 57 58 59 60) + (**50** extreme)
	V.1.	(46 47 48 49 51 58) + (**59** extreme)
	V.1.1.	(46 47)
	V.1.2.	(48 58)
	V.1.3.	(49)
	V.1.4.	(51)
	V.1.5.	(**59**) extreme
	V.2.	(53 54)
	V.3.	(55 56 50)
	V.3.1.	(55 60)
	V.3.2.	(56)
	V.4.	(57)
	V.5.	(**50**) extreme
Group	VI.	(28 29 45)
	VI.1.	(28 45)
	VI.2.	(29)
Group	VII.	(24 43 44 52 61)
	VII.1.	(24 43 52)
	VII.2.	(**44 61**) extreme sub-group
Group	VIII.	(23)

TABLE 3. Grouping by the M. Paprzycki's FARELL-mod method

Group I.	(3 6 7 8 9 10 11 12 13 15 18 19 20 21 23)
Group II.	(1 2)
Group III.	(3 5)
Group IV.	(16 17)
Group V.	(22 29 30 31 32 33 34 35 36 37 38 39 40)
Group VI.	(24 43)
Group VII.	(25)
Group VIII.	(14 26 28 45)
Group IX.	(27)
Group X.	(41 42)
Group XI.	(46 47 48 49 50 51 53 54 56 57)
Group XII.	(52)
Group XIII.	(58 59)
Group XIV.	(55 60)
Group XV.	(44)
Group XVI.	(61)

TABLE 5. Grouping by the Z. Piasecki's IDVER method

Group I.	(5)
Group II.	(43 44 52 61)
Group III.	(3 4 33)
Group IV.	(22 24 35 36 37 47 49 51 57)
Group V.	(53 54)
Group VI.	(34 38 46 48 50 55 56 58 59 60)
Group VII.	(19 21)
Group VIII.	(23 26 28 29 30 31 32 39 40 41 42 45)
Group IX.	(27)
Group X.	(2 6 7 8 10 11 12 13 14 15 16 20 25)
Group XI.	(9 18)
Group XII.	(17)
Group XIII.	(1)

For letter symbols see: Annex 3

Numeral symbols applied in these tables correspond with those used by Professor Kostrowicki in his paper *A hierarchy of world types of agriculture* — published in the present volume, Table 2 p. 131.

THE FARELL-mod METHOD REPRESENTS THE METHODS OF PATTERN RECOGNITION

The idea of the FARELL-method, worked out at the Novosybirsk University, is retained in the modification. The FARELL method is an attempt at a simulation of methods which would be used by man if he visually divided a set of points in the two-dimensional space into internally homogeneous groups. Its modification by M. Paprzycki consists of introducing the requirement of the affiliation of the object to a group with the centre of gravity lying closer to the geometrical centre.

The division of the analysed set was obtained for the radius $r = 6.5$. The dividing results are given in Table 3.

THE GRAVITY METHOD REPRESENTS CENTROIDAL METHODS

This method is an adaptation of the physical phenomenon of gravity to numeric taxonomy, combined with the use of statistical evaluation of significance of changes in the internal structure of groups in the process of grouping.

By means of this method a hierarchical division of the analysed set was obtained (Table 4) while the following three levels of significance: $\alpha_1 = 0.01$ $\alpha_2 = 0.05$ and $\alpha_3 = 0.10$ were used. As — contrary to other methods applied here — the GRAVITY method produces a hierarchical division it had to be modified to ensure comparison. Therefore the division by GRAVITY method was replaced by two nonhierarchical divisions: into 8 groups and into 26 groups corresponding with the division into sub-groups of the first rank (Table 4).

THE IDVER METHOD REPRESENTS METHODS WHICH APPLY A FRAME OF REFERENCE

Its elements are as follows:

(1) the manner of transformation of characteristics describing the object leading to the acquisition of the so-called angular values depicting structural dependence between characteristics,

(2) the frame of reference, called in the IDVER method the 'basic set' which in theoretical assumption is a set of differentiable representants, i.e. which can be distinguished, of types of agriculture,

(3) the classification of the set, based on the principle of identifying the given set with a frame of reference (a basic set), which can be referred to sets with a very big, theoretically infinite, number of objects, i.e. on open sets; this makes the IDVER method differ from the previous four taxonomic methods, operating on closed sets. The conception of the IDVER method implies that comparability in time is equiponderant with comparability in space because every object described in two different time cross-sections may be treated as two spatially differing objects.

When the given set of the spatial units of the world was divided by means of the IDVER method, the following basic set, composed of the pairs of units: 42-41, 6-2, 60-55, 10-11 and 26-27, was used. The dividing results are given in Table 5.

THE RESULTS OF THE APPLICATIONS

Table 6 contains results obtained by using the system of 14 criteria of goodness of the division of the set and selected taxonomic methods:

TABLE 6

Criteria		WARD'S method	ORLINE	FARELL -mod	GRAVITY I.	GRAVITY II.	IDVER
	d_{wm}	7.28	6.16	4.12	8.16	3.70	6.20
	d_{ws}	5.63	5.22	3.41	5.54	3.18	4.54
K_{10}	d_{sm}	8.10	8.82	9.49	6.48	8.63	8.15
K_{11}	d_{Mx}	13.53	19.03	15.97	10.05	14.76	15.23
K_{12}	d_{mx}	3.87	3.46	3.87	4.24	3.87	3.16
K_{13}	d_{sm}/d_{ws}	1.44	1.69	2.78	1.17	2.71	1.79
K_{14}	$d_{Mx} \cdot d_{wm}$	98.47	117.25	65.79	82.00	54.58	94.48
K_{15}	$d_{Mx} \cdot d_{ws}$	76.15	99.30	54.41	55.70	46.99	69.16
K_{16}	$d_{wm} \cdot d_{mx}$	1.88	1.78	1.06	1.92	0.95	1.96
K_{17}	$d_{ws} \cdot d_{mx}$	1.45	1.51	0.88	1.31	0.82	1.44
K_{20}	d_s	1.68	1.49	1.44	2.18	1.32	1.80
K_{21}	d_M	3.00	3.15	3.46	3.50	2.53	4.05
K_{22}	d_m	1.14	1.00	1.00	1.25	1.00	1.00
K_{23}	$d_s \cdot d_{ws}$	9.47	7.78	4.90	12.09	4.22	8.15
K_{24}	$d_M \cdot d_{wm}$	21.84	19.42	14.27	28.57	9.36	25.13
K_{25}	$d_M \cdot d_{ws}$	16.89	16.45	11.80	19.41	8.06	18.40
	n	15	17	16	8	26	13

The results obtained reveal that:

— no division is best if all evaluation criteria are taken into consideration,

— each division possesses a criterion which makes it good,

— the biggest number of best ratings was yielded by the GRAVITY method (26 groups),

— in the light of 14 criteria adopted in our research the order in which the methods are arranged is as follows: starting with GRAVITY II, GRAVITY I, FARELL-mod, WARD'S, ORLINE, IDVER.

CONCLUSIONS

1. As an outcome of the application of a number of criteria of the formal evaluation of classification methods a table of numerical results of evaluation of the analysed quantitative methods is obtained (Table 6). The table should in turn be formally evaluated by means of a method which to a great extent is conditioned by the subject of research. Various formulas are used to reduce the figures describing every method to an unequivocal criterion, for example:

— the maximum of the number of the highest ratings,

— the maximum of the number of the lowest ratings,

— the maximum of the sum of ratings normalized in the criteria of the formal evaluation,

— the maximum of the weighted sum of ratings normalized in the criteria of the formal evaluation (weights depending on the significance of the criterion),

— the maximum sum of 'places' obtained by the ratings in the criteria of the formal evaluation,

— the maximum sum of the ranks of ratings in the criteria of the formal evaluation.

The above-described procedure makes the evaluation of goodness of the classification methods an easier task; however, it does not provide an answer to the question whether the method found the best from the formal point of view is the most efficient from the cognitive point of view.

The 'chosen' method must be tested by:

(1) a formal evaluation,

(2) a cognitive evaluation of results obtained by its application,

(3) the verification of conclusions drawn from the application of the method to research object.

And only then the method can be recognized as the most efficient.

The methods should be tested in the given order 1, 2, 3, and at every stage ineffective methods should be eliminated. This means, for example, as regards the formal evaluation, that those methods out of the analysed set should be eliminated which received the biggest number of bad ratings in the criteria of the formal evaluation.

2. When evaluating the results obtained through division of the set of 61 spatial units of the world by means of the six selected methods the following should be taken into account:

(1) differences in the character of divisions (hierarchical division obtained by means of the GRAVITY method, and other divisions) are caused by various properties of the methods,

(2) the analysed methods differ in the scope of their application: the IDVER method can be used not for grouping but for ordering and identifying the abjects with a model structure,

(3) if all the criteria of the formal evaluation of division of the set are based on the distances between the objects, a certain one-sidedness would occur,

(4) a possible enrichment of the body of the evaluation criteria would only widen the gap between the ratings given to every classification method and bring nothing to the assessment of the method itself as far as its goodness is concerned.

3. The results of the grouping carried out in our research prove that the classified set of the 61 agricultural types of the 3rd rank would be a perfect 'basic set' for the IDVER method and therefore the result of grouping by the IDVER method cannot be positive in this case.

4. The method of FOURTEEN CRITERIA worked out by M. Paprzycki for the formal evaluation is a diagnostic instrument enabling the researcher to obtain an answer — on the basis of the formal evaluation of the results of the grouping of a set — which of the two classification methods is more efficient from the formal point of view.

ANNEX 1. The 'popular' methods analysed by the authors

1. The R technic of the factor analysis
2. The method of principal component analysis
3. The method of grouping by the Q technic of the factor analysis
4. The Berry method, grouping based on the initial characteristics
5. The Berry method, grouping based on the Hotelling components
6. The single linkage method
7. The complete linkage method
8. The paired group method
9. The Hubert divisive method A

10. The Hubert divisive method B
11. The McQuitty elementary linkage analysis
12. The McQuitty restricted linkage analysis
13. The McQuitty maximum distance replacement
14. The Wrocław Taxonomy method
15. The FARELL method
16. The Ward method

ANNEX 2. F. A. Szczotka's formal criteria of the evaluation of goodness of the division of a set

1. Indices characterizing the frequency of the groups
   (1) Number of one-object groups
   (2) Number of objects in the most numerous group
   (3) Variance of the number of the objects in groups
2. Indices characterizing the homogeneity of the groups
   (4) Sum of squares of intergroup distances
   (5) Average square of intergroup distances
   (6) Relative sum of squares of intergroup distances
   (7) Sum of squares of distances from the center of intergroup gravity
   (8) Sum of squares of distances between groups
   (9) Ratio of the sum of squares of distances between groups and sum of squares of distances from the center of intergroup gravity.

ANNEX 3. Numbers and symbols of 61 objects of the classified set*

No.	Symbol	No.	Symbol	No.	Symbol	No.	Symbol
1.	Tsf	17.	Tse	32.	Mmn	47.	Sem
2.	Tsb	18.	Tsc	33.	Mml	48.	Smc
3.	Toc	19.	Tmk	34.	Mxm	49.	Smm
4.	Ton	20.	Tmc	35.	Mxg	50.	Scc
5.	Tnn	21.	Tmm	36.	Mxc	51.	Sll
6.	Tem	22.	Tml	37.	Mxl	52.	Srr
7.	Tec	23.	Lcc	38.	Mcc	53.	Stc
8.	Tds	24.	Lll	39.	Mvm	54.	Sth
9.	Tdh	25.	Lpp	40.	Mvh	55.	Shv
10.	Tia	26.	Mii	41.	Mvn	56.	Shf
11.	Tin	27.	Mss	42.	Mpp	57.	Soo
12.	Tii	28.	Mhg	43.	Mrr	58.	Sin
13.	Tjn	29.	Mhf	44.	Muu	59.	Sii
14.	Tji	30.	Mmc	45.	Mgg	60.	Sgg
15.	Tjm	31.	Mmm	46.	Sec	61.	Suu
16.	Tsv						

* Source: J. Kostrowicki, *World types of agriculture*, Warsaw 1976, International Geographical Union, Commission on Agricultural Typology, pp. 24–35; also: *A hierarchy of world types of agriculture* — published in the present volume, Table 2, p. 131, and table 3 p. 138.

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TYPES OF AGRICULTURE IN MACEDONIA AS A SAMPLE OF THE TYPOLOGY OF WORLD AGRICULTURE

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The objective of this paper is to apply the concept and method of the typology of world agriculture[1] to the agriculture of Macedonia, a federal republic of Yugoslavia.

Statistical data used in this study were collected by the author during her stay in Yugoslavia in 1974 and 1975, mostly from the Statistical Office in Skopje.[2]

Macedonia forms the South-Eastern part of the Federal Socialist Republic of Yugoslavia. A considerable part of the republic is occupied by mountains surrounding numerous basins and valleys, where agriculture has flourished since immemorial time. Cultivated land covers no more than 25.7 per cent of the country's area. But for centuries the mountains have been also used for seasonal livestock grazing.

Because of the great variety of relief, the climate is also very varied. In the areas where agriculture is practised the mean temperature varies from 0 to 2° in January and from 22° to 25° in July. The precipitation ranges from 400 mm in the East to 900 mm in the West. The climate is continental with dry summers. The southern part of Macedonia borders on the Mediterranean climatic zone.

The population of Macedonia is heavily concentrated in the basins and valleys. It consists first of all (69.3 per cent) of the Slavic Macedonians. The Albanians (17 per cent) live predominantly in the western part of the country. The Turks (6.6 per cent) are more scattered. There are also Serbs, Gipsies as well as Tzintzari and Vlachs — the remnants of the ancient Romanized population. The Albanians and the Turks are mostly Moslems (together about 24 per cent of the total population), which has an impact on the orientation of farming.

Because of the long-lasting foreign occupation and a relative isolation of the country, the agriculture retained its obsolete character for a long time. Only after World War II, when a new socialist system was introduced and Macedonia became an autonomous federal republic, a notable impetus was given to a rapid economic and social development of the country. The land reform eliminated large landed estates, which since the emigration of Turks

[1] J. Kostrowicki, *The typology of world agriculture. Principles, methods and model types*, IGU, Commission on Agricultural Typology, Warszawa 1974. 74 p.

[2] It is the author's pleasant duty to thank Professor M. Panov, Dr M. Gramatnikovski and Mr. U. Daskalovski for their help in making these data available as well as for all their information, suggestions and comments that made the present paper possible.

had not been very numerous, and the modern socialized large-scale agriculture was introduced. However, within such a short period as 30 years, the long-lasting backwardness could not be overcome. As a result the most modern techniques together with numerous archaic ones characterize the present-day Macedonian agriculture.

An *opština* (i.e. a commune), the only administrative unit below the federal republic, has been adopted in the present study as the basic unit. There are 30 *opštinas* in Macedonia and their size ranges from 223 to 1823 square kilometers. Most of the data collected are from the years 1971 or 1972.

In accordance with the 1974 version of the typology of world agriculture[3] the study was based upon 22 variables, characterizing the most important aspects of agriculture,[4] namely:

(1) Land ownership,

(2) Land operation,

(3) Size of holdings in terms of the number of actively employed per 1 holding,

(4) Size of holdings in terms of the number of hectares of agricultural land per 1 holding,

(5) Size of holdings in terms of the number of livestock measured in conventional (large) animal units per 1 holding,

(6) Size of holdings in terms of gross agricultural production per 1 holding,

(7) Inputs of labour measured by the number of actively employed in agriculture per 100 hectares of agricultural land,

(8) Inputs of animal power measured by the number of draught animals in conventional (horse) units per 100 hectares of cultivated land,

(9) Inputs of mechanical power measured by the number of tractors and self-propelling machinery in the number of HP per 100 hectares of cultivated land,

(10) Chemical fertilizing measured as the amount of chemical fertilizers in pure content NPK used per 1 hectare of cultivated land,

(11) Irrigation measured as the percentage ratio of irrigated to total cultivated land,

(12) Intensity of cropland use expressed as the ratio of harvested to cultivable land (including fallow),

(13) Importance of the system of perennial cropping measured by the percentage ratio of perennial cropland to total agricultural land,

(14) Importance of the permanent grassland system measured by the percentage ratio of permanent grasslands to total agricultural land,

(15) Intensity of livestock breeding measured as the number of farm animals in conventional (large) animal units per 100 hectares of agricultural land,

(16) Land productivity measured in gross agricultural (crop and animal) output in conventional (grain) units per 1 hectare of agricultural land,

(17) Labour productivity measured, as above, per one person actively employed in agriculture,

(18) Degree of commercialization expressed as the percentage ratio of commercial to gross agricultural production,

(19) Level of commercial production as a volume of commercial agricultural production measured in the same units, per 1 hectare of agricultural land,

[3] J. Kostrowicki, *op. cit.*, pp. 18–28.

[4] Indices are calculated separately for individual and socialized (state and collective farms) agriculture.

TABLE 1. Classes of world ranges of individual variables (according J. Kostrowicki, *The typology of world agriculture ... op. cit.*)

No. of the variable	Classes 1 very low	2 low	3 medium	4 high	5 very high
1.	non measurable variables				
2.	non measurable variables				
3.	0–2	2–8	8–50	50–200	200
4.	0–5	5–20	20–50	50–200	200
5.	0–2	2–10	10–50	50–200	200
6.	0–100	100–900	900–10,000	10,000–80,000	80,000
7.	0–3	3–15	15–40	40–150	150
8.	0–2	2–8	8–16	16–30	30
9.	0–6	6–15	15–36	36–90	90
10.	5–10	10–30	30–80	80–200	200
11.	0–10	10–25	25–50	50–80	80
12.	0.–0.1	0.1–0.3	0.3–0.7	0.7–1.3	1.3
13.	0–10	10–20	20–40	40–60	60
14.	0–20	20–40	40–60	60–80	180
15.	0–10	10–30	30–80	80–180	180
16.	0–5	5–20	20–45	45–100	100
17.	0–40	40–100	100–250	250–800	800
18.	0–20	20–40	40–60	60–80	80
19.	0–3	3–12	12–30	30–80	80
20.	0.05–0.1	0.1–0.2	0.2–0.4	0.4–0.8	0.8
21.	0–20	20–40	40–60	60–80	80
22.	0–20	20–40	40–60	60–80	80

* Numbers of variables the same as listed in the paper.

(20) Degree of specialization measured by the method described by J. Kostrowicki,[5]

(21) Orientation in gross production measured by the percentage share of livestock products in gross agricultural production,

(22) Orientation in commercial production measured as the percentage rate of livestock products in commercial production.

As suggested, the normalization of the quantifiable variables was based on their world ranges, subdivided into 5 classes (Table 1). Letters were used to denote the two non-quantifiable variables.[6]

(1) The first variable — land ownership — clearly differentiates Macedonian agriculture as consisting of private farming (P) — 58.1 per cent of agricultural land in 1972, state farming (G) covering 31.1 per cent, and collective farming (K) accounting for 10.8 per cent of agricultural land. Proportions between these three forms of land ownership vary in the various *opstinas* (Fig. 1). State farming is the most common in Central and Western Macedonia, where it exceeds 40 or sometimes even 50 per cent of agricultural land, while in the North-East and South-West its share falls under 10 per cent of agricultural land and in 4 *opstinas* there are no state farms at all. Collective farming (K) is even more

[5] J. Kostrowicki, *op. cit.*, Appendix No. 4.
[6] J. Kostrowicki, *op. cit.*, pp. 2–18.

Fig. 1. State farming in percent of agricultural land (Key to Figs. 1–3)

Fig. 2. Collective farming in percent of agricultural land

concentrated (Fig. 2). In few South-Western and North-Eastern *opstinas* it exceeds 20 or even 30 per cent of agricultural land, while in the most of Macedonia it spreads over less than 10 per cent of agricultural areas and in 5 *opstinas* collective farming is absent. Consequently, the share of individual farming (P) is the highest (Fig. 3) in the Eastern and South-Western parts of Macedonia, where in several *opstinas* it exceeds 80 or even 90 per cent of agricultural land, while in Central and North-Western Macedonia it does not reach 50 or even 40 per cent of agricultural land.

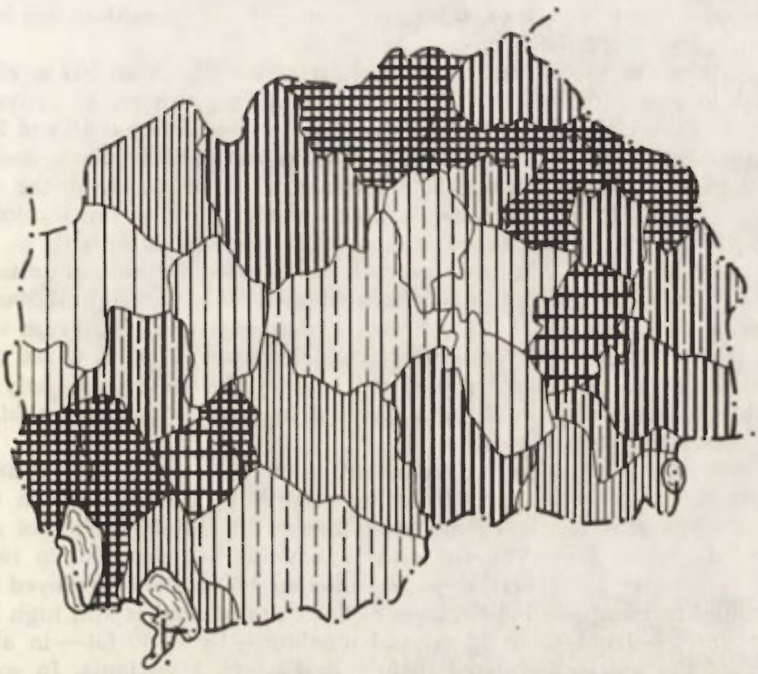

Fig. 3. Individual farming in percent of agricultural land

(2) In private farms most of the labour force consists of the owners and their families (P). Tenancy is rare, and hired workers, whether permanent or seasonal, do not play any role in the total number of people employed in private agriculture. On the other hand, state farms are worked by hired hands (H) and in collective farming the members of the collectives and their families (K) provide most of the labour force, with some seasonal hired workers, particularly in the *opstinas* engaged in tobacco or fruit growing.

(3–6) The size of individual holdings differs greatly from that of the socialized farms. Most of the individual farms are very small. Their average for most *opstinas* varies from 2 to 5 hectares (1), being larger — from 5 to 6 hectares (2) — only in the four North-Eastern *opstinas*. Consequently, the number of people employed in agriculture per one individual holding is also very small, and generally varies from 1 to 2 persons; in two *opstinas* only it amounts to 0.7 person (1). In 9 *opstinas*, situated mostly in the North and East, where farms are larger it ranges from 2.0 to 2.7 persons per one holding.

The number of livestock is also low in individual farming. It oscillates between 2 to 6 conventional large animal units per 1 holding (2). Finally the gross output per one private holding is very low, as it ranges between 38 and 99 grain units only[7] (1).

The socialized farms are much larger. Out of the total number of 92 state farms 16 are larger than 5000 hectares, 16 range between 2000 and 5000 hectares, 10 are between 500 and 2000 hectares, 7 have 300–500 hectares, and out of the remaining 43 that have less than 300 hectares, 33 of them are under 100 hectares.

The collective farms are slightly smaller. Out of 100, only 4 are larger than 5000 hectares and 17 range between 2000 and 5000 hectares, 28 have 500–2000 hectares. 3 — from 300 to 500 hectares and 48 have less than 300 hectares, 27 of them are under 100 hectares.

In two-thirds of the *opstinas* socialized farms average from 500 to 2000 hectares and in one-third exceed 2000 hectares (5). The number of actively employed per one socialized farm in most *opstinas* varies between 50 and 200 persons (4); exceeding 200 persons (5) in 5 *opstinas* of central Macedonia, and falling under 50 persons (3) per holding in 8 *opstinas*, situated mostly in the western mountains. Owing to a higher specialization the number of farm animals per 1 holding is greatly differentiated and varies from under 2 units (1) in 4 *opstinas*, which evidently do not breed animals, up to over 200 animal units (5) per 1 holding in over one-third of the *opstinas* situated mainly in central Macedonia.

Gross production per 1 holding[8] varies from 1800 to 10,000 grain units (3) in most of the Eastern and Western *opstinas* and from 10,000 to 68,000 units (4) in the Central and Southern parts of the country. In one *opstina* only (Demir Hisar) the size of socialized farms expressed in gross output per holding fell slightly under 750 units (2).

(7) With industrialization and urbanization of the country agricultural population is rapidly decreasing, both in its relative proportion and its density. The ratio of persons employed in agriculture to the total number of actively employed decreased from 67.9 per cent in 1953, to 58.9 per cent in 1961, and 48.3 per cent in 1971.[9] Nevertheless, the number of actively employed (Fig. 4) in individual farming per 100 hectares of agricultural land is still high in most of the country — from 40 to 78 (4) and medium — 18 to 40 (3) — in about 40 per cent of the *opstinas* situated mainly in Eastern Macedonia. In socialized farming the inputs of labour are much lower — mostly low — 3–15 persons per 100 hectares of agricultural land (2). In fact, this class can be subdivided into two sub-classes with 3–8 persons in the *opstinas* where general farming is practised, and 8–15 persons per 100 ha in those more specialized in horticulture. In 3 *opstinas*, even more specialized in fruit farming, inputs of labour are higher — from 15 to 32 per cent (3). In 5 other *opstinas* with a high proportion of grasslands, the inputs of labour range from 1.3 to 2.1 persons (1).

(8) The inputs of animal power (Fig. 5) are still high in individual farming.

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[7] As the compilation of the data was completed before the new conventional units were proposed, all production characteristics were calculated in grain units (see J. Kostrowicki, *op. cit.*, Appendix No. 2). As these units do not differ much from one another, all variables for Macedonia expressing production attributes could be compared with the classes established for world typology of agriculture based on the new simplified conventional units.

[8] The data for 1972 collected by the author comprise crop production only. Animal production had to be based therefore on estimates. In those estimates the production of skin, feather and dung was not taken into account. Consequently, in reality animal production is probably slightly higher. This, however, will not alter the position of individual variables in classes representing their world ranges.

[9] *Statisticki Pregled* No. 29, S. R. Makedonija, Skopje 1972.

In most of the country they amounted to 16–30 draught units (4) per 100 hectares of cultivated land.[10] In 6 *opstinas* they reached 30 to 39 units (5).

Horses, mules, asses, oxen and buffaloes constitute the draught animal power, their proportion varying from commune to commune. In socialized farming the use of animal power (mostly horses) is negligible — in most cases there is less than 1 and often less than 0.1 unit per 100 hectares of cultivated land (1).

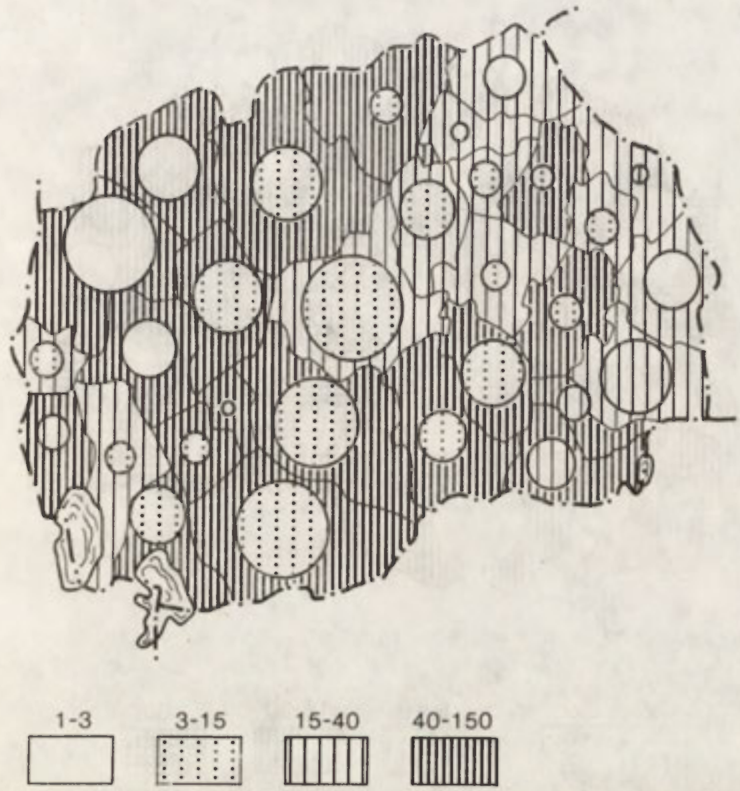

Fig. 4. Number of actively employed in agriculture per 100 hectares of agricultural land

In this and all further maps circles represent socialized farming. The size of circle is proportional to the ratio of socialized farming in total agricultural land. Individual farming is marked on the background

(9) The inputs of mechanized power in individual farming were low (2), varying from 6 to 15 HP per 100 hectares of cultivated land, in about a half of the country. In 13 *opstinas,* situated mostly in the North-East and South of Macedonia, they were still lower — 0.1 to 6 HP (1). Only in 3 *opstinas* they exceeded 15 HP with a maximum of 21 HP per 100 hectares of cultivated land. High inputs of labour and animal power and a low mechanization point to a low level of technology in many individual farms. Horse or oxen driven ploughs and even ards, hoes and scythes are still in use in many villages, situated particularly in the more remote areas, while at the same time the use of

[10] Total agricultural land minus an area under rough pastures has been accepted as cultivated land.

tractors and combines is increasing; these are usually rented from some richer neighbours or from agricultural cooperatives.

Mechanization in socialized agriculture is much higher. All the *opstinas* but one possessed more than 90 HP per 100 hectares of agricultural land (5), some of them had even 250 HP or over. Tractors with associated machinery and combines constitute basic draught power in both the state and collective farms.

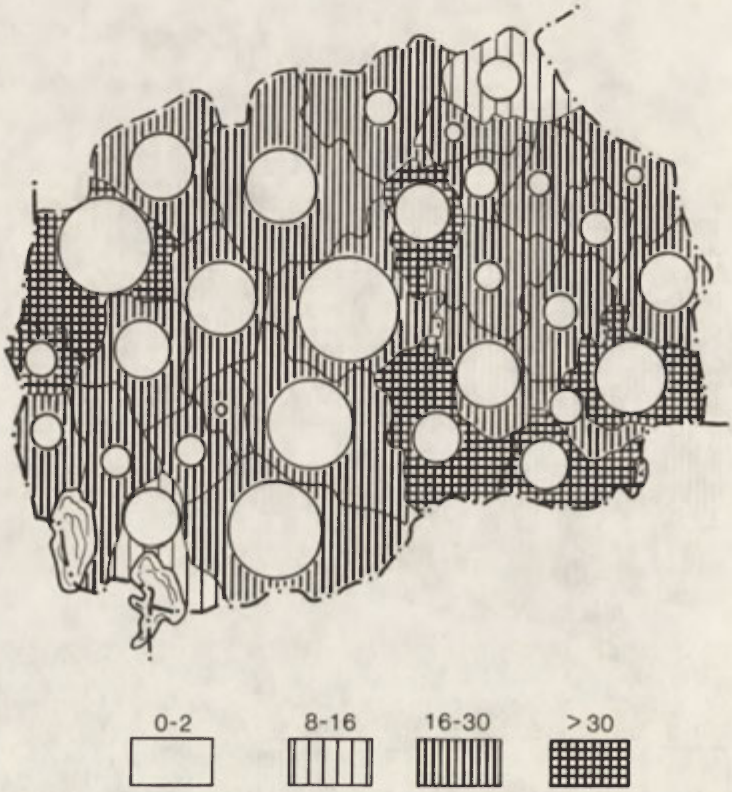

Fig. 5. Animal draught power per 100 hectares of cultivated land

(10) The contrasts are much less noticeable as far as the use of mineral fertilizers is concerned. In individual farming the use of fertilizers in about a half of the *opstinas* ranges from 30 to 80 kg in pure content (NPK) per one hectare of cultivated land (3) and in the remaining half from 80 to 140 kg (4). In socialized farming mineral fertilizing is usually high, from 80 to 200 kg (4) to 220–230 kg (5) in 2 *opstinas*. Only in 7 *opstinas* mineral fertilizing was lower, ranging from 43 to 80 kg NPK per 1 hectare.

(11) Although water deficiency is one of the principal obstacles to agricultural development and irrigation has been known in Macedonia for centuries, in individual farming in 3 *opstinas* only more than 25 per cent of cultivated land was irrigated, and in 10 *opstinas* from 10 to 25 per cent.[11] Out of the

[11] As in the period of collecting material accurate data on irrigation were lacking, the estimates made by the Institute of Geography of the University of Skopje have been accepted as a basis.

remaining 17 *opstinas* irrigation is negligible in 11 and there was no irrigation in 6 *opstinas*. In socialized farming over 25 per cent of cultivated land was irrigated in 9 *opstinas*, 10 to 25 per cent in 11; it did not exceed 10 per cent in 5 and there was no irrigation in 5.

(12) The intensity of cropland use is high (4) in most parts of the country, both in individual and socialized farming. As, however, in some holdings current fallow is still applied, indices of cropland use fall usually under 0.9 and in some *opstinas* even under 0.7 (3). In socialized farming the picture is similar; in 2 *opstinas*, which have, however, few socialized farms, indices rise over 1.3, which points to some double cropping. The extremely low index in one *opstina* (Gostivar) in individual farming and in another in socialized farming (Resen) cannot be interpreted without further investigation.

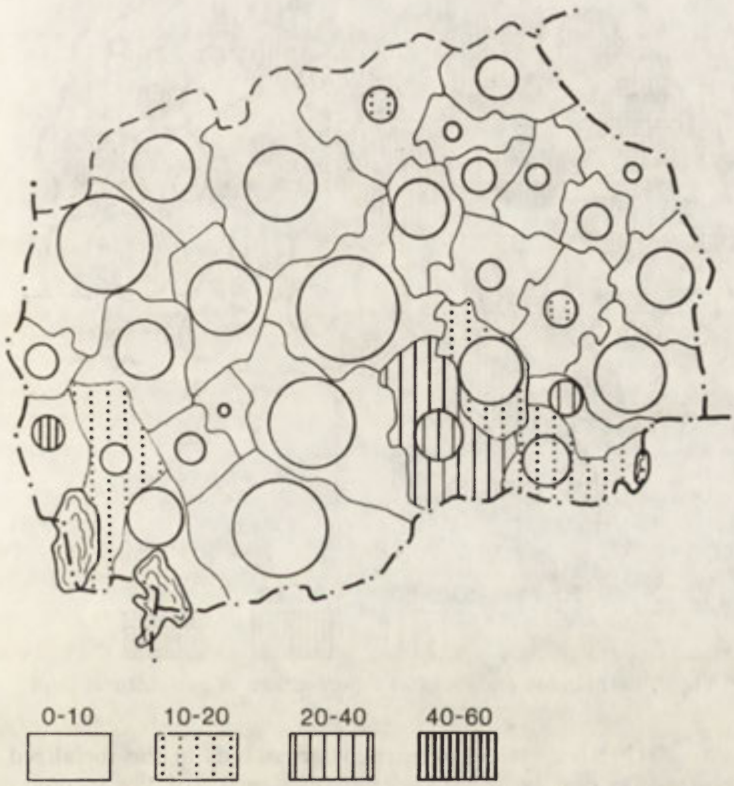

Fig. 6. Perennial crops as a percentage of agricultural land

(13) Although, as in other Balkan countries, perennial crops are grown everywhere, their rate in the total agricultural land (Fig. 6) is low (1) in most of the *opstinas*, both in individual and socialized farming. Only in some southern *opstinas*, in the Vardar valley and around Ohrid and Prespa lakes, they exceed 10 per cent of agricultural land. In individual farming the *opstinas* Kavadarci (23%) and Resen (25%) and in socialized farming Kavadarci (20%), Valandovo (29%) and Struga (46%) are particularly well known for their fruit culture.

(14) The rate of permanent grasslands (Fig. 7) differs greatly in individual and socialized farming. In individual farming it is very low in about a half

of the *opstinas*, varying between 3–20 per cent of agricultural land (1) and low in the other half — 20 to 34 per cent (2). In socialized farming the proportion of grasslands is greatly differentiated. It ranges from a very low or low — 2 to 20 per cent — in several *opstinas* (1–2) of South-Eastern Macedonia to a very high (5) exceeding 80 and even 90 per cent of agricultural land in most of the mountain *opstinas* of the Western and in some of the Eastern parts of the country.

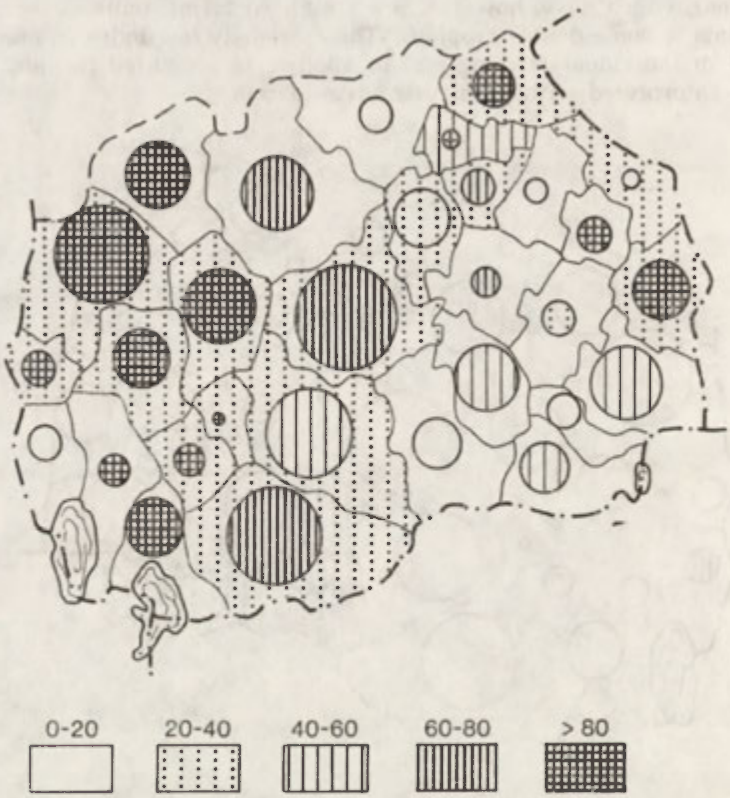

Fig. 7. Permanent grassland as a percentage of agricultural land

The particularly high rate of permanent grasslands in the socialized farming of those *opstinas* is due to the transfer to this sector of the former mountain common pastures. They are still used by individual farmers, who pay for their utilization, depending on the number and kind of animals grazed. The same pastures are also used for grazing by socialized farms. Mown meadows constitute only a small fraction of Macedonian permanent grasslands.

(15) Density of livestock (Fig. 8) in individual farming is high — 80 to 160 large animal units (4) — in about two-thirds of the country, and medium — 65 to 80 (3) — in the remaining territory covering the North-Eastern part of the country. Sheep and cows constitute the bulk of animals bred, with addition of some buffaloes and goats. Pig breeding is less developed. The density of livestock in socialized farming is very low — below 20 large animal units per 100 hectares of agricultural land in most of the country, with some socialized farms having no farm animals at all. Only in 8 *opstinas* there are more than 20 large

animal units per 100 hectares of agricultural land. In a number of *opstinas* the low animal density is due to the large tracks of mountain pastures included in agricultural land, which can be used only in a very extensive way.

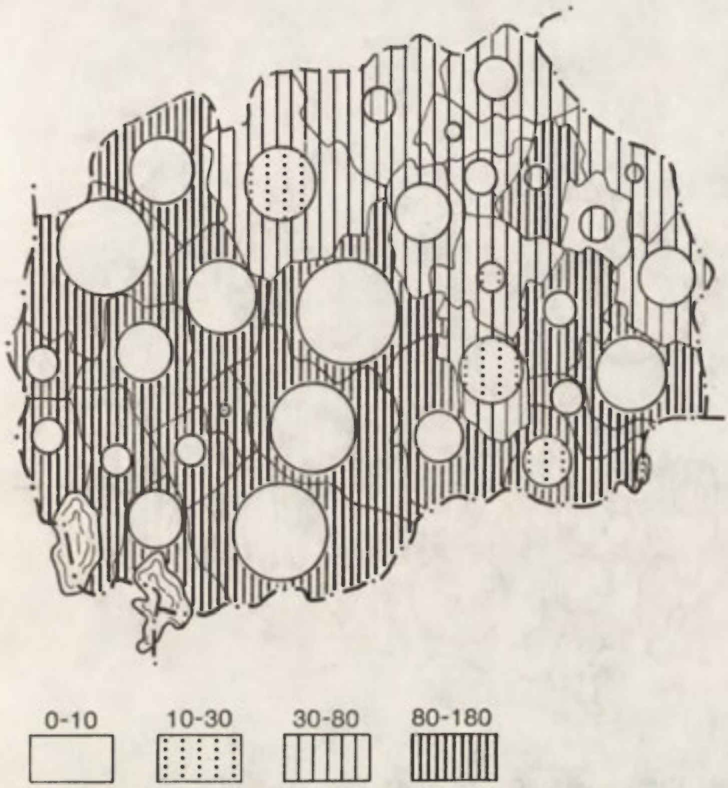

Fig. 8. Density of livestock per 100 hectares of agricultural land

16) Land productivity is low in most *opstinas*, both in individual and socialized farming (Fig. 9). In individual farming it ranges between 5 to 20 grain units (2) per 1 hectare of agricultural land in over two-thirds of the *opstinas*, reaching 20 to 30 grain units (3) mostly in the South-Eastern and Nord-Western parts of Macedonia. In socialized farming land productivity is much more diversified. It is very low — from 0.7 to 5 grain units (1) in the mountain areas with a high rate of permanent grasslands. In about one-third of the *opstinas* land productivity is low — 5–20 grain units (2) and in 8 *opstinas* it is medium (3) reaching 20 to 44 grain units.

17) Labour productivity (Fig. 10) is very low in individual farming — 22 to 40 grain units per one person actively employed in agriculture (1) in about two-thirds of the *opstinas* and low — 40 to 72 grain units (2) in the remaining ones. In socialized farming it is much higher, ranging from 135 to 250 units per one person employed (3) in 12 *opstinas*, 250 to 460 units (4) in 7 *opstinas*. In 10 mostly eastern and western *opstinas* it falls under 100 units (2).

18) The degree of commercialization (Fig. 11) in most of the individual

farms is still low.[12] In most of the *opstinas* commercial production accounts for no more than 20 to 40 per cent of gross production (2) and in 5 of them even less than 20 per cent (1). In socialized farming the degree of commercialization is much higher and in most of the country exceeds 60 per cent (4) or even 80 per cent (5) of gross production.

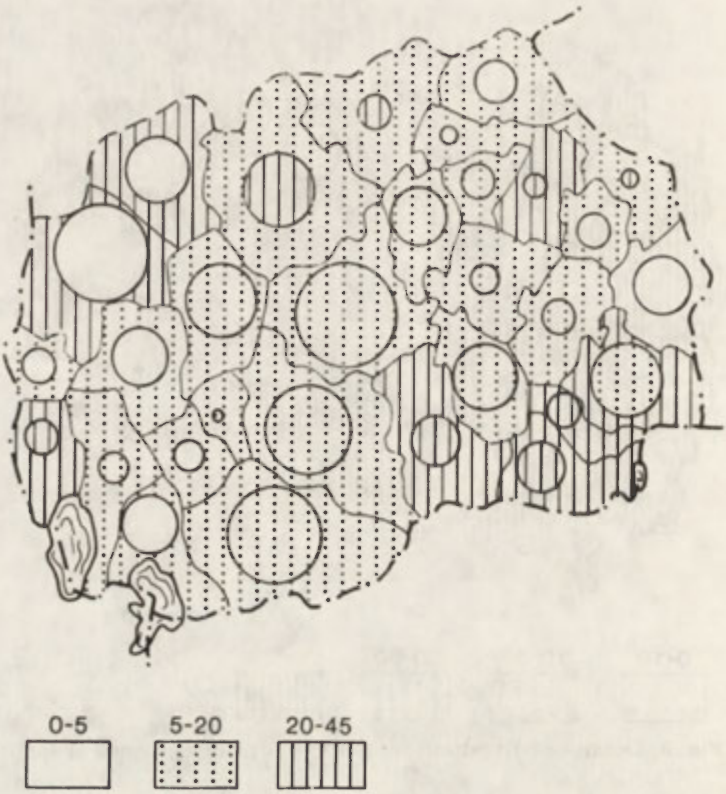

Fig. 9. Gross production in conventional units per 1 hectare of agricultural land

(19) Commercial production per 1 hectare (Fig. 12) of agricultural land is low — 3 to 12 grain units (2) in most of the country and in 6 *opstinas* of Eastern Macedonia falls from 1.3 to 3 grain units per 1 hectare (1). In socialized farming great differences appear again between mountain *opstinas*, where commercial production per 1 hectare of agricultural land varies from 0.7 to 3 grain units only (1), and those lying in the basins or valleys, where it reaches 12 to 35 grain units (3–4).

[12] As statistical data on commercial production for Macedonia are not available, it was calculated based on estimates. The total gross production of industrial crops was treated as commercial production, while the total gross production of hay crops, whether cultivated or obtained from permanent grasslands, as well as production of straw was acknowledged as non-commercial. The degree of commercialization of such other products as grains, potatoes, vegetables, fruits as well as milk, eggs, wool, honey and meat (live weight) was estimated separately for individual and socialized farming based on the information obtained from Macedonian specialists.

(20) The specialization of individual farms[13] is usually low (1). Only in some, mostly southern, *opstinas* specialized in growing tobacco, poppy for opium, sugar beet or in fruit production, the degree of specialization is higher (2–4). In general, the degree of specialization in socialized farming is higher, however in about a half of the *opstinas* it is low (2), reaching a high degree of

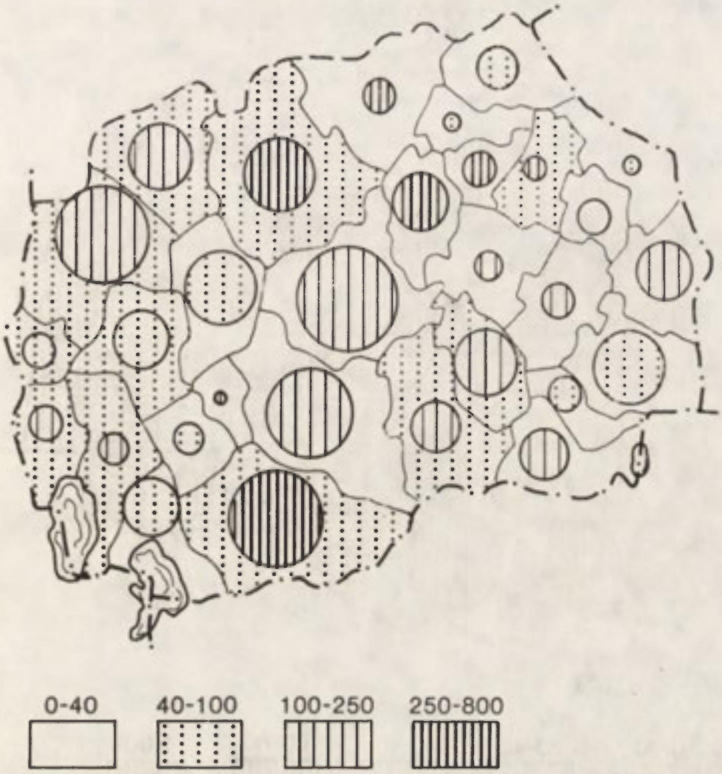

Fig. 10. Gross production in conventional units per 1 actively employed in agriculture

specialization (4) in 7 *opstinas* and a very high (5) in one *opstina* only, specializing in either industrial crops, wheat or fruits.

(21–22) The rates of crop and animal production in gross and commercial production do not differ much in individual farming (Fig. 13). In about a half of the *opstinas* crop production exceeds animal production, both gross and commercial (2–2), and in four — lying mostly in the South — it highly predominates (2–1, 1–1). However, as crop production in Macedonia as a whole is more commercial, there are several *opstinas* where the rate of animal production in commercial production is lower than in gross production (3–2, 2–1). In three *opstinas* only (Struga, Debar and Brod), lying in Western Macedonia, the rate of animal production in commercial production is higher than in crop production (2–3, 3–4), which points to a certain specialization in animal production. In four other *opstinas*, mostly in Eastern Macedonia, a kind of mixed

[13] The degree of specialization was estimated in accordance with the guidelines provided by J. Kostrowicki in: *The Typology...*, p. 74.

farming is practised, in which the proportion of crop and animal production is almost the same in both gross and commercial production (3–3).

The rates of animal to crop production in socialized farming do not differ much from individual farming. In most of *opstinas* it was low in gross production and very low to low in commercial production. Within gross production in 5 *opstinas* only crop production was more or less equal to animal

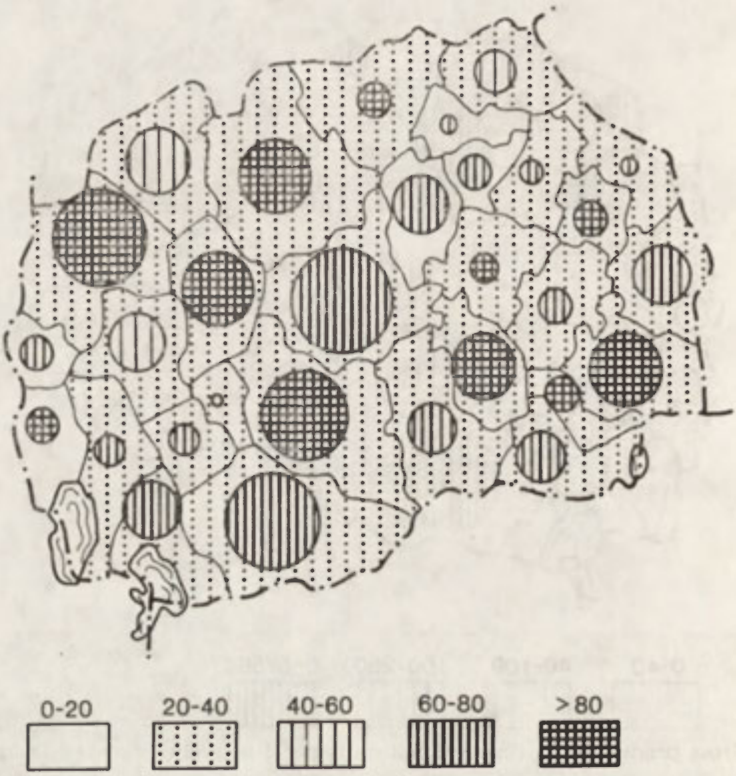

Fig. 11. Percentage of commercial production in gross production

production and in 2 *opštinas* animal production was higher than crop production. In commercial production in 6 *opštinas* animal production equalled crop production.

The variables discussed above compiled for each *opština* for individual and socialized farming separately and presented in codes were compared with the model codes elaborated for world types of agriculture.[14]

The codes for *opštinas* that differed from the model codes by not more than 10 per cent of the total possible variance, i.e. by not more than 8 deviations (22×4 = 88), were identified as belonging to the type represented by the given model-code.

The comparison reveals that, as far as the averages for all the *opštinas* are concerned, individual farming in Macedonia can be classified as 'traditional small-scale mixed agriculture' (group 4) more or less similar to Model Types

[14] J. Kostrowicki, *op. cit.*, pp. 30–60.

4.1, 4.2 and 4.3 identified in 'The Typology of World Agriculture' and represented by the following codes:

4.1. Continuous or semi-continuous subsistence or semi-subsistence mixed agriculture

$$R-F-P, E-M-T-P, 2, 1-2, 1-2, 1-2 \times$$
$$\times \frac{2-3, 3-4, 1, 1, 1-2, 3-4, 1-2, 2-3, 2-3}{2-3, 1-2, 1-2, 1-2, 1-2} \; 2-3, 3-4$$

4.2. Semi-commercial mixed agriculture with crops prevalent

$$P, E-M-T-P, 1-2, 1-2, 1-2, 1-2 \times$$
$$\times \frac{3-4, 3-4, 1, 1-2, 2-3, 4-5, 2-3, 2-3, 2-3}{3-4, 1-2, 2-3, 3-4, 2-3} \; 2-3, 2-3$$

4.3. Semi-commercial mixed agriculture

$$P, P-T, 1-2, 1-2, 2, 1-2 \; \frac{3-4, 3-4, 2-3, 2-3, 1, 4, 1, 1-2, 3-4}{2-3, 2-3, 2-3, 2-3, 1-2} \; 2-3, 3-4$$

Out of these model types Type 4.1 represents the least developed, traditional subsistence or semi-subsistence small-scale agriculture with high utilization of animal draught power, very low, if any, mechanization and mineral fertilization, usually with a current fallow, with a very low to low labour productivity and commercialization. Model Types 4.2 and 4.3 represent a more technically de-

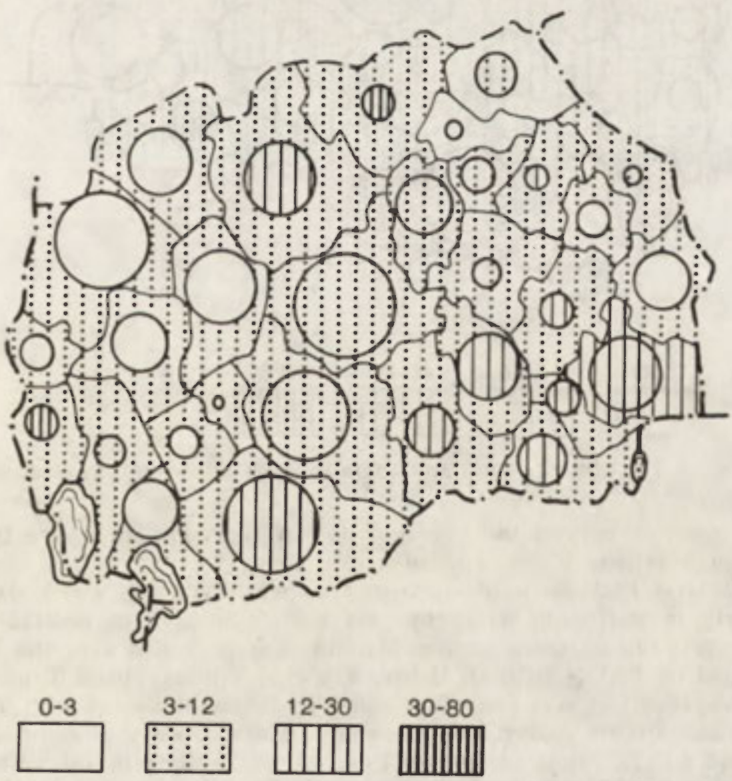

Fig. 12. Commercial production per 1 hectare of agricultural land

veloped agriculture but with higher inputs of labour resulting from the full cropland use, and a more intensive land cultivation. The differences between them connected with the fact that Model Type 4.2 is characteristic of a warmer and drier environment, where multicropping is possible, irrigation feasible and perennial crops play a more important role, while Type 4.2 represents cooler and more humid conditions, where irrigation is not needed and multicropping is hardly possible. As a result Model Type 4.2 is characterized by a lower mineral fertilization and a lower, if any, mechanization, higher land productivity and level of commercialization and specialization but lower labour productivity, and a lower rate of animal products, particularly in commercial production, while Type 4.3 is usually more oriented towards animal breeding, more advanced technologically, and thus has higher labour productivity.

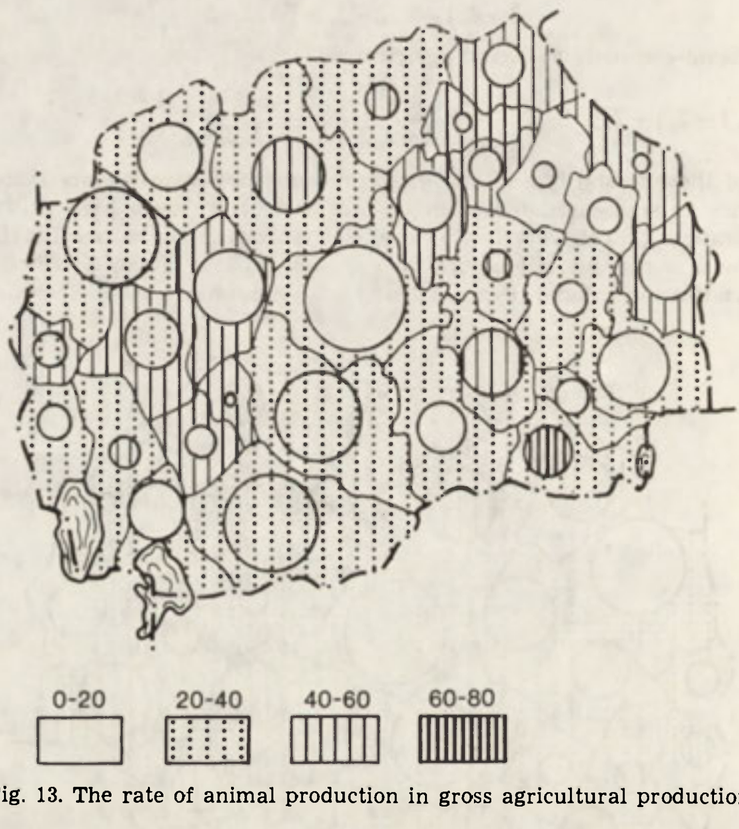

Fig. 13. The rate of animal production in gross agricultural production

With some exceptions the averages do not represent any pure type, but various combinations of the types described above.

In 1971 and 1972 the most common type was Type 4.3, which dominated particularly in the South (Gevgelija, Kavadarci, Struga); in several *opstinas* of the central and northern part of Macedonia it prevailed over the Type 4.2 (Kumanovo) or Type 4.1 (Brod, Debar, Kruševo, Vinica). Model Type 4.2 was least widespread and was identified either in the combination with Type 4.3. (Demir Hisar, Prilep, Radovis) or elsewhere as a secondary element with Types 4.3 and 4.1. The most antiquated Type 4.1 was leading in one *opstina* only (Berovo), but in six other *opstinas,* situated mostly in north-eastern Macedonia

(Kriva Palanka, Kratovo, Sv. Nikole), prevailed over Model Types 4.2 and 4.3, or equalled in importance to the Type 4.3 (Delcevo, Probistip, Gostivar).

The *opstina* Resen is a special case. Its code which is the closest to Model Types 4.2 and 4.3, differs from them by 11 or 12 deviations respectively. From the Model Type 4.2 it differs by higher mineral fertilization, much higher specialization, higher density of livestock, but its intensity of cropland use, proportion of permanent grasslands, land productivity, level of commercialization and proportion of animal products in commercial production are lower. From Type 4.3 it differs by a much higher irrigation, higher mineral fertilization, much higher proportion of perennial crops and much higher specialization, but is characterized by a lower intensity of cropland use, lower labour productivity and a much lower proportion of animal products in commercial production.

Resen is an *opstina,* in which over one-fourth of cultivated land is covered by orchards, mostly apple trees, in great proportion irrigated. Fruits constitute the principal basis of its commercial production.

In comparison with the closest types of the market-oriented agriculture (8.2, 8.3 and 8.5) it differs by 12, 16 and 18 deviations respectively. From the commercial small-scale agriculture oriented toward fruit growing (Model Type 8.3) it differs by a much lower land and labour productivity, much lower degree and level of commercialization, lower mechanization, lower intensity of cropland use, but a higher use of animal power, higher irrigation, much higher density of livestock population, which seems to be used mostly for home consumption as the proportion of animal products in gross production is higher than in commercial production.

Such characteristics of the *opstina* can possibly be interpreted as caused, first of all, by its dual character. In its lower part, situated close to lake Prespa, the *opstina* specializes in commercial fruit growing, technologically probably less developed than its analogues in Western Europe. Other parts of the *opstina,* which are situated higher, represent a semi-commercial agriculture of Type 4.2 or 4.3, much less commercial, less specialized and less productive.

The differences in proportion between the types occurring in various Macedonian *opstinas,* can serve as a basis for grouping them according to their similarity.

By means of the technique of successive products (multiplicators)[15] the *opstinas* with similar deviations from the model types were grouped in the following way (A — represents Model Type 4.1, B — 4.2, C — 4.3, D — 8.3):

1. AAAC	Berovo
2. AABC	Kratovo, Kriva Palanka, Svety Nikol
3. AACC	Delcevo, Gostivar, Probistip
4. ABCC	Bitola, Kičevo, Negotino, Ohrid, Skopje, Štip, Tetovo, Titov Veles, Valandovo
5. BBCC	Demir Hisar, Prilep, Radovis, Strumica
6. ACCC	Brod, Debar, Kruševo, Vinica
7. BCCC	Kumanovo
8. CCCC	Gevgelija, Kavadarci, Kocani, Struga
9. Y(BC/DD)?	Resen

[15] The technique of subsequent products (derived from the technique of subsequent quotients — see J. Kostrowicki, Some methods of determining land use and agricultural orientations as used in the Polish land utilization and typological studies, *Geogr. Pol.*, 18, 1970, pp. 93–120 has been used for transitional cases to define

The first three groups represent agriculture, where Type 4.1 (A) is still important, groups 3, 4 and 5 — agriculture where Type 4.3 (C) is important and predominates in groups 6, 7 and 8. Group 5 represents certain cases where Type 4.2 (B) plays a more important role. Group 9 represents the case of Resen, discussed above.

Socialized farming in Macedonia is much more diversified than individual farming. On the basis of *opstina* averages, similarity to at least the following 8 model types was observed.

13.1. Incipient socialized mixed agriculture

$$K-G, K-H, 3-4, 4-5, 3-4, 3-4 \times$$
$$\times \frac{2-3, 2-3, 2-3, 3-4, 1, 3-4, 1, 1-2, 2-3}{2-3, 2-3, 2-3, 2-3, 2-3}\ 2-3, 3-4$$

13.2. Socialized mixed agriculture

$$K-G, K-H, 4-5, 4-5, 4-5, 4-5 \times$$
$$\times \frac{2-3, 1-2, 4-5, 4-5, 1, 4, 1, 1, 1-2, 2-3}{2-3, 3-4, 3-4, 2-3, 1-2}\ 2-3, 3-4$$

13.3. Collective extensive mixed agriculture

$$K, K, 4-5, 4-5, 4-5, 3-4 \times$$
$$\times \frac{2-3, 1-2, 2-3, 2-3, 1-2, 3-4, 1-2, 2-3, 1-2}{2-3, 3-4, 3-4, 2-3, 2-3}\ 1-2, 2-3$$

14.1. Socialized agriculture specialized in grain or grain with livestock breeding

$$K-G, K-H, 5, 5, 5, 5\ \frac{1-2, 1, 4-5, 2-3, 1, 3-4, 1, 2-3, 1-2}{2-3, 3-4, 4-5, 2-3, 3-4}\ 2-3, 3-4$$

14.2. Socialized agriculture specialized in intensive livestock breeding

$$K-G, K-H, 5, 5, 5, 5\ \frac{2-3, 1, 4-5, 4-5, 1, 4, 1, 1-2, 3-4}{3-4, 3-4, 4-5, 3-4, 3-4}\ 3-4, 4-5$$

14.3. Socialized agriculture specialized in extensive livestock breeding

$$K-G, K-H, 4-5, 5, 5, 4-5\ \frac{1-2, 1, 2-3. 2-3. 1. 3-4. 1, 4-5, 2}{2. 4-5. 4-5. 2. 3-4}\ 3-4, 4-5$$

16.1. Socialized agriculture with prevalent mixed crop growing

$$K-G, K-H, 5, 5, 5, 5\ \frac{3-4, 1-2. 3-4, 3-4, 2-3, 4, 1-2, 1-2. 2-3}{3-4, 2-3, 4-5, 3-4, 2-3}\ 1-2, 2-3$$

16.2. Socialized horticulture

$$K-G, K-H, 4-5, 4-5, 4-5, 4-5 \times$$
$$\times \frac{3-4, 1-2, 4-5, 4-5, 1-2, 4-5, 2-3, 1-2, 2-3}{3-4, 2-3, 4-5, 3-4, 4-5}\ 1-2, 1-2$$

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their position in relation to two or more model codes of world types of agriculture. In the situation when the differences between a code for a given case and two or more model codes of types of world agriculture are less then 11 the number of those differences is multiplied subsequently by 1, 2, 3, 4 ... Out of the resulting products, the smallest 2, 4 or 6 products are selected according to the degree of detail desired, to define distances between a given transitory case and the two or more types of agriculture.

16.3. Collective medium-sized horticulture

$$K, K, 3-4, 4, 2-3, 3-4 \times \frac{3-4, 1-2, 3-4, 3-4, 1-2, 4, 3-4, 1-2, 1-2}{3-4, 2-3, 4-5, 3-4, 4-5} 1-2, 1-2$$

Out of these models Types 13.1 and 13.3 represent some kind of incipient socialized agriculture characterized by rather low capital inputs, a low mechanization and mineral fertilization, but still considerable labour inputs and the use of animal power, as well as by low to medium productivity and commercialization. The principal differences between these two types consist in their orientation; Type 13.1 is more oriented toward animal products, particularly in commercial production, while Type 13.2 — toward crop growing with animal production playing a secondary role. It seems that Model Type 13.3, originally described on the basis of the Mexican *ejidos*,[16] can successfully be extended to South-Eastern Europe, with some possible modifications, to represent more extensive forms of socialized mixed crop agriculture. With further development this type tends to be transformed into much more intensive Type 16.1 — 'socialized agriculture with prevalent mixed crop growing', described mostly on the Bulgarian examples, where socialized farming is, in general, more developed.[17] Model Type 13.2 'socialized mixed agriculture' is characteristic of Central Europe, where the climate is cooler and there is more precipitation. Besides Type 13.2 the even more oriented toward livestock breeding Type 14.2 is characteristic of that region. Type 14.1 represents a more specialized and less intensive agriculture. Model Type 16.2 constitutes socialized horticulture to be found both in South-Eastern Europe and in Central and Eastern Europe, where it usually occurs in the suburban zones of big or medium-size towns. Finally, Type 16.3 was based mainly on the Yugoslavian examples of medium-sized collective farms specialized in horticultural production.

As in individual farming the *opstina* averages for socialized farming represent in most cases a combination of types. As the types are more numerous, the combinations tend to be more complicated.

Similarly as in individual farming big characters were used to mark the model-types of socialized agriculture (I–13.1, J–13.2, K–13.3, L–14.1, M–14.2, N–14.3, O–16.1, P–16.2, R–16.3). The following combinations were identified:

1. IJKO — Delčevo
2. JJKL — Bitola
3. JJKO — Gevgelija
4. JJKN — Štip
5. JJKK — Kruševo
6. JKLO — Negotino, Prilep, Skopje
7. JKLP — Probištip
8. JKPR — Kočani
9. JMOP — Kumanovo
10. JKKL — Titov Veles
11. KKKK — Kriva Palanka, Strumica
12. KKLL — Sv. Nikol
13. KPPR — Radoviš
14. KPRR — Kavadarci
15. LLLL — Gostivar
16. MMMM — Ohrid
17. PPPR — Struga, Valandovo

As one can see from the above, Types 13.2 (J) and 13.3 (K) seem to be the most widespread in socialized farming. Type 13.3, representing a more extensive, rather crop-oriented agriculture, dominates in three *opstinas* (Debar, Kri-

[16] J. Kostrowicki, *op. cit.*, p. 55.
[17] J. Kostrowicki, *op. cit.*, p. 60.

va Palanka and Strumica), co-dominates with Type 13.2 in one *opstina* (Kru-sevo) and with Type 14.1 in another (Sv. Nikol). As a secondary element it occurs also in 11 other *opstinas*. A similar but more livestock-oriented Type 13.1 (I) appears, as a secondary element, in one *opstina* only (Delcevo).

Type 13.2 (J), 'socialized mixed agriculture' is a leading element in three *opstinas* (Bitola, Gevgelija, Štip), co-dominates with Type 13.3 in one *opstina* (Kruševo); it also occurs as a secondary element in five other *opstinas*.

Type 14.1 (L), specialized in extensive grain or grain and livestock breeding, dominates in one *opstina* (Gostivar), co-dominates in another (Sv. Nikol). As a secondary element it also occurs in four other *opstinas*. The Type 14.2 (M) — agriculture oriented toward intensive livestock breeding — dominates in one *opstina* (Ohrid). The Type 16.2 (P) — 'socialized horticulture' — is the leading element in one *opstina* (Radovis) and co-dominates with Type 16.3 (R), also horticultural, in two other *opstinas* (Struga, Valandovo). The latter is in turn the leading element in one *opstina* (Kavadarci). As a secondary element Type 16.2 can be identified in three other *opstinas*, and Type 16.3 — also in two *opstinas*.

The codes, however, for 8 *opstinas* (Berovo, Brod, Demir-Hisar, Kicevo, Kratovo, Resen, Tetovo, Vinica) differ considerably from any model codes. As further analyses showed these were exactly those *opstinas* that had consider-able areas of mountain rough pastures incorporated in the socialized farms; in many cases they exceed 80, or even 90 per cent of their total acreage. As al-ready pointed out, these pastures are only in part used by state farming, the majority being rented to individual farmers.

If those pastures were eliminated, variables 4, 7, 13, 14, 16 and 19, i.e. those in which indices were computed per unit area, would undergo considerable changes, namely if those pastures are not included, most of the socialized farms of the respective *opstinas* will be much smaller, more labour intensive, with a higher rate of perennial crops, with higher land productivity and level of commercialization. With their variables so modified they would not differ greatly from the model types and can be grouped in the following combina-tions:[18]

KKRR — Berovo
PPRR — Kicevo, Vinica
PRRR — Tetovo, Resen
RRRR — Brod, Demir Hisar, Kratovo

With the exception of Berovo, where the extensive crop-oriented socialized agriculture (13.3) co-dominates with medium-scale socialized horticulture (16.3), in the other *opstinas* the last type either co-dominates with large-scale horticul-ture or fully dominates, showing that in these and probably in some other *opstinas* many socialized farms are in fact typical of Yugoslavia — medium-sized horticultural enterprises with which large mountain rough grasslands seem to be rather artificially connected.

These cases, as well as the case of individual farming in Resen, call for

[18] This experience led to the establishing of a new variable — the productivity of cultivated land calculated in terms of gross agricultural production from cultivated land (without rough pastures and fallow land) per unit area of cultivated land (See. J. Kostrowicki, *A hierarchy of world types of agriculture*, published in the present volume) which is particularly important for either extensive agriculture or agriculture in the mountains where productivity of cultivated land differs greatly from the productivity obtained from other forms of land use. In such a situation the mean productivity for agricultural land as a whole does not reflect the real situation.

certain caution, particularly when basic units of study are of aggregate character. The case when the sets of variables that represent them differ greatly from the model types, does not necessarily mean that we are dealing with a new type, not yet described. Very often this is caused by a greater internal differentiation of a given unit, the average for which does not represent any real type. Thus, before such a case is described as a new type, it is advisable to investigate the case in greater detail as to its internal differentiation.

But a considerable internal differentiation can be found even within some agricultural holdings. This is again often the case of extensively used rough pastures being a part of holdings with the remaining land used much more intensively. In such cases most indices compiled per unit area represent in fact an average of two or more highly differentiated parts of the holdings. On the other hand, such situation can also be characteristic of certain agricultural types that have developed in the mountain areas, where intensive use of the lowland part and extensive use of the highland one is a typical occurrence.

In the opinion of the present author the problem is worth discussing, as such a discussion might lead to the clarification of this point, which otherwise could be interpreted in various ways.

Figure 14 presents an attempt to apply the legend for mapping world types of agriculture — as proposed by J. Kostrowicki in his paper submitted to the

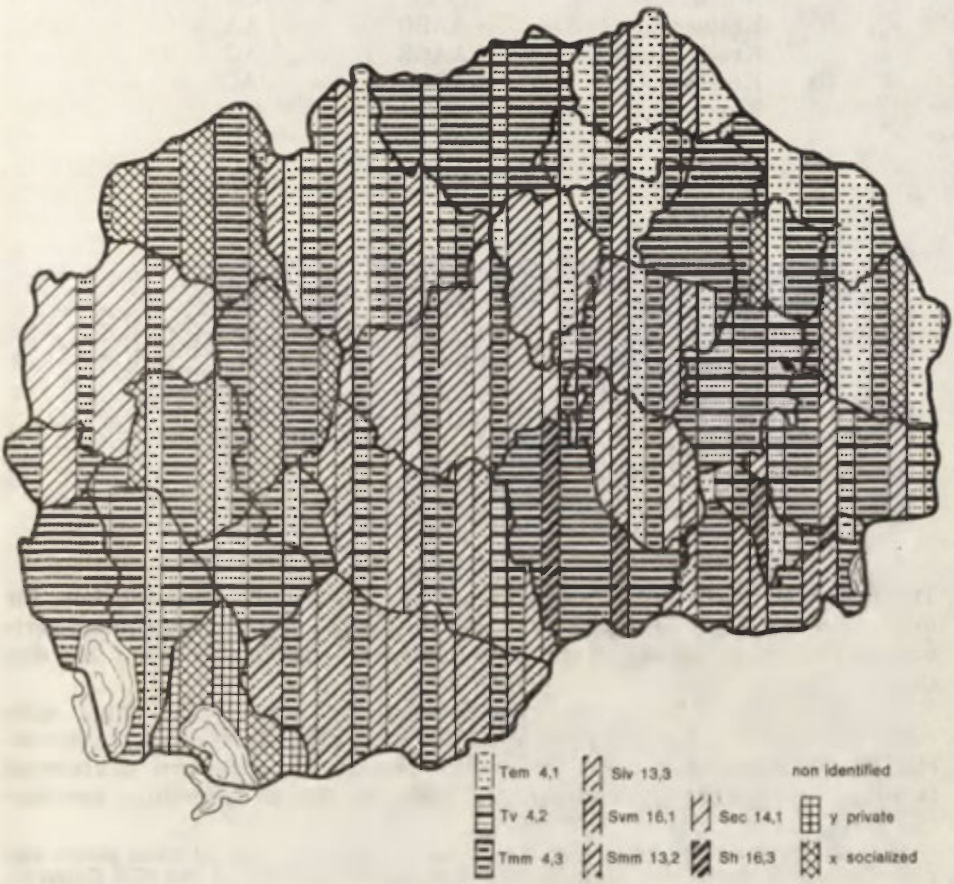

Fig. 14. Types of agriculture in Macedonia (Map designed by W. Jankowski)

7th meeting of the IGU Commission on Agricultural Typology — to map types of agriculture of Macedonia.[19] In order to do so, first the proportion between individual and socialized farming was defined by use of successive quotients technique and then such number of types of agriculture was selected by use of successive products (multiplicators) and included to the combinations representing both individual and socialized farming, that fell to each of those groups. The use of both four and two quotients was tested. In result the following combinations of agricultural types characterize individual *opstinas*:

	4 quotientes	2 quotients
Berovo	AACX	AX
Bitola	CJJK	CJ
Brod	CCXX	CX
Debar	CCKK	CK
Delčevo	AACC	AC
Demir Hisar	BBCC	BC
Gevgelija	CCJO	CO
Gostivar	BLLL	LL
Kavadarci	CCCR	CC
Kičevo	ACCX	CC
Kočani	CCCC	CC
Kratovo	AABC	AA
Kriva Palanka	AACK	AC
Kruševo	ACCC	AC
Kumanovo	BCCC	CC
Negotino	ACJL	CL
Ohrid	ABCC	AC
Prilep	BCJK	CJ
Probištip	AACK	AC
Radoviš	BBCC	BC
Resen	YYXX	YX
Skopje	ABCJ	AC
Struga	CCCC	CC
Strumica	BCCK	BC
Sv. Nikol	AKKL	AK
Štip	ACJK	CJ
Tetovo	CCXX	CX
Titov Veles	CKKL	KL
Valandovo	ABCR	CR
Vinica	ACCX	CX

The map was finally based on four quotients version. The problem how far to go in detail when basic units are relatively large and therefore their agriculture represents an aggregate of various types, is another point for discussion.

In conclusion, it seems that Macedonia with its partly individual agriculture, which is in a stage of transition from the subsistence or semi-commercial peasant farming with all its archaic features to a modern commercial farming, with its partly socialized, still more diversified agriculture, develop-

[19] J. Kostrowicki, *The scheme of world types of agriculture. Some weak points and possible improvements* (the paper presented at the 7th meeting of the IGU Commission on Agricultural Typology in Fontenay-aux-Roses, France, mimeographed).

ing in very varied natural conditions, in the country inhabited by the population with varied ethnic and cultural background, with a varied degree of economic development, is both an interesting area for geographical study and a good object for testing various methodological solutions.

It is the intention of the present author to continue this study in a greater detail and to base research on statistical data for villages and individual socialized farms as well as on field observations and inquiries. As some field studies have already revealed, the differentiation of individual farming is actually much greater than averages for *opštinas* can show. Here a new question arises how representative the codes compiled for the units of such a size as the *opština* are or, at least, how representative they are for a majority of cases, how much different the typology will be for such a unit if based on data for villages and socialized farms separately. Whatever the answer, it seems that the agricultural typology presented above, characterizes properly the principal spatial differentiations of the Macedonian agriculture.

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INDUSTRIALIZATION AS A FACTOR OF REGIONAL DEVELOPMENT IN POLAND

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This paper presents a preliminary report on the research aimed at determining the role of industrialization in the regional development in Poland, with particular emphasis on the problem of underdeveloped regions.

The impact of industrialization on an underdeveloped region takes various forms. The immediate impact of growing employment in industry permits a shift of a part of the labour force occupied in the low-productivity agricultural sector to more productive and more remunerating activity; the outflow of the redundant labour force from agriculture raises the per capita incomes of those who remained in that sector. Less immediate but also important is the impact created by regional industrial growth on the volume and productivity of other regional activities via the increased demand of the population: this is due to raising incomes or via intersectoral backward and forward linkages created by expanding industrial output. The effects of all these types, conditioned by numerous cricumstances of both national and regional character, and involving complex chains of causal relationships and feedbacks, present a vast field of research.

In the present study, only some of the more general relationships are analysed and attention has been focused on the main end-result of the economic growth processes, and in particular personal incomes — an aspect hardly touched on before in a systematic way in Polish geographical literature.

A research so focused had to rely on the data presented in the studies on regional breakdown of the national income statistics produced at irregular intervals by the Central Statistical Office. This, in turn, determined both the periods covered by the analysis and the types of approach.

The period selected is 1961–1973. This choice was based on considerations relating to the agricultural sector. Because of relatively large year-to-year oscillations in the volume of agricultural production, it is very important that the value added data should be computed for the years of a 'normally good' harvest — a condition met by the two years taken as a basis for measuring the changes in time. It must be remembered, however, that the year 1961 represents a point in time at which regional industrialization processes were already well under way.

Further, since income data were available only for provinces (voivodships) according to the previous administrative division (17 provinces plus five of the biggest cities), the same level of areal generalization had to be adopted in the present study. This determines also the very 'soft' techniques of analysis due to the small number of observation units. The conclusions based on the analysis of data aggregated at the provincial level have been, however, compared with and verified by the results of research conducted on a more detailed areal scale by other authors as well by the author of the present study. In any case the conclusions on some relevant questions are only of a hypothetical character and their significance lies in directing further research.

DESCRIPTION OF DATA

From the national income statistics for the provinces, data were extracted on personal income from economic activities, namely: wages in the public sector of the economy and farmers' income derived from agricultural production. These income figures have been classified according to four sectors of economy: 1) private agriculture, 2) socialized agriculture and forestry, 3) industry, 4) tertiary sector. To the last class estimated figures on incomes derived from 'nonmaterial services' have been added (education, health care, public administration etc.) which are not included in the Polish national income statistics. Another table has been constructed on employment in the same four sectors (data from employment statistics in the socialized sector of economy plus figures on occupation in private agriculture, interpolated or extrapolated on the basis of the census data).

Thus, a comparable set of tables for regional economies in the years 1961 and 1973 has been obtained, comprising the bulk of personal incomes as well as economic activities. No incomes other than those derived from economic activities are included (e.g. rents, pensions), neither are employment and incomes in the private sector of economy outside agriculture, the share of which in the total employment and income was negligible, although in the case of some regions not without significance (e.g. incomes from private tourist services).

The above set of tables permitted one to calculate all kinds of per capita figures; it should be noted that the expression 'per capita' as used in this report refers always to 'personal income per one working person'.

It has also to be kept in mind that the income figures are computed in current prices and thus the 'growth of income' figures refer to nominal rather than real incomes. The consideration of price level changes alters the comparative significance of the growth of income indices for assessing the differentiation of the rates of growth in real terms: it must be remembered that the growth of real income *indices* are proportionally lower, resulting from the division of the nominal indices by the rise of the price-level index, but the differentiation of the resulting *rates* of growth of real incomes is greater than the corresponding differentiation of the rates of growth of nominal incomes.

All the arguments as to agriculture presented in the paper refer to the private agriculture sector, since in the area defined later as 'underdeveloped', on which the analysis was concentrated, the sector of socialized agriculture is quite insignificant in terms of employment and production. The personal incomes from privately owned farms have been used also as a measure of productivity, which seems permissible considering that they form about 90% of the value added.

POLICY OF INDUSTRIALIZATION AND REGIONAL DISPARITIES IN THE LEVEL OF ECONOMIC DEVELOPMENT

The regional differences in the level of economic development in Poland are rooted not only in the varying distribution of natural resources but also, and predominantly so, in the historical circumstances determining the different situation of various parts of the country, forming in the 19th century the marginal provinces of three foreign powers which entered the stage of industrial revolution at different periods.

In consequence, the spatial distribution of industry in the post-war period was far from uniform and characterized by a high concentration in the Upper and Lower Silesian industrial regions as well as in the big textile industry centre — the city of Łódź. Regional differentiation of the level of economic development and the pattern of regional income disparities did not fully coincide with the spatial pattern of industrialization. From the former point of view one continuous area could be clearly distinguished comprising seven Eastern voivodships, predominantly agricultural and characterized by the low incomes of the population, low efficiency in agriculture, high to very high agricultural density of population and poorly equipped with infrastructure; enclaves in this area were two urban-industrial agglomerations, Warsaw and Łódź (constituting separate voivodships). The level of industrialization of these voivodships was generally low, but not uniformly: in the South-Western part of the area (voivodship Cracov and Kielce) the share of industrial employment in 1961 was equal to 15–18%, which were the percentages not very much lover or even higher than in some regions in this part of Poland which was denoted as 'developed'.

To appreciate the significance attached to the industrialization of the underdeveloped areas, it must be pointed out that industrialization was considered the main factor in accelerating growth of the national economy — it was supposed to transform the backward, largely agricultural country, into a modern industrialized nation. A measure of the importance attached to this national policy may be the fact that the industrial investments for the entire post-war period amounted to about 40% (in some years of the decade of the 1950's even up to 47%) of the total investment outlays of the country.

In this context, the main factor of national economic growth became considered also the primary agent of *regional* economic growth. The development of previously backward regions was measured above all by the rate of their industrialization and concomitant urbanization. The instrument of this type of strategy was the industrial location policy executed by the central planning bodies which, in locating new plants, were giving preference to the underdeveloped areas. Although, in view of the high rate of national industrial growth it was possible to channel a substantial part of industrial investments towards the backward regions, this policy — for obvious economic reasons — could only gradually and partially alter the existing pattern of the spatial distribution of industry.

A generalized measure of the changes in the distribution of industry in the post-war Poland and of the share of underdeveloped regions in these changes provide the results of the shift-share analysis for two periods: 1949–60 and 1961–70, summarized in the Table 1.

The table shows that the underdeveloped area experienced in the first period a positive shift amounting to 121,000 persons, which was the figure equal to 43% of the total growth of industrial employment in this area; in that figure, 100,000 (36%) represents the differential effect. In the next decade the

TABLE 1. Summary figures of the shift-share analysis of industrial employment growth in Poland

Area	Components of employment growth	Time period	
		1949–60	1961–70
Poland	Total employment growth	1 165	1 298
	Total shift*	319	240
	Differential shift*	229	226
Underdeveloped regions	Total employment growth	279	445
	Total shift	+121	+138
	Differential shift	+100	+134
Voivodship Katowice	Total employment growth	192	164
	Total shift	−150	−152
	Differential shift	−100	−105
City of Łódź	Total employment growth	20	28
	Total shift	−91	−56
	Differential shift	−40	−39

* Sum of positive shifts in regions.

shift increased in absolute terms but decreased in percentage of the total figure of employment growth (29%); the shift, however, occurred this time almost entirely due to the differential effect equal to 134,000 persons.

The question arises, naturally, whether the differential shift can represent the effect of location policy intended to spread industry towards the less developed regions and motivated by regional development considerations. Certainly, in some areas at least (Western part of the Cracov voivodship, part of the Warsaw industrial region outside the limits of the capital city), the differential effect might be attributed to the 'natural' tendencies due to favourable conditions of development of certain industries. On the other hand, it must be admitted that in the case of the larger part of the underdeveloped area of the country the same conditions were comparatively unfavourable, so that the interpretation of positive effects as a measure of achievement of locational policies motivated by regional development considerations tends rather to underestimate the latter.

Accepting, therefore, this interpretation of positive differential effects for the underdeveloped area as a whole, one may state that the locational policy of promoting industrial growth in this area was both persistent and fairly effective.

INDUSTRIALIZATION AND THE OUTFLOW OF THE LABOUR FORCE FROM AGRICULTURE

The consideration of regional employment problems was certainly one of the motivations of industrial location policies; this seems to be confirmed by the fact that the new industrial plants located in underdeveloped regions tended to be more labour intensive than capital intensive in comparison with the previously industrialized areas (Wróbel and Zawadzki 1966). The situation on the regional labour market in the underdeveloped agricultural regions was indeed critical, since the overabundance of employment in agriculture was associated with the high post-war rate of population growth. The question arises, however, to what degree the resulting outflow of labour from agriculture was conditioned by *regional* industrialization processes, and to what degree by the changes in the structure of the national economy connected with industrialization on a national scale.

In this context, two hypotheses have been checked:

(1) that the intensity of the outflow of labour from agriculture was conditioned by the regional differences between the agricultural per capita income and industrial wages,

(2) that the intensity of the outflow of labour from agriculture was determined by the intensity of regional industrialization processes.

In order to check the first hypothesis, the regional per capita incomes from agricultural activies in the private sector were compared with the regional average wages in industry. The economic significance of both sets of figures is not exactly the same, since agricultural incomes are burdened with productive investment outlays, whereas the industrial wages were subject to tax-deduction averaging about 6%; still, the figures can serve as fairly adequate measure of average regional personal incomes in both types of activity.

Comparison of these two sets of figures for the year 1961 reveals a striking but not unexpected fact, that the sharp differences between the remuneration of work between the two types of activities were characteristic only for the

Fig. 1. Regional differentiation of personal incomes per capita in 1961

1 — Personal incomes per head of working population (regional average in thousand zlotys): a — 13-14.5, b — 18-19.9, c — 20-21.9, d — > 22; 2 — Personal incomes per head of working population: a — agriculture, b — industry

regions classified as underdeveloped (this seems, indeed, to be the classical situation in underdeveloped countries). Although the average industrial wage in those regions was generally lower than in the more developed part of the country, due to the different industrial structure (greater share of low-wage industries), the ratio: industrial wage/agricultural income was here mostly around 1.7, reaching in some provinces values exceeding 2; this areal differentiation was caused not so much by differention in agricultural incomes — since those were rather uniformely low — but, again, by regional differentiation of industrial mix.

In the more developed part of the country (excluding the highly industrialized voivodship of Katowice), the highest value of the above ratio was 1.24, whereas in most regions it was close to 1 (Fig. 1).

Taking into account that the labour outflow from agriculture was occuring with a similar average intensity both in the underdeveloped and in the developed part of the country, the hypothesis under consideration seems hardly tenable on a national scale. If we focus attention on the regional differentiation within the underdeveloped part of the country, we find some degree of correlation between the income ratio and agricultural labour outflow, since the high ratio voivodships of Cracov and Kielce are characterized also by the heavy values of the second variable. Still, the personal income differential on a regional scale seems at best only a contributory factor in the outflow of labour from agriculture, in view of the answers provided by the verification of the second hypothesis posed.

This other hypothesis referred to the positive association between the relative magnitude of the outflow of labour force from agriculture and the intensity of regional industrialization processes. Here, it must be stated first, as already mentioned, that the outflow of labour from agriculture was a process occurrying in all parts of Poland. In the underdeveloped area taken as a whole, this outflow in relative terms was, in the period analysed, on the level of the national average (—10%), whereas the rate of industrial employment growth was particulary high.

Analysis of the interregional differentiation of the intensity of the process within the underdeveloped area does not reveal any correlation with the intensity of industrialization (this also applies to the interregional differentiation within the developed area).

On the other hand, in the underdeveloped regions a close positive correlation exists between the intensity of the labour outflow from agriculture and the agricultural density of population (see Table 2).

It must be noted that the relative decrease of the labour force engaged in agriculture cannot, of course, be treated as a full measure of the process known as outflow of population from agriculture, considering the high natural increase in the post-war years (especialy high in the rural areas), reflected in the fact of the increase of the total labour force of the country by 23% in the period analysed. In none of the underdeveloped regions (and some of the developed regions too) was the industrialization and accompanying urbanization intensive enough to absorb the stream of migrants from rural areas, so that the migration balances of these regions show heavy negative values.

The above considerations derived from the analysis of the provincial aggregates are confirmed by various studies conducted on a more detailed areal scale. These studies show that in most cases the rapidly expanding urban-industrial centres have a notable influence on the rate of outflow of labour from agriculture only in the area of the neighbouring county (*powiat*) and in case

TABLE 2. Basic characteristics of underdeveloped regions

Region (voivodship)	State in 1961					Changes 1961–1973		
	share of industry in total employment (%)	income per capita (thousand zlotys)	income in agriculture per capita (thousand zlotys)	agricultural density* (1960)	outflow of labour force from agriculture (1961 = = 100)	indices of growth (1961 = = 1.00) income in agriculture	income in agriculture per capita	industrial employment
Rzeszów	12.8	13.7	10.6	74	−13.2	1.35	1.5	1.96
Kraków	18.3	14.2	9.9	72	−14.1	1.5	1.6	1.45
Kielce	14.9	13.4	10.0	55	−13.2	1.6	1.9	1.76
Lublin	8.2	13.9	11.9	54	−8.0	1.75	1.9	1.87
Łódź	18.0	14.2	11.3	44	−5.4	2.0	2.2	1.52
Warszawa	10.4	14.5	12.0	39	−7.6	2.3	2.4	1.84
Białystok	8.0	13.3	10.9	39	−8.0	2.2	2.4	1.95
Katowice	50.9	23.9	12.0	52	−22.6	1.7	2.2	1.20
Remaining regions (excluding five metropolitan cities)	27.3	20.1	20.1	24	−8.3.	1.6	1.7	1.43

* Persons working in agriculture per 100 ha of agricultural land.

of the lesser centres — only on the scale of the neighbouring communes. In the case of the biggest centres (e.g., Warsaw), the decline in agricultural employment was to be observed on the somewhat larger — intraprovincial — areal scale, and only in case of the most heavily industrialized voivodship of Katowice (small in areal extension) did it show a marked dimension on the provincial level (−23%).

Therefore, it must be concluded that the labour outflow from agriculture was a process conditioned by the industrialization process on a national scale, and dependent regionally more on the particular conditions of farming than local industrialization processes.

This does not mean that there was no significant, spatially determined influence of the growth of industries and opportunities they offered, on rural communities. If the decision to look for employment outside agriculture was only in a small degree dependent on local industrial development, the latter was of tremendous importance for the form this decision was taking: migration or commuting, with the subsequent consequences for the rise or decline of rural population, for income of rural families, and indeed their 'way of life'. It was these latter phenomena which were the subject of numerous studies in Polish geographical literature. In one of these studies, the author comes to the following characteristic conclusion: "The congruence of the basic trends of industrialization and of the 'occupational urbanization' within the rural areas supports the initial hypothesis, according to which urbanization phenomena in the rural areas are a function of industrialization" (Łoboda 1976).

IMPACT OF INDUSTRIALIZATION ON PRODUCTIVITY AND INCOMES IN THE AGRICULTURAL SECTOR

Apart from the consideration of the role of industrialization as a source of employment, the question arises as to the impact of industrialization on the growth of other sectors of regional economies, and especially on production and per capita incomes in the sector dominating in the employment structure of underdeveloped regions, i.e. agriculture.

The analysis of the data on changes in regional incomes as compared with the data on changes in industrial employment disprove the hypothesis of the existence of such an impact, disclosing no correlation at the provincial level of aggregation.

In the underdeveloped regions, the indices of growth of aggregated value of agricultural incomes (closely related to the value added figures) in current prices ranged from 1.35 to 2.3.* The areal differentiation of these indices is in no way correlated with the regional differentiation of the intensity of industrialization processes. On the other hand, the high negative correlation of these indices with the differentiation of the agricultural density of the economically active population (see Table 2) suggests that a decisive factor in the rise of productivity in agriculture was the size-structure of the farms, representing the ability of farms to react to the rise in *national* demand and the opportunities created by national economic progress for improving farming techniques (availablity of fertilizers, electrification, agricultural services, investment materials etc.).

This conclusion finds confirmation in the micro scale studies on the influence of new industrial centres on their agricultural surroundings. Thus, for example, in the study on the influence of urbanization on agricultural production in the region of Płock — a city, the rapid growth of which in the period 1961–73 from 45 to 82,000 inhabitants was due to the location and growth of a big petrochemical plants — the author, basing his observations on detailed studies of a large sample of individual farms, concludes that the observed growth of the industrial center, associated with flows of commuting from the surrounding rural area, had a very limited effect on the agricultural production in the area, and that the changes observed concerned rather the structure of agricultural production than its dynamics. "The direction of development of agriculture which were to be observed in the period analysed are very similar in the region of Płock to those in the neighbouring *powiat* (county) of Ciechanów (which was not subject directly to industrialization), as well as indeed in the whole voivodship of Warsaw. This means that the agriculture of the region was at that time more influenced by the general national situation determined by the given stage of economic development and the agricultural policy executed, and much less by the impact of the specific situation created by the rapid industrialization of the region" (Kłodziński, 1972, pp. 11–12).

In particular, the same author points out that the agricultural production around a rapidly expanding city does not rise under the influence of the growing local demand for agricultural products, since the latter is met by an increase of supply by the centralized commercial apparatus. Thus, "one can conclude that in our conditions the traditional mechanisms of influence of industrialization on the development of agriculture, typical for the economics of capitalistic agriculture and finding their expression, e.g. in the theory of

* As noted earlier, the differentiation of rates of growth in constant prices is, in fact, much greater than 0.35–1.3.

Thünen's rings, are largely inapplicable" (Kłodziński, 1972, p. 112). This is quite an adequate description of the situation linked with the specific features of the functioning of the market in our economy, where both the prices of consumer goods sold to the population and those paid to the farmers for their products are as a rule (with very few exceptions) equal throughout the country, i.e. are independent of location. Distance from a local market was, therefore, an important growth factor only for this part of agricultural production which was particulary sensitive to transport costs and/or time — like some fruits and vegetables, delivered to the consumers market to a great extent by the producers. Only in the case of the largest urban agglomerations (like Warsaw) local demand for these products corresponded to more than a fraction of the total agricultural output of the area and could affect significantly both the structure and the productivity of agriculture of a larger suburban zone.

INDUSTRIALIZATION AND THE GROWTH OF THE TERTIARY SECTOR

The influence of industrialization on the tertiary sector is difficult to measure since the sector was quite obviously expanding under the influence of a number of factors. The growth of employment and income in that sector might be treated as dependent variables, the magnitude of which is determined by growth both in primary and secondary sectors. On the other hand, the growth of the tertiary sector might also be considered as a means of policies destined to stimulate other sectors, and to some extent it was certainly considered so by the Polish regional development planning (e.g., certain aspects of the development of transport and communication). A special role was also played by the development of education and health services, guided by the goals set by the national social and cultural policy and thus conducted quite independently of regional industrialization policies.

Thus, it is difficult to interpret the occurrence of high rates of growth of employment and incomes in that sector in the underdeveloped regions (in most cases above the national average), as the result of the high rates of industrialization in these regions. The aggregated provincial data do not lead to conclusions as to the areal association between the growth of the secondary and tertialy sector, also due to the hierarchical structure of spatial distribution of the latter sector: the voivodships, the capitals of which were large urban centres were characterized, not unexpectedly, by the greatest increase in employment and incomes in the tertiary sector. One may observe, however, that the intensive industrialization of the selected larger cities was undoubtedly one of the means of the policy aimed at creating a number of strong regional centres, fully equipped with a broad array of service functions, including those of the very high order (e.g., the cities of Lublin and Białystok).

INDUSTRIALIZATION AND THE DIMINISHING OF REGIONAL INCOME INEQUALITIES

The above considerations permit an interpretation of the findings on the changes in the relative level of regional incomes and an assesment of the role of industrialization in these changes. We shall limit our discussion to the problem of change in the relative income situation of the underdeveloped regions, referring to the figures on personal income per one person actively engaged in economic activities.

TABLE 3. Regional incomes per capita (nominal personal incomes per one person engaged in economic activities)

Area	Incomes per capita (national average = 100)		Index of income per capita growth 1961–1973 (1961 = 1.00)
	1961	1973	
Voivodship of:			
Rzeszów	74	75	1.89
Kraków	77	79	1.91
Kielce	72	79	2.02
Lublin	75	77	1.90
Łódź	77	81	1.94
Warszawa	78	92	2.19
Białystok	72	83	2.16
City of Warszawa	134	139	1.92
Other metropolitan cities (Kraków, Łódź, Poznań, Wrocław)	120	122	1.88
Remaining regions	118	110	1.72
POLAND	100	100	1.86

The basic figures are presented in Table 3. They indicate that the average level of personal incomes in all underdeveloped regions was rising at a rate higher than the national one. Within the underdeveloped part of the country the regional growth rates were differentiated. This differentiation cannot be attributed either to the initial state of industrialization or to the rates of industrial growth. It appears to be a joint effect of industrialization, growth of the tertiary sector and the highly differentiated growth of agricultural incomes — the latter two factors being largely independent of the intensity of regional industrialization processes.

This conclusion does not belittle the enormous significance of national industrial growth for the *totality* of the conditions in which the processes of regional economic growth were occurring.

However, on a regional scale, the significance of industrialization seems to consist predominantly in:

(1) diminishing of the flows of interregional migrations and thus preventing the large-scale depopulation of less developed regions (and — conversly — the excessive agglomeration of population in the most developed regions),

(2) the compensatory effect in the raising of income level in the areas of high agricultural density of population, where due to the size-structure of farms the conditions for substantial growth of agricultural production were not favourable.

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SPATIAL PROBLEMS OF POLAND'S POSTWAR INDUSTRIALIZATION, 1945–1975

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INTRODUCTORY REMARKS

The purpose of the present paper is to provide general assessment of changes in the spatial structure of industrialization of Poland during the postwar period of 1945 till 1975 (as observed according to the new administrative division of the country into 49 voivodships, in force since June 1st 1975). Some attempts at formulating assessments of such changes in industry location in Poland, whether within the frame of the previous 22 voivodships or within the poviats, liquidated in 1975, were made earlier by many authors, e.g. by A. Wrzosek 1960, S. Leszczycki 1965, A. Kukliński 1966, A. M. Dawson 1970, S. Róg 1972, L. W. Murray Jr and G. J. Karaska 1975, or R. Wilczewski 1978. Because of the essential reshapement of the administrative division of the country which took place in 1975 all these attempts became largely out of date.

The notion of industrialization is understood here as the development of industry coupled with the growth of its share in the employment structure of the overall socio-economic activity and in the national income produced within a given territory. Hence, as a measure of the degree of industrialization the industry's per cent share in active labour force and in national income produced on a given territory, this share including industrial handicraft as a part of industry can be taken. Since this sort of retrospective data do not exist in Poland for territories defined by actual administrative layout another measure was utilized in this paper, namely the number of employed in industry per 1000 inhabitants. The data needed for this indicator could be reconstructed for the territories of new voivodships on the basis of existing statistical material. The indicator does *mutatis mutandis* correspond approximately to the share of industry in the structure of active labour force within voivodships.

On the basis of the approximate measure of industrialization adopted here one can define six groups of territories:

(1) very weakly industrialized, with the indicator value below 50 employed in industry and industrial handicraft per 1000 inhabitants roughly corresponding to industrialization level below 10% of the active labour force (all employed [1]),

(2) weakly industrialized, with the indicator value from 50 to 100 employed in industry per 1000 inhabitants, corresponding approx. to 10–20% of all employed,

[1] The category of active labour force does not include, e.g. temporarily employed pupils of professional high schools or some contract holders in service and trade; for purposes of this paper it can safely be assumed that it equals all employed.

(3) medium industrialized, with the indicator value 100–150 per 1000 inhabitants, i.e. approx. 20–30% of all employed,

(4) highly industrialized, with the indicator value 150–200 per 1000 inhabitants, i.e. approx. 30–40% of all employed,

(5) very highly industrialized, with the indicator value above 200 per 1000 inhabitants, i.e. above 40% of all employed,

(6) territories undergoing the postindustrial development phase which had reached in the past indicator values for highly or very highly industrialized ones but then because of the almost complete use of the available labour force in sector I (agriculture) their share of industry (sector II) in the structure of employement started to show a downward trend, with the indicator of sector III (service) growing.

Application of the above classification in the study reported here has facilitated assessment of changes in the industrialization of voivodships.

INDUSTRIALIZATION OF POLAND IN 1939 AND IN 1946

The present territory of Poland seen as a whole belonged before the World War II to those less industrialized parts of Europe. In the beginning of 1939 the entire employment in industry (in the broad sense, i.e. together with industrial handicraft) over this territory was 2727 thousand, while population was 32.1 million. Thus the indicator of number of employed per 1000 inhabitants equalled approx. 85 (per 10 sq. km — 87). Analogous indicators for highly developed western European countries were 2–3 times higher.

It should be mentioned that in 1939 differences existed between the industrialization levels of the so-called old territories and the territories regained thereafter in 1945. The latter were on the whole a bit more industrialized (90 employed in industry per 1000 inhabitants) than the old territories (76 employed per 1000 inhabitants).

Much bigger divergences existed among the levels of industrialization reached within the territories of the present voivodships. Out of 49 spatial units corresponding to present voivodships only the territory of Łódź voivodship could be qualified as very highly industrialized according to the classification introduced (216 employed in industry per 1000 inhabitants), territories of 4 voivodships (Jelenia Góra — 190, Katowice — 153, Wałbrzych — 171 and Zielona Góra — 154) could be qualified as highly industrialized, and territories of two voivodships (Warsaw — 144 and Wrocław — 114) as medium industrialized. These seven voivodships comprised together 11% of the present surface of Poland and accounted in 1939 for 45% of the whole employment in industry and in industrial handicraft. They represented the level of industrialization nearing that of the western European countries.

Territories of the other present voivodships were in 1939 either very weakly (15 units) or weakly industrialized (27 units). Particularly low indicator values characterized the territories lying to the East of Vistula (and Raba), where industrial activities were carried out mainly by handicraft and by small mineral, wood and foodstuff factories. Within the eastern part of the present territory of Poland, accounting for about 42% of the area, only about 16% of all employed in industry did work.

The World War II caused great losses to industry on the present territory of Poland. This resulted in the return — in terms of employment — to the level of industrialization reached in 1970's and 1980's of the 19th century. At the end of

1946, i.e. almost two years after the end of the war, employment in industry and in industrial handicraft was 1463 thousand, that is only about 54% of the 1939 value. It should be emphasized that the losses in industry differed among the regions. The greatest relative losses occurred within these voivodships which already belonged to the group of very weakly industrialized and within medium industrialized Warsaw and Wroclaw voivodships. On the other hand, in most of the highly industrialized voivodships the losses were relatively lower. Hence, spatial differentiation of industrialization was in 1946 bigger than ever before.

Within the above context it is worth mentioning that on the territory of Katowice voivodships, covering only 2.1% of country's area, worked as much as 27% of all employed in industry and in industrial handicraft in Poland (31% without handicraft). On the territories of this one, together with still very highly industrialized Łódź voivodship and with medium industrialized Wałbrzych voivodship, the three covering only 3.9% of country's area, were concentrated in 1946, 43% of the whole Polish employment in industry and handicraft (49% without handicraft). Territories of other present voivodships belonged in 1946 to groups of very weakly (34 units) and weakly industrialized (12 units). On the very weakly industrialized territories of Poland, east of Vistula, accounting for 42% of country's area, employment in industry and in industrial handicraft was in 1946 only 11% of the national total. This great differentiation of industrialization and industrial location among territories of present voivodships in the just-after-the war period is illustrated by the value of localization coefficient — 0.510 area-wise and 0.336 population-wise in 1946, as compared to 0.374 and 0.221 in 1939, respectively.

PRINCIPLES GUIDING POLICY OF INDUSTRIALIZATION OF POLAND IN 1946–1975

Because of the low level of industrialization of the country the quick industrial growth has become one of the most important directions in the Polish economic policy after the war. One of the essential motives for such a policy was the necessity of activating and employing large reserves of labour force with the purpose of full employment. In the inter-war period the reserves of so-called latent labour force were estimated as approx. 4.5–8 million people. Great divergences in location of industries and in spatial structure of industrialization caused introduction of the principle of diminishing the interregional differences as the leading one within the regional policy of the state. This principle became one of the main directives of the overall economic policy, aiming not only at improvement of but also at equity in life conditions of population in various regions.

In consecutive periods of the 30 post-war years this principle took on varying formulations. In the late 1940's the official formula stipulated 'deconcentration' of the two biggest industrial agglomerations of the country, i.e. the Upper Silesian Industrial Region (GOP) and Łódź. During the first half of the 1950's the formula became 'even distribution of industry', and in the second half — 'more rational distribution of industry'. Then, in the 1960's, these formulations have been replaced by 'deglomeration of the biggest urban-industrial agglomerations in the country' (that is, besides GOP and Łódź also Warsaw area and Gdańsk, Poznań and Cracow agglomerations). Since the beginning of 1970's the formula realized proposes 'tempered, poly-centric concentration'.

CHANGES IN INDUSTRIALIZATION IN 1939–1975

During the period 1945–1975 from an agricultural country Poland has turned into a highly industrialized one. Though the level of developed western European countries has not been reached yet, nevertheless the difference in levels as measured with output of basic industrial products per capita decreased importantly. In some products (e.g., related to energy carriers, sulphuric acid, cement) corresponding indicators for Poland are already greater than in many of these countries.

The number of employed in industry and in industrial handicraft on the territory of Poland increased from 2727 thousand in 1939, 1463 thousand in 1946 and 2050 thousand in 1949 to 5565 thousand in 1975. Almost all of the increase occurred in the industry itself without industrial handicraft. Employment in the industrial handicraft was in 1975 only a little higher than in 1949. It seems therefore that one can state that in the period 1949–1975 workplaces have been created in Polish industry for over 4 million people, of which 3.5 million workplaces in the years 1950–1975.

It should be noted that the growth of production value was quicker than that of employment. During 1950–1975 the value of global production of the socialized industry has grown by the factor of 13, while the value of net product by the factor of 10.

These undoubtedly important results in industrialization have been achieved with a great effort of the whole society, and to a high degree with a detriment of other sectors of economy. From 1946 till 1977 over 40% of all investments made in the whole of country's economy went into development of industry. The effect of this was that the growth in value of productive assets has been in industry ten-fold, and the share of industry in the national income produced has grown from 26.1% in 1946 to 52.7% in 1977, i.e. more than twice.

Industrial growth was much quicker than population growth and because of that the indicator of employed in industry and in industrial handicraft per 1000 inhabitants increased for the present territory of Poland from 85 in 1939 and 61 in 1946 to 163 in 1975. Nowadays the level of industrialization of the country's territory is therefore twice as high as before the World War II, and almost three times higher than in 1946.

This rapid process of industrialization has been accompanied by essential changes in the branch structure of Polish industry. These changes consisted mainly in the great growth in importance of the metal and machinery as well as chemical industries, with a drop in significance of other sectors, particularly fuel and energy, metallurgic and light (textile) industries. The share of metal and machinery industries in the overall industrial employment has increased from 18.1% in 1946 (21.5% in 1939) to 34% in 1975, and the one of chemical industry from 4% in 1946 (4.9% in 1939) to 6.6% in 1975. On the other hand, the share of fuel and energy industries (mainly coal industry) dropped from 21.9% in 1946 (13.8% in 1939) to 10.4% in 1975, of metallurgy — from 7.2% in 1946 to 5.2% in 1975, and of textile industry — from 15.8% in 1946 (16.1% in 1939) to 10% in 1975.

The policy of slowing down industrial growth within the most industrialized areas (particularly in GOP and Łódź) with the aim of promoting less developed regions, carried out — with significant difficulties — since the end of the war, resulted in essential changes as to distribution of industries and levels of industrialization of individual voivodships. Introduction of these changes was facilitated by the above-mentioned shifts in the branch structure of industry, and specifically by growth in importance of the metal and machinery industry, whose plants can be relatively freely geographically located, and of the chemical industry, consuming large amounts of water resources, to be found mainly in the northern part of the country, less industrialized before the World War II. An advantageous factor for these changes consisted in discoveries and developments of new deposits of mineral raw materials, especially lignite around Konin, sulphur near Tarnobrzeg and copper ores near Lubin and Głogów.

Both in the whole postwar period observed (1946–1975) and in the period after the essential reconstruction had in principle been accomplished (1950–1975) the least dynamics of industrial growth can be seen in the three most industrialized voivodships: Łódź, Katowice and Wałbrzych. The greatest dynamics — some 2–4 times higher than the national average — showed in the period 1946 to 1975 the areas of least industrialized eastern voivodships, whose industry, in addition, was during the war damaged the most. Similar dynamics of growth characterized the northern and north-western voivodships, where war losses were also great, and till the end of 1946 not all of the remaining plants could be put into operation.

Thus, after completion in principle of essential reconstruction (i.e. from 1950 till 1975) the greatest (2–4 times higher than national average) dynamics of industry's employment growth occurred in 10 eastern voivodships, in centrally located Konin voivodship and in the northern, seaside Słupsk voivodship. This phenomenon resulted mainly from the low initial employment.

In spite of the low growth dynamics, however, agglomeration economies caused that the absolute increases in industrial employment were the greatest in these voivodships which were already before the World War II the most industrialized or on whose territories already in 1939 existed industrial agglomerations (whole districts or large centres). It should be added that extreme war losses of some of the agglomerations (e.g., Warsaw, Wrocław, or Szczecin regions) did not have much influence on the magnitudes of employment increases in industry. This part of plants' infrastructure which was not damaged constituted an important factor of reconstruction and further development of the centres.

On the territory of these 14 voivodships where already before the war existed big industrial agglomerations the increases in the number of employed in industry from 1946 till 1975 did as a rule exceed 100 thousand.[2] In all of these voivodships the appropriate industrial agglomerations (districts or centres) were fully reconstructed and then further developed. The voivodships mentioned have absorbed in 1946 through 1975 nearly 2/3 of all the national employment increase in industry and in industrial handicraft. It is worthy mentioning that Katowice voivodship and its four neighbouring voivodships comprised in the Upper Silesian-Cracovian Industrial Macroregion (Bielsko, Częstochowa, Cracow and Opole) covering together merely 9% of the country's area have in the timespan observed absorbed 25% of the whole employment increase in the sector under study. This resulted certainly from the proximity of the country's greatest fuel-and-energy base, but also from an evidently too intensive — from the point of view of labour force shortage — growth of the metal and machinery industries in Katowice voivodship, quite loosely connected with mining and metallurgy. In 1946 through 1975 the share of metal and machinery industries

[2] On the territory of Katowice voivodship the increase of employment in industry and in industrial handicraft over the years 1946–1975 was 535 thousand, in Warsaw voivodship 326 thousand, Gdańsk 151 thousand, Wrocław 150 thousand, Łódź 147 thousand, Kielce 140 thousand, Bielsko 135, thousand, Opole 134 thousand, Cracow 133 thousand, Poznań 123 thousand, Bydgoszcz 114 thousand and Szczecin 107 thousand.

in the overall employment in industry of this voivodship increased from 11.5% to 23%, i.e. twice.

On the territories of 20 voivodships situated mostly or wholly to the East of Vistula and Raba the employment in industry and in industrial handicraft increased from 160 thousand in 1946 to 1083 thousand in 1975, i.e. almost seven times. The increase itself was 923 thousand, of which in the period 1949–1975 about 870 thousand. Taking into consideration the eastern part of Warsaw voivodship as well one obtains for the postwar increase in industry's employment in this part of the country a figure over 1 million people. Hence, this weakly industrialized part of the country has absorbed over 25% of the total postwar increase of employment in the sector observed. One should note, that on these eastern territories almost the same number of people were in 1975 employed in industry (handicraft excluded) as in the whole of Poland in 1946. The share of eastern voivodships in the national employment in industry and in industrial handicraft has increased in the years 1946–1975 by the factor of two, from about 10% to 20%.

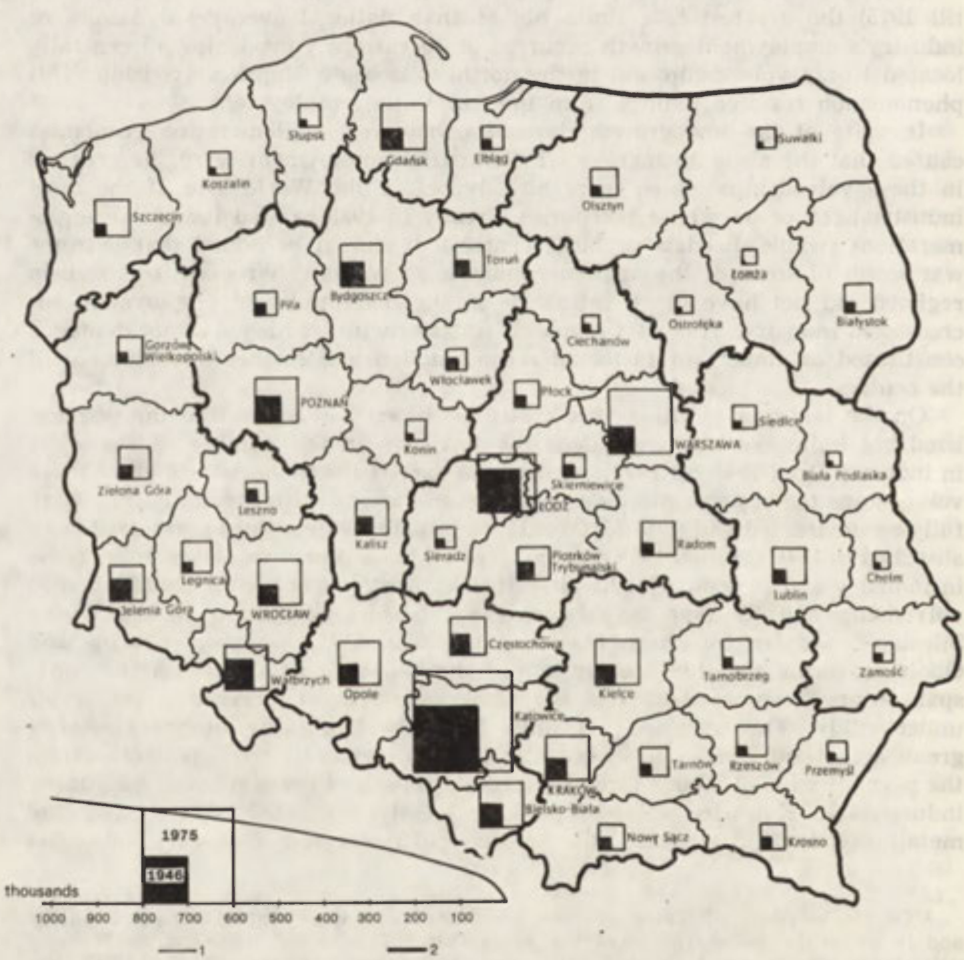

Fig. 1. Distribution of industry in voivodships in the years 1946 and 1975
1 — voivodship boundaries, 2 — boundaries of long-term planning macroregions

Creation after the war of new workplaces for over 1 million people in the very weakly industrialized part of the country to the east of Vistula, and about two-fold increase of its share in national employment constitutes undoubtedly an important, though not fully satisfying success of the Polish locational policy. Within this context it should perhaps be emphasized that some analogous attempts of accelerating industrialization of the territories lagging behind which has been undertaken in the countries of southern Europe (in Spain and in Italy) were unsuccessful. Studies reported by A. L. Rodgers indicate that the share in the overall employment in industry of the southern part of Italy, known as Mezzogiorno, which was industrialized in a planified manner decreased from 16.4% in 1951 to 14.6% in 1971 (Rodgers 1976), and the absolute increase of employment in industry was in this period only 200 thousand people. Analyses of M. Ferrer Regales point out that the policies aiming at acceleration of industrialization in the lagging central and southern provinces of Spain did not succeed either. From 1962 till 1973 the share of the Interior (Madrid and Valladolid areas exluded) accounting for 30% of Spain's surface, in the employment in sector II diminished from 14.3% to 11.4%, and the share of Andalusia, covering 18% of the country's surface, remainned on the level of 12% (Ferrer Regales 1977).

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The roles of territories of individual voivodships have undergone essential changes as a result of war losses, important postwar population movements and of much differentiated speed of reconstruction. Very few present voivodships, which in 1946–1975 have lost in industrial importance showed negative intervoivodship shift values of employment in industry and in handicraft, as obtained using formulae of the shift-share analysis. Other voivodships were characterized by positive shift values. Of the total of negative shift 88.2% were brought in by the already mentioned three voivodships having had in 1946 the highest level of industrialization, with Katowice voivodship accounting for 51.2%, i.e. more than half, of the total. The highest positive shifts occurred in these voivodships, where there has been the greatest growth of the share of employment in industry and in industrial handicraft. These positive shifts were more uniformly distributed, so that the share of any of the voivodships did not exceed 15%.

The changes and shifts described above caused that in the years 1946–1975 discrepancies in distribution of industry and handicraft among territories of present voivodships importantly decreased. Difference between the two voivodships with the greatest and the least number of employed per area unit in this sector (Łódź and Łomża, respectively) diminished by factor of 17, while in comparison with 1939 — by factor of 13. The downward trend in the spatial differentiation of industrialization in the years 1946–1975 is furthermore corroborated by the values of localization coefficients based upon employment in industry and handicraft, calculated with regard to areas of the new voivodships, and corresponding location curves (see Fig. 2). The value of this coefficient decreased from 0.510 to 0.366, i.e. by about 38%, while in the years 1939–1975 it did decrease merely from 0.374 to 0.366, i.e. by about 2%. In other words, the present degree of concentration of employment in industry and handicraft — according to new voivodships — does not differ substantially from the one of 1939.

CHANGES IN INDUSTRIALIZATION OF VOIVODSHIPS IN YEARS 1939–1975

Mass movements of population after the war caused that the decrease in differentiation of industrialization level was much bigger that of actual industrial location, this fact being illustrated by indices of employment per 1000 inhabitants. Further corroboration bring here the values of localization coefficients based upon employment in industry and handicraft calculated with regard to voivodship population, and corresponding localization curves. The difference between Łódź and Łomża voivodships where, respectively, the greatest and the least number of people are employed in industry and handicraft per 1000 inhabitants, diminished by factor of 12 from 1946 till 1975, and the value of industry localization coefficient with regard to population dropped from 0.336 to 0.133, i.e. by 61%. On the other hand, in years 1939–1975 the difference between these extremally industrialized voivodships decreased by factor of 6, and the value of localization coefficient dropped from 0.221 to 0.133, i.e. by 40%.

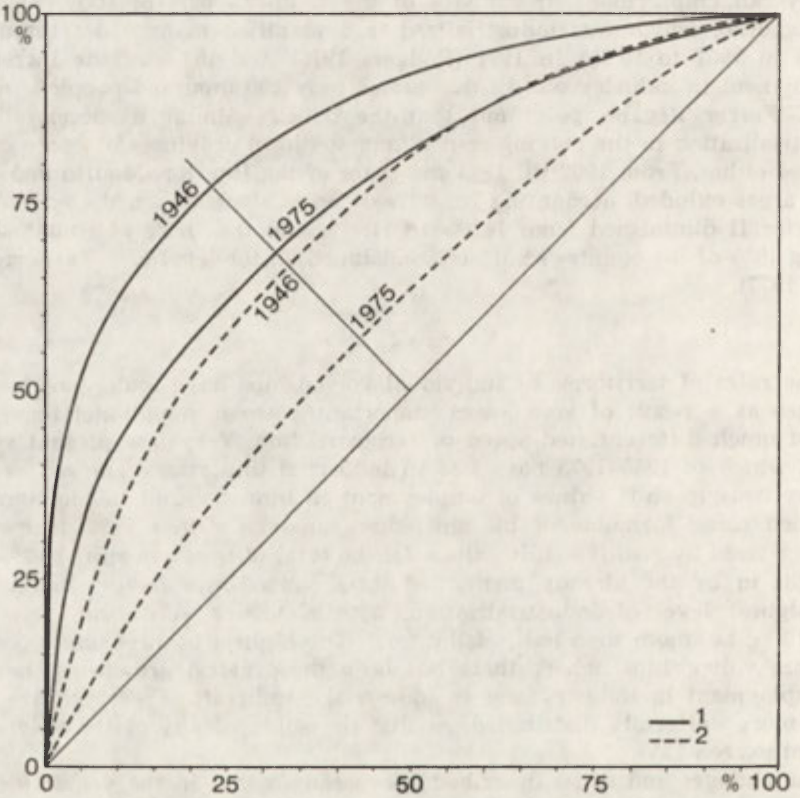

Fig. 2. Industry localization curves with regard to area (1) and to population (2); employment in %

In general, the rapid process of industrial development after the war increased the level of industrialization of all the voivodships. It should be emphasized that in the recent five-year period the group of very weakly industrialized voivodships, i.e. the ones with employment in industry and handicraft per 1000 inhabitants below 50 has disappeared. As already mentioned this group comprised in 1939 territories of 13 voivodship, and in 1946 of as many as 33 voivodships, that is 2/3 of their overall number.

In the postwar period the group of weakly industrialized voivodships with indicator values between 50 and 100 has also diminished importantly. While in 1939 as much as 26 voivodships belonged to this group, and in 1946 — 13 voivodships, in 1975 only 9 voivodships were left. In 1975 this group was composed exclusively from eastern voivodships. Covering 19.5% of the country's area and accounting for 11.2% of its population these voivodships comprised in 1975 only 5.4% of total employment in industry and handicraft. The level of employment in this sector was in these voivodships not much higher than in 1939, and the absolute increase ranged from 9 to 14 thousand. Quite important increase of relative industrial employment indices was in these voivodships due to drop in population number rather that to growth of employment itself. In fact, the population was there in 1975 usually lower than in 1939, and not much higher than in 1946. Outmigrations from these voivodships to those more industrialized was in the postwar years almost equal to the natural increase rates.

In the period studied the group of medium industrialized voivodships (100–150 employed in industry and handicraft per 1000 inhabitants) has increased the most. While in 1939 only two voivodships belonged to this category (Warsaw and Wrocław), and in 1946 only one (Wałbrzych), in 1975 already 20 voivodships belonged there, i.e. almost 40% of their total number. Covering together 42% of the country's area and accounting for 29.5% of its population these voivodships did in 1975 comprise 22.8% of total employment in industry and handicraft.

Somewhat smaller, composed of 15 units, was in 1975 the group of highly industrialized voivodships with indicators ranging from 150 to 200 employed in industry and handicraft per 1000 inhabitants. While in 1939 only 4 voivodships belonged to this group and in 1946 just the Katowice voivodship, in 1975 the fifteen highly industrialized voivodships (Warsaw, Bydgoszcz, Częstochowa, Gdańsk, Kalisz, Kielce, Cracow, Krosno, Legnica, Opole, Piotrków, Poznań, Toruń, Wrocław and Zielona Góra), accounting for 31.9% of country's surface and for 40% of its population, comprised 41.1% of the national total employment in the sector observed.

During the postwar period the group of very highly industrialized voivodships, i.e. with more than 200 employed in industry per 1000 inhabitants increased from just Łódź voivodship in 1939 and in 1946 to five voivodships: Bielsko, Jelenia Góra, Katowice, Łódź and Wałbrzych. These voivodships account for 6.5% of the country's area and for 19.3% of population and comprise 30.7% of the national total employment in industry and in handicraft.

CONCLUSION

Summarizing the results of analyses reported here one could state that in the postwar period simultaneously with the rapid process of industrial growth there has also been a process of gradual decrease of discrepancies in industrial location concentrations, as observed according to the new administrative layout, and a decrease of divergences of industrialization levels. The differentiation is nowadays much lesser than in 1946 and also somewhat lesser than in 1939: It can therefore be proposed that the regional policy in Poland attained in this domain important though not fully satisfying results.

TABLE 1. Changes in industrialization of territories of voivodships and plan-oriented macroregions in the period 1939–1975*

Macroregion (voivodship)	Employment in industry, in 1000			Share of voivodship in employment in industry, in %			Employment in industry per 1000 inhabitants		
	1939	1946	1975	1939	1946	1975	1939	1946	1975
Poland	2727.0	1463.0	5565.1	100.0	100.0	100.0	85	61	163
Nort Eastern	124.7	24.8	225.3	4.6	1.7	4.0	50	15	95
Olsztyn	36.1	8.2	69.0	1.3	0.6	1.2	56	28	104
Suwałki	21.0	2.8	34.8	0.8	0.2	0.6	44	13	83
Łomża	13.0	1.6	21.5	0.5	0.1	0.4	37	5	67
Ostrołęka	16.3	3.1	28.2	0.6	0.2	0.5	42	9	78
Białystok	38.3	9.1	71.7	1.4	0.6	1.3	64	19	116
Central Eastern	112.8	34.2	240.5	4.1	2.2	4.3	41	15	97
Siedlce	28.5	6.0	48.1	1.0	0.4	0.8	40	10	80
Biała Podlaska	13.6	2.9	19.8	0.5	0.2	0.4	40	11	70
Lublin	34.6	15.3	112.9	1.3	1.0	2.1	43	24	127
Chełm	13.1	3.5	24.9	0.5	0.2	0.4	34	16	112
Zamość	23.0	6.5	34.8	0.8	0.4	0.6	36	14	73
South Eastern	246.9	133.5	743.8	9.1	9.1	13.4	49	31	141
Kraków	49.6	44.9	177.8	1.8	3.1	3.2	63	63	159
Nowy Sącz	20.2	11.4	57.4	0.7	0.8	1.0	31	24	96
Krosno	26.3	12.0	63.2	1.0	0.8	1.1	48	33	150
Przemyśl	19.6	5.1	33.5	0.7	0.3	0.6	44	14	90
Rzeszów	17.9	8.2	86.9	0.7	0.6	1.6	33	17	142
Tarnów	21.1	10.6	76.5	0.8	0.7	1.4	39	21	132
Tarnobrzeg	24.3	10.0	77.0	0.9	0.7	1.4	44	22	144
Kielce	67.9	31.3	171.5	2.5	2.1	3.1	65	36	166
Southern	575.4	517.4	1414.7	21.1	35.2	25.3	123	131	237
Bielsko Biała	57.4	47.7	183.0	2.1	3.3	3.3	99	94	235
Katowice	384.2	398.9	934.2	14.1	27.1	16.7	153	189	268
Częstochowa	56.6	35.7	128.7	2.1	2.4	2.3	83	62	177
Opole	77.2	35.1	168.8	2.8	2.4	3.0	84	50	174
South Western	518.9	194.5	746.6	19.0	13.6	13.4	130	79	187
Wrocław	129.2	34.9	184.8	4.7	2.4	3.4	114	71	180
Wałbrzych	113.4	77.3	174.5	4.2	5.5	3.1	172	109	244
Legnica	36.0	8.4	79.3	1.3	0.6	1.4	93	49	191
Jelenia Góra	97.8	37.3	110.6	3.6	2.6	2.0	190	97	227
Leszno	17.0	11.5	37.8	0.6	0.8	0.7	52	44	110
Zielona Góra	81.6	17.3	96.9	3.0	1.2	1.7	154	76	167
Gorzów	43.9	7.8	62.7	1.6	0.5	1.1	99	43	144

*** Elaborated on the basis of data contained in publications and archives of the Central Statistical Office and the Committee for Space Economy and Regional Planning of Polish Academy of Sciences and in German industrial census of 17.05.1939.**

TABLE 1 cont.

Central Western	252.5	185.7	674.7	9.2	12.7	12.2	62	54	146
Poznań	72.1	64.1	187.5	2.6	4.4	3.4	86	85	160
Kalisz	36.0	24.0	100.3	1.3	1.6	1.8	58	45	156
Konin	19.3	5.8	44.0	0.7	0.4	0.8	41	15	103
Włocławek	26.2	11.5	42.2	1.0	0.8	0.8	57	32	104
Toruń	25.4	18.8	88.8	0.9	1.3	1.6	50	46	152
Bydgoszcz	48.9	48.6	162.5	1.8	3.3	2.9	65	74	163
Piła	24.6	12.9	49.4	0.9	0.9	0.9	60	46	118
Central	664.8	297.9	1062.0	24.5	20.4	19.2	112	68	173
Warszawa	268.4	57.8	383.6	9.8	4.0	7.0	141	59	178
Skierniewice	24.2	14.2	47.9	0.9	1.0	0.9	65	42	123
Łódź	207.6	160.8	308.1	7.6	11.0	5.6	216	235	285
Sieradz	29.7	7.6	39.0	1.1	0.5	0.7	55	19	100
Piotrków Tryb.	47.8	26.5	96.9	1.8	1.8	1.7	78	48	166
Radom	42.8	13.7	100.6	1.6	0.9	1.8	62	23	148
Płock	23.2	11.5	57.4	0.9	0.8	1.0	49	28	119
Ciechanów	21.1	5.8	28.5	0.8	0.4	0.5	52	15	71
Northern	231.0	75.0	457.6	0.8	5.1	8.2	77	47	138
Szczecin	83.0	13.9	121.1	3.0	1.0	2.2	94	55	142
Koszalin	23.8	4.9	48.1	0.9	0.3	0.8	59	17	11
Słupsk	24.4	5.4	46.3	0.9	0.4	0.8	72	20	130
Gdańsk	62.7	43.0	193.6	2.3	2.9	3.5	73	72	155
Elbląg	37.1	7.8	48.5	1.3	0.5	0.9	74	54	114

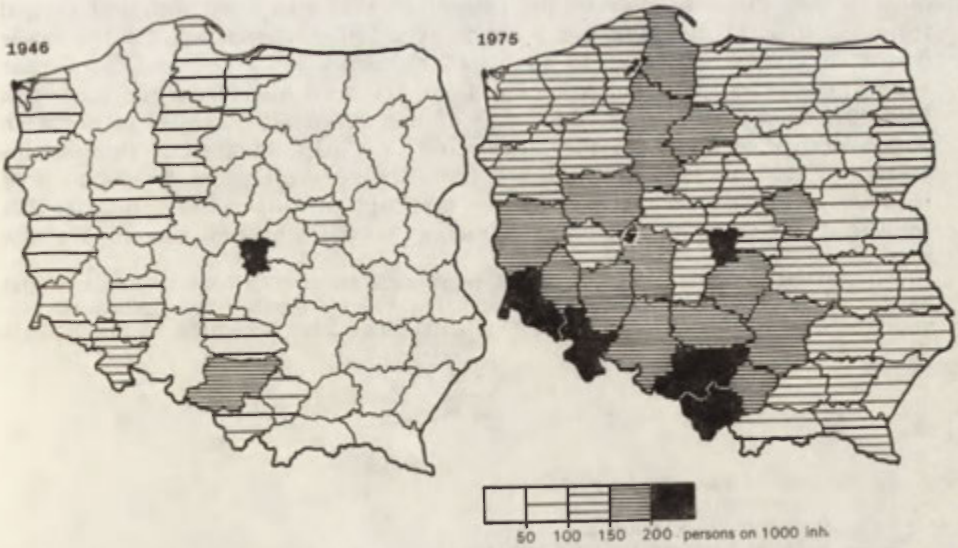

Fig. 3. Industrialization of voivodships in number of employed per 1000 inhabitants

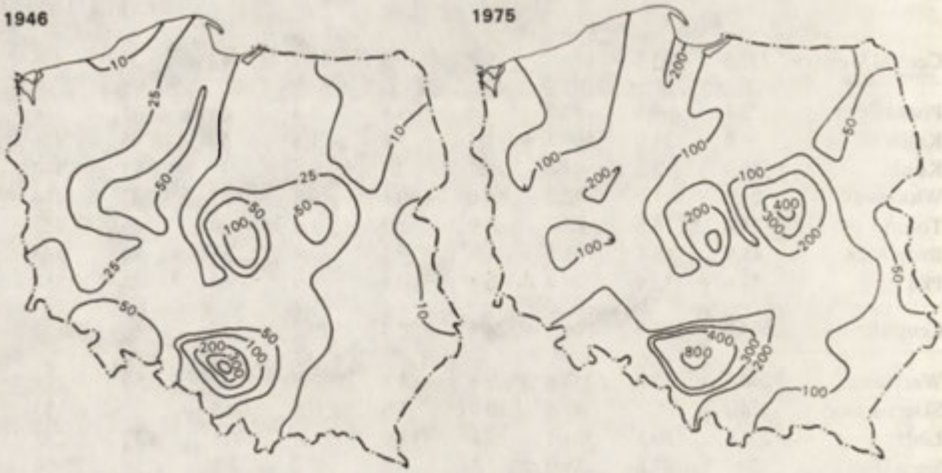

Fig. 4. Industrial potential of Poland in 1946 and 1975 (in thousand of employed in industry per 1 km)

During these thirty years substantial changes in spatial distribution of industry have been made, so that from the main concentration in southern and central voivodships, according to the policy's prerequisites, shifts were made in northern and eastern directions.

The assessment of the changes in distribution of industry and industrialization in the layout of new voivodships in the period 1946–1975 presented in this paper is corroborated by an analysis of maps showing industrial potential[8] and its changes during the time-span observed. These maps are treated as an additional, complementary element in description of reshapements in the spatial structure of industry. They indicate that the highest values of the potential of employment in industry and handicraft (above 100 thousand per 1 km) occurred in 1946 in Katowice and Łódź voivodships, and in 1975 also in Warsaw voivodship. In 1946 differentiation of the potential value was very high and ranged from less than 10 thousand per 1 km to over 100 thousand. In 1975 the lower bound on values moved up to almost 50 thousand per 1 km, and the higher bound to over 800 thousand per 1 km. Comparison of maps from the time-span 1946–1975 indicated quite distinct shift of the industrial potential in northern and eastern directions. On the other hand, the map illustrating absolute increases in the potential does indicate, however, very intensive development of industry over this time period on the territory of Upper Silesian-Cracovian Industrial Macroregion, including Wrocław voivodship, and also in Warsaw

[8] Industrial potential was calculated from data on employment in industry and handicraft in voivodships, with the respective values ascribed to capitals of voivodships. The calculation of values of potential was done according to the formula

$$P_i = \sum_{j=1}^{49} \frac{Z_j}{D_{ij}} + Z_i$$

where
P_i — value of potential in point i,
Z_i — employment in point i,
Z_j — employment in point j,
D_{ij} — distance between points i and j,
i, j — 1, 2, 3, ..., 49.

voivodship, and somewhat less intensive development in Łódź voivodship. Furthermore, this map points out that the development of industry was quite intensive in Gdańsk, Bydgoszcz, Poznań, Szczecin, Wałbrzych, Radom, Kielce, Cracow and Lublin voivodships, and shows very low intensivity of development in north-eastern and easternmost voivodships.

Fig. 5. Changes in industrial potential of Poland in years 1946–1975 (in thousand of employed in industry per 1 km)

The postwar tendency of diminishing differentiation in industries' distribution, and in industrialization of these voivodships both seen in the layout of new voivodships was accompanied by the process of spatial concentration of industry in great agglomerations (industrial districts and centres). The latter is illustrated by an increase in values of location indices for the areas of smallest administrative units, i.e. towns and gminas. From 1946 till 1977 the total national value increased from 0.837 to 0.852. It seems that the process of spatial concentration of industry goes on not only on the national scale, but also within most of the individual voivodships. This hypothesis could be corroborated by the fact that in 1/3 of all voivodships over 50% of the whole employment increase in industry in years 1946–1975 was absorbed by one town, namely the voivodship's capital, in 1/3 of voivodships — by two towns being the biggest industrial centres of these voivodships, and only in 1/3 of voivodships the employment increase was distributed more uniformly over a bigger number of centres. Full documenting of this hypothesis would require, however, more detailed studies.

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THE UPPER-SILESIAN CORE REGION: ITS GROWTH AND EVOLUTION

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The present contribution is part of my studies on the processes of industrial agglomeration in the group of industrial districts of the Upper-Silesian Core Region.* It is intended to show how agglomeration processes in industry take place parallelly to the growth of industrial potential and to structural changes, and how they affect the space-functional integration of the Upper-Silesian Industrial District (hereafter referred to as USID) with the four districts around it.

The process of concentration in space of production now under way and the reinforcement of integrative links of different scope speed up the emergence of a spatially continuous industrial core region. The processes of industrial integration between the different districts around the USID with the USID itself are a good illustration of the theory that industrial core regions develop by 'burgeoning'.

THE RATE AND GENERAL TRENDS IN INDUSTRIAL DEVELOPMENT

The growth in industrial potential of the Upper-Silesian Core Region is presented together with what seems to be the most likely course of its development till the year 1990. That potential is doubtlessly one of the most significant factors speeding up the process of agglomeration and of structural change in the industry as well as the more general socio-economic changes the entire Southern Macroregion.

The Southern Macroregion, and especially its industrial core, hold an exceptional position in Poland's national economy. It concentrates nearly half the total industrial potential of all Poland. Its unique position is also due to the highly complex spatial and sectoral structure of its industry and to the fact that about one-third of Poland's total industrial capital is concentrated on 2.7% of her entire territory (33% of the territory of the Southern Macroregion). The presence of that capital there is a main factor in making new locations and in economic decision-making.

* The group of industrial districts of the Upper-Silesian Industrial District called also the Industrial Agglomeration of Upper Silesian Industrial District consists of: Upper-Silesian Industrial District (in Polish GOP) and 4 fringe districts, namely Rybnik Coal District (ROW), Częstochowa Industrial District (CzOP), Bielsko Industrial District (BOP), and East-Opole Industrial District (WOOP).

The rapid development of industry over the past 33 years has called forth significant structural and qualitative changes not only in the Upper-Silesian Core Region but in the economy of the entire Southern Macroregion as well, and that both in the sectoral and spatial aspects. Those changes have been proceeding at a rapid pace especially from 1965 onwards, the year that saw the first pronounced effect of the new investment projects completed before. Those changes were taking place largely in the districts surrounding the USID, especially those of Rybnik and Bielsko-Biała where structural and spatial change has been particularly quick-paced. The causes of this are complex, but planned economic processes and location policies are the two main factors in this respect.

During the post-war period, the CSID area as well as the districts around it went through a strong growth and concentration of economically active population, especially in the state-owned and cooperative (or 'socialized') sector of the economy. Industrial employment claimed as much as 51% of the 2,065,000 people employed in the socialized sector in 1976, with the upward trend of this indicator still maintaining. This indicator in the USID exceeded the national average throughout the post-war period (in 1976, by 12%) which evidences the immense role of industry in total employment in that region. It is slightly lower within the USID than in the Rybnik and Częstochowa districts (where it is close to 60%), a fact which suggests that functions such as building, transports and services are in the heart of the Upper-Silesian Core Region more advanced than on its fringe.

Planning trends suggest that the increase in employment in the socialized economy predicted at some 700,000 people in 1970–1990 is going to distribute evenly in the particular sectors of national economy. Industrial employment will increase but slightly its proportion in total employment (by some 2–3%) but is always going to diverge from the corresponding national average.

The Upper-Silesian Core Region was inhabited by 4.3 million people in 1976, or 71% of the total population of the Southern Macroregion and 12.5% of Poland's total population. The population of the USID itself, which had meanwile incorporated most of the former Jaworzno-Chrzanów district within the framework of the 1975 reform, grew to 2.7 million, up from 2.2 million in 1970, or 62% of the population of the entire Upper-Silesian Core Region in 1976.

The fringes of the USID were inhabited by 1.6 million people but the growth rate there exceeded that in the USID; the passive dispersal policies pursued through appropriate investment policies and the provision of new jobs in the outer-fringe areas, especially in the Rybnik and Bielsko-Biała districts, were strong factors in this respect. The concentration of such a big number of people in the Upper-Silesian Core Region was due to its high growth rate in 1946–1976, a period during which it increased by some 1.5 million people, or by 35%. The population increase in that core region anticipated to amount to some 600,000 between 1970 and 1990 will bring it close to the five-million population limit. The strong concentration of population on the small area of 8300 km^2 accounts for the high population density; in 1976 it was 520 persons per km^2 for the entire core region, 856 for the USID, and 240 for the Southern Macroregion.

The Upper-Silesian Core Region is Poland's biggest agglomeration, both in terms of population and industrial capacity. In 1976 it claimed some 23% of Poland's total industrial employment (1,052,000 people) and still keeps on a high level though it fell slightly with regard to the year 1970. Characteristically enough, throughout the post-war period the fringe area displayed higher growth rates of industrial employment than the USID while its proportion in employment in the entire industrial core region increased by only 4%

between 1938 and 1976. In 1970 industrial employment in the fringe area was 40% of the entire Upper-Silesian Core Region but, as already mentioned, one of the fringe districts — that of Jaworzno-Chrzanów — had in the meantime integrated with the USID not only industrially but from 1975 also administratively.

A follow-up of the regularities now obtaining suggests that the distance in industrialization level between the USID and its fringe is going to decline steadily in the future. The readily available free labour, the rising investment in infrastructure facilities, abundant resources of valuable minerals such as coking-coal and iron ores, sand and limestone, and large reserves of territory as well as a full gamut of industries — all these are factors reinforcing the process of agglomeration.

The index of employment per 1000 population is the best indicator of the role the Upper-Silesian Core Region plays in socio-economic life. In 1976 it was 245 (with the national average at 137); since 1965 onwards it has been keeping at much the same level. All the districts display employment indices exceeding the national average, with the Bielsko-Biała district having 330 and in the town Bielsko-Biała itself even 525. The growth rate of the industry in the Upper-Silesian Core Region and the degree of its modernization is well characterized by the value of total output; since 1970 onwards it has claimed about 22% the entire national industrial output. These data are an indirect confirmation of the raw-material-dominated character of the industry of the entire core region, especially of the Rybnik district. This also reflects the development of Poland's other industrial districts where manufacturing accounts for a considerable proportion of output.

The basic structural changes effected in the industry of the region were due to heavy investment activity. The industries in the region have claimed the biggest share of investment outlays over the past 33 years. In 1946–1949, 65% of Poland's total industrial investment went there; 45% in 1950–1960 and some 27% in 1961–1970. After 1970, several huge industrial projects of high capital-intensity were put to use in the studied area, among them the 'Katowice' metallurgical works at Dąbrowa Górnicza (Łosień), the passenger-car (Polski Fiat 126p) factory at Tychy, the power-generating station at Rybnik as well as several coking-coal-mines.

The strong and persistent concentration of capital on the small territory of the studied industrial core region results in an advancing accumulation of fixed assets, productive capacities and technical and economic infrastructure there and pushes forward the process of spatial integration of its constituent districts. At the same time, though, it entails a number of disadvantages of social and economic nature.

This gives rise to the important problem of long-term investment. The seven-fold increase in financial expenditure vis-à-vis the proceeding decade planned for 1970–1990 will probably go above all to the reconstruction of industrial capacities and to the development of industries auxiliary to the leading branches. A special role in this respect pertains to the districts of the outer zone of the USID, which is now, and will be in the future, an area of alimentation for establishments cooperating with the industries in the USID. One direct consequence of the privileged position the region's industry holds in investment allocation, especially the industries of the USID fringe districts, that these latter will integrate territorially and in their landscape to produce in effect a continuous area of high industrialization and concentration of capacities. That continuity implies that industrialization will be encroaching into the area by narrow ribbons along lines of infrastructure facilities rather than by a wide zone.

How important the Upper-Silesian Core Region actually is can be seen still more clearly from the national outputs of a number of individual industries. The area concentrates the biggest capacities of the coal industry, of metallurgy, of some groups of the machine industry such as mining machinery, heavy-duty machine-tools and boilers, of nonferrous metallurgy and of power-generation of all Poland.

The Upper-Silesian Core Region increased its proportion in Poland's total employment in coal-mining from 93% in 1960 to 95% in 1975 while the corresponding proportion in employment in the national fuel industry dropped over that period from 83% to 77%. Employment in coal-mining grew there by 27,000 in 1960–1975 while the districts around it increased their proportion in that employment from 17% to 40%. That increase in employment in coal-mining over that period came entirely to the mines of the Rybnik district, with as much as 86% of it having been due to newly opened mines. The coal-mines in the USID reduced their employment by 18,000 people over the same time. It is expected that many coal-mines will not increase their crews till the year 1990. The increase in coal output is to reach the planned 220 million tons by 1990 mainly through increased productivity and by setting into operation seven or eight new mines, a scheme which is to secure a 90 per cent proportion of Poland's total coal output to the studied region. The decline in the proportion is due to the development of a new coal-basin in the Lublin region.

Employment in ferrous metallurgy, which in the Upper-Silesian Core Region grew by about 15% in 1970–1976, changed in strict connection with setting into motion the modern metallurgical works 'Katowice' and with the modernization of the old Upper-Silesian forges which are planned to terminate by 1990 production in the raw-material departments and to switch over exclusively to specialized metallurgical manufacturing. It is expected that the USID will in the future concentrate three-fourths of Poland's total output of conventional pig-iron, almost 60% of steel, and more than 80% of steel pipes.

This specific pattern of metallurgical production to be pursued in the future will presumably call forth intrasectoral changes in the iron metallurgy of the Upper-Silesian Core Region as well as external changes, especially as regards environmental protection.

The USID occupies a historically inherited monopolistic position in the national zink and lead industries and though its proportion in the national value of nonferrous metal output will in 1976 be down to 42% from 59% in 1960, the output of zink, for instance, will grow by 53%. Zink manufacturing will concentrate in the USID. There, too, the eight mines will provide the entire national output of zink and lead ores (some five million tons).

As regards coke production, the Upper-Silesian Core Region accounted for 64% of Poland's total 1976 output of 12 million tons, of which more than a half concentrated in the fringe districts, mainly the Opole and Częstochowa districts where that production has gradually been moving to. By 1990 only two of the old unattached cokeries are to remain — those at Radlin and Zdzieszowice.

The grouping of the Upper-Silesian Core districts has ever since the end of the Second World War been Poland's power-supply spine, its steadily declining proportion in Poland's total output of energy notwithstanding. In 1970–1976 that proportion fell from 35% to 30%, though power-generation grew during that time from 22,500 to some 30,000 million kWh. This downward trend is going to persist till 1990, because big power-generating plants working on brown coal are under construction in other parts of Poland. The plan to assign to the power plants of this area the task of supplying the entire energy needed in the Southern Macroregion seems to be correct if we consider that that macroregion concentrates most of Poland's power-generating units.

The machine industry is yet another branch of great importance in the Upper-Silesian Core Region. In 1970–1976 it claimed some 20% of the total national employment in that branch and as much of the total employment in the region. Remarkably, the fringe districts dispose over more modern sections of that industry than the USID. Long-term plans provide for a more rapid growth of total industry by 1990 than in the past; the value of total output of the industry is to make one-third of the region's entire industrial capacity by 1990. Most important within the machine industry is the production of cars developing in the Bielsko district, the production and maintenance of mining machinery, electronics, coal-mining and the machine-tools industry. The development of the electric-machine and electronic industries in the Upper-Silesian Core Region is a prerequisite for the modernization of the entire industrial structure of the Southern Macroregion.

What has been said above shows that the heavy industries concentrating in the Upper-Silesian Core Region are of crucial importance in Poland; except for the electric-machine industry, all other industries claim at least one-fourth of the respective national outputs. This bestows on the heavy industry of the studied region the role of the base on which Poland's entire industry is dependent.

The industrial capacity installed in the region works like a powerful magnet to more and more new kinds of industrial production. It is to be regarded as a very significant factor of integration-inducing processes and all other structural changes in industry both now and in the future.

TRENDS OF CHANGE IN THE SPACE-SECTORAL STRUCTURE OF INDUSTRY

Any change in the spatial or sectoral structure of industry in the Upper-Silesian Core Region is connected with the all-decisive fact of the considerable increase in industrial employment — between 1938 and 1976 it was about 657,000 people, or 63% of the present total figure. This amounted also to a 21 per cent increase in Poland's total industrial employment. In the USID itself the increase was 354,000 people, a figure not much above that in the districts around it (303,000), and that in spite of the incorporation of the former Jaworzno-Chrzanów district.

This huge number of new jobs together with the soaring employment both raised the level and scale of industrialization of the whole area, especially of the USID fringes. The constituent districts of the area became more differentiated as regards their industrialization. This manifested itself in the coefficient of redistribution of industries, which in 1976 was 0.14 with respect to that for 1938.

The districts of Rybnik and Bielsko-Biała have made the most considerable departure from the former pattern of space-sectoral structure of industry; in the former, apart from old and new coal-mines concomitant industries such as power-generation, the mining-machinery industry and concrete production have been emerging, while in the latter the electric-machine and car industries have outpaced in their potential the historically established textile industry.

The degree of saturation with industrial capacity and the changes in spatial structure in the studied agglomeration have been expressed as the index of employment per unit area. That coefficient was for the entire studied region 126 persons per km^2 with the nation average at 15 persons, or three times the corresponding index for 1938. A general measure of spatial changes is the systematic decline in industrial concentration as expressed by the location coefficient; for the districts around the USID alone it was 0.42 in 1976, down from 0.57 in 1938, though individual districts differ strongly in this respect.

Rational changes in the spatial structure of industry have in the post-war period manifested themselves in the narrowing gap in the degree of industrialization between the grouping of fringe districts and the USID as well as in extending the process of growth into the inner areas of the individual districts. Spatial integration understood as the continuous occurrence of industrial activities effected through the successive integration of productive centres and clusters manifests itself at present in the growing number of sites and areas of the USID adjoining one another. In addition to the former West-Cracow district, which has already been spatially, productively and formally (since 1975) integrated with the USID, the Rybnik and Częstochowa districts are now integrating with the USID in the NE direction due to the construction of the 'Katowice' metallurgical works; the same process takes place in the case of the eastern part of the Opole district, especially along the line Gliwice, Łabędy, Sławęcice-Blachownia-Kędzierzyn.

The spatial structure of industry is unlikely to change a lot in the future. Further establishments will be cropping up along the infrastructure ribbons and in towns (such as Dąbrowa Górnicza, Jastrzębie, Rybnik and others) which are currently incorporating a number of small but industrialized rural centres and small towns through administrative boundary corrections.

To prevent a further spillover of the 'industrial fat spot' beyond its boundaries it might be advisable to fix in spatial plans clearly and precisely the functions the areas of the Southern Macroregion outside the Upper-Silesian Core Region are to fulfill in the future. Moreover, areas with some capital investment already localized in them within the particular districts, e.g., the large stretch of land after sand extraction in the eastern part of the USID should be assigned purposeful and rational functions. The long-established practice of localizing certain establishments along some infrastructure ribbons should be revised too.

Another desirable change is the creation of a more correct sectoral structure of the industry in the studied area which is now being put into effect. The tendency to decrease the sectoral location coefficients is a welcome development; in practice this means that new industrial activities arise outside the traditional centres concentrating several leading industries. Generally, those are production branches ancillary to the leading industries, cooperating industries, or industries complementary to the sectoral structure of the existing centres.

The sectoral structure of industry is not a permanent factor in the industrialization process but undergoes slow but clearly noticeable changes. The industry's structural mutations reflect its qualitative evolution. Structural modifications in industry are as a rule accompanied by higher industrial productivity. One major cause of structural changes is the technological advance and innovation as well as substitution of raw materials.

The evolution of the sectoral structure of industry in the Upper-Silesian Core Region is presented in Tables 1 and 2. The data compiled in the Tables generally confirm the regularities and similarities in the changes in sectoral structure of the components of the Upper-Silesian Core Region and of Poland

TABLE 1. Changes in the sectoral structure of the industry of the USID fringe districts, 1960–1976, by employment in percentages

Groups of branches	Fringe districts of the USID			Upper-Silesian Industrial District			Upper-Silesian Core Region	Poland		
	1960	1970	1976*	1956	1970	1976*	1976*	1960	1970	1976*
1. Mature industries: coal-mining, metallurgy, iron and nonferrous mining zink and lead ores	30.84	32.74	35.85	66.30	58.10	55.46	47.95	17.40	15.50	14.35
2. Development industries: electric-machines, chemical and rubber industrial, power-generation	28.69	33.97	32.81	21.00	27.10	29.25	30.61	32.60	40.10	41.68
3. Near-obsolete industries: others	40.47	33.29	31.34	12.70	14.70	15.29	21.44	50.00	44.40	43.97
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Statistical yearbooks 1977/78 for the Częstochowa, Katowice, Opole and Bielsko voivodships; the author's own materials from field studies in the Bielsko voivodship and materials of the Voivodship Statistical Offices.

* The data for 1976 were determined for the new administrative boundaries as instituted on June 1,1975.

TABLE 2. Changes in the sectoral structure of the industry of the Upper-Silesian Core Region

Groups of branches	Proportion of employment in the entire industry, 1970 (in %)		Employment, 1976*		
	USID	Fringe districts	USID	Fringe districts	Proportion of the region in national total (%)
Industry:					
fuels and power-generation	39.42	26.39	257 000	112 091	35.08
metallurgy	16.12	8.64	113 800	36 896	14.32
electric machines	19.22	23.92	137 625	111 395	23.68
chemicals and rubber	3.90	7.76	41 500	16 293	5.49
minerals	9.50	6.56	28 750	22 450	4.87
timber and paper	1.40	4.60	6 000	9 326	1.45
light industry	3.72	17.01	32 628	67 007	9.48
food	5.66	4.38	23 186	17 817	3.89
other industries	1.06	1.34	8 623	9 665	1.74
	100.00	100.0	649 112	402 940	100.00

Source: as in Table 1.
* See Table 1.

as a whole. They point to a general decline in the proportion of the raw-material industries, mainly of coal-mining and of the extraction of zink and lead ores as well as of metallurgy.

The insignificant rise in that proportion recorded for the fringe areas around the USID should be associated exclusively with the provision of seven new coking-coal mines in the Rybnik Coal District. In contrast to the USID, the raw-material industries in the fringe districts are less of a 'monoproduction' than in the USID itself, though their proportion in the overall industrial structure there is still more than twice that of Poland as a whole. This group of industries is going to grow but slightly in the whole region, though long-term plans provide for the construction of several coking-coal mines as well as zink and lead ore-mines.

The behaviour of indices in the second group of industries — those referred to as development industries — is clear, too, but less propitious. Generally, notwithstanding its upward trend the proportion of this group of industries in the industrial structure of the entire industrial core region is distinctly below the national indices. The industries localized in the core of the Southern Macroregion are still in the phase of making up for the retardation in modernizing their capacities.

In the long run, the development of this group of industries is a precondition for modernizing the whole industrial structure of the Upper-Silesian Core Region which still has all the indispensable prerequisites for expansion. It can safely be said that this group of industries in the studied area has so far been developing secondarily, on the basis of technological or economic links as industries ancillary either to coal-mining coke chemistry, power-generation or to metallurgy and various types of mining or even to the textile industry (textile machinery at Bielsko).

The long-term plans should put stronger emphasis on the development of the branches that are not tied to the needs of the heavy industries in the studied region, especially on the electric-machine industry. Electronics and high-precision appliances are the two industries that should be developed at the highest rates. They can open their latent reserve jobs for unemployed women, especially in centres with a homogeneous industrial structure, as in the Rybnik district or in the towns Olkusz, Jaworzno, Czeladź and other localities.

This group of industries still displays high material-intensity rates of production. Hence their modernization implies also a reconstruction of their production mix, the automation of technologies, and superseding the customary heavy raw materials by new lighter ones. At the phase of development attained by now we must also revise the forms of organization and production of the developing industries. One way to do this is to develop several industrial combines or production groupings, following the example set by the car-production combine Bielsko-Tychy.

The third group of industries, which is referred to as near-obsolete industries, displays features of development typical in that group. Its proportion in the entire national industrial structure is steadily declining at rates close to the national averages. The light industry and the timber and paper industries are the decisive factors responsible for that decline, industries that modernize their production technologies most by automating them. They played a significant role in the industrialization of the Rybnik and Częstochowa districts as well as in several centres such as Andrychów, Chełmek or Kęty. This group of industries does not fully conform to these general regularities in the USID itself where its proportion has increased slightly. The small increase recorded is mainly due to the food and clothing industries, a development understandable in so big an agglomeration.

The regularities in the development of this group of industries up to now suggest that the rate of decline of their proportion in the industrial structure of the core of the Southern Macroregion will be lower than the corresponding national average. They will continue to be complementary to the homogeneous structure of heavy industry in many centres and will furnish new jobs for women, especially in centres of coal-mining.

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PRODUCTION AND SPATIAL LINKS OF POLAND'S INDUSTRY WITH FOREIGN COUNTRIES

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Industry of a given country may be treated as a system functioning in an accepted international setting. This is a more or less open system. The present-day national systems of industry are characterized by an increasing degree of openness necessitated by a highly developed division of labour and specialization. One of the preconditions of an efficient and effective national system of industry is its close cooperation with this 'setting.'

Poland's economy and her industry in particular have been marked by a relatively low degree of openness to the outside. This is confirmed, among other things, by a low index of foreign trade turnover per 1 inhabitant which amounted to $ 218 in 1970 and $ 863 in 1978. Apart from USSR, Yugoslavia and Rumania this was the lowest index among the socialist countries, not to mention the countries of Western Europe.

Poland's share in the world's industrial and agricultural production amounts to over 2% while in the world's foreign trade to as little as some 1.2%. In most European countries these proportions are completely reversed or stand at least as 1:1.

The already considerable industrial potential of Poland is oriented in merely some 15% for export (1978) as compared with 40–60% of goods exported by highly developed countries. Low, too, is the share of imports in the provision for the home market, this constituting 8–9% in the years 1972–75 as compared with 20–60% in countries of Western Europe.

The pattern of Poland's economy in recent years has above all been most evident in industry which to a growing extent has been entering into international associations both with the CMEA and western countries. Beside a considerable increase in foreign trade turnover the cooperation of industry with countries abroad is carried out in more composite organization-production and trade-financial forms corresponding to the actual needs and tendencies in the world. These include for example joint investments and various forms of industrial cooperation.

Joint industrial investments are one form of cooperation among the CMEA countries (Bożyk, 1977). Poland has participated or participates in some of these thus securing supplies of deficient raw materials or products as, for instance, Soviet crude oil (12–13 mill. tons a year in recent years) — thanks to participation in the construction of the pipeline 'Friendship', natural gas — as a result of participation in the construction of a gas pipeline from Orenburg, pig-iron — through its share in the construction of steelworks in the region of Kursk, potassium salts — thanks to the construction of one of the mines in Byelorussia, cellulose — through its share in erecting cellulose plants at Ust'-Ilimsk in Siberia and at Braila in Rumania, asbestos — because of participation in the construction of a mine in the Urals and of others. Poland's share in these investments was realized either in the form of credits, machinery and equipment, or by provision of manpower.

On the other hand, Czechoslovakia has, for example, participated on similar lines in raw material investments carried out in Poland. These included the construction of a sulphur mine in the vicinity of Tarnobrzeg and copper mines in the region of Lubin-Glogów. This kind of cooperation continues to expand and also included western countries. For instance, a three-sided agreement between Poland–Austria–Czechoslovakia was signed in 1977 to supply electrical energy from Poland to Austria (by way of the electrical energy system of Czechoslovakia) with Austria partially financing at the same time the extension of Polish power-stations. An Italian-Austrian scheme to build a coal pipeline directly from Upper Silesia to Italy across Austria (to the works Voest-Alpine in Linz) is also being considered.

The need for assuring the effectiveness of industrial investments and of profits from specialization and large-scale production is more and more frequently possible solely on an international scale. Hence a tendency (and often a necessity) has appeared to develop bi- and multi-lateral international cooperation and to internationalize production.

Internationalization of production takes various forms such as, for instance, the purchase of foreign licences and know-how, that is to say a transfer of new technologies, cooperation and specialization of production, creation of joint-ventures industrial or trade in character, cooperation on the markets of other countries etc.

A turning-point in this respect, not only for Poland but also for the whole of economic relations between East and West, was the signing by Poland and the Soviet Union of a licence agreement with FIAT in 1965 and even earlier by Yugoslavia (in 1954). The licence policy in Poland as well as in other socialist countries had gained firm ground since 1970. For example, there were 154 licences — based on products manufactured in Poland in 1971 while there were as many as 343 in 1975, of which 87 licences were purchased in FRG, 52 in Great Britain, 40 in France, 36 in the USA, 24 in Sweden, 21 in Italy, 19 in Japan and a number in other countries. The share of production based on licences in 1974 amounted to 14% in the machine-building industry, to 9% in the chemical industry, and at the same time the export of licence-based products constituted some 5% of the total exports of Poland (Brzost, 1977). The most active recipient of the licences in Poland appeared to be the car industry (Fig. 1), that is to say one of industrial branches most liable to technological innovations.

A higher form of external links in industry are cooperational agreements, now one of the most effective forms of international economic cooperation. Cooperation in industry is a new and stimulating form of international economic relations. Its importance consists not only in the transfer of technologies and of new forms of organization, but above all in the shaping of a new model of economic relations in the world (J. Stanovnik, Executive secretary of the ECE, quoted after Zagórski, 1977).

In the years 1976–77 the CMEA countries were involved in more than 600 bi- and multi-lateral cooperation and specialization production contracts, Poland's share amounting to 255 agreements. The share of supplies by virtue of cooperation and specialization worked out at more than 15%. Poland's share was similar and amounted to 21.6% in exports and 11.7% in imports from other CMEA countries. Poland succeeded in maintaining an active balance sheet of

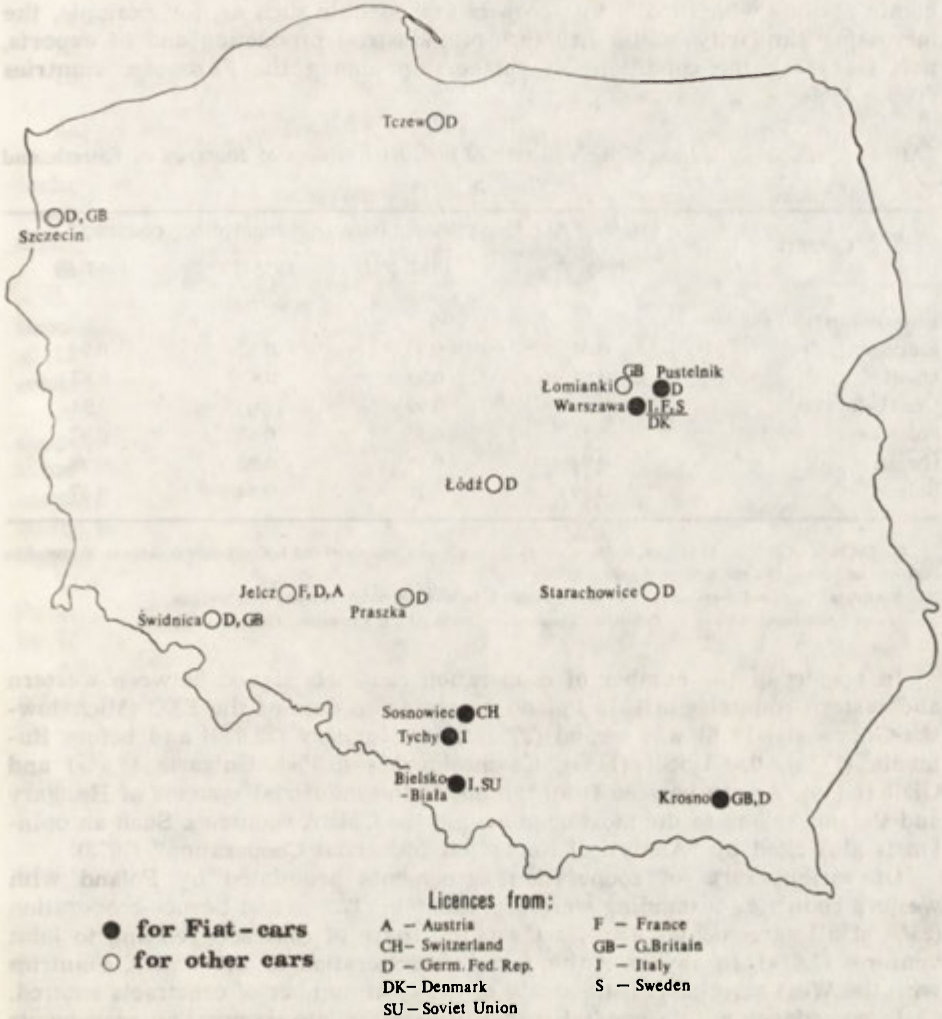

Fig. 1. Automobile industry centres producing on foreign licences

this cooperation. The share of cooperation and specialization of Poland's trade turnover with individual CMEA members was as follows (1976–77): Hungary — 25%, Yugoslavia — 25%, Czechoslovakia — 20%, Rumania — 20%, Bulgaria — 18%, the USSR — 15%, GDR — 14%. It is foreseen that this type of trade with the CMEA countries will increase to 25–30% by 1980.

Industrial cooperation developed much earlier and on a larger scale in countries of Western Europe. For instance, in 1972 in the six countries of the EEC the number of cooperation agreements amounted to 1136 (Rajpolt, 1978).

Both trade turnover as well as cooperation contracts between the countries of the East and West also expanded. For instance, the share of trade turnover of the CMEA countries with other countries amounted to 36% in 1971 and to 45% in 1975.

Apart from favourable political circumstances there are, too, objective economic reasons which make this cooperation possible such as, for example, the increasing similarity of the structure of industrial production and of exports, that is to say the conditions of partnership among the European countries (Table 1).

TABLE 1. Similiarity indices of the structure of industrial exports of countries of Eastern and Western Europe

Countries	France, FRG, Great Britain, Italy		Eight other countries*	
	1955–57	1967–69	1955–57	1967–69
Five countries of the Eastern Europe	0.87	0.93	0.85	0.94
USSR	0.84	0.85	0.85	0.87
Czechoslovakia	·	0.99	·	0.94
Poland	0.51	0.95	0.67	0.92
Hungary	0.94	0.95	0.90	0.98
Bulgaria	0.39	0.76	0.64	0.67

On the basis of data for 14 sectors. Value of the coefficient ranges between 0 and 1. Coefficient 0 denotes a complete lack of similiarity, 1 — absolute similiarity.

* Austria, Belgium-Luxembourg, Denmark, Finland, Ireland, Holland, Norway and Sweden.

Source: Analytical Report on Industrial Cooperation among ECE Countries, Geneva 1973, UN.

In respect of the number of cooperation contracts signed between western and eastern countries in 1975 Poland according to data of the EEC (Michałowska-Gorywoda, 1976) was second (27%) after Hungary (32.8%) and before Rumania (17%), the USSR (11%), Czechoslovakia (6.8%), Bulgaria (3.9%) and GDR (1.4%). As can be seen from the above the industrial systems of Hungary and Poland belong to the most open among the CMEA countries. Such an opinion is also cited by "Analytical Report on Industrial Cooperation" (1973).

Of various sorts of cooperation agreements negotiated by Poland with western countries oustanding were coproduction (37.5%) and licence-cooperation (25% of all agreements). The least was the share of contracts relating to joint ventures (1.8%). In any case, this form of cooperation of the CMEA countries with the West covered as little as 3% of the total number of conctracts entered.

In accordance with a general tendency to enter into cooperation agreements it was the engineering industry which was dominated (36% of the number of contracts) followed by the metallurgical industry (16%), the electrical engineering and electronic industries (11%), the transportation equipment industry (9%) and by light industry (7%).

Poland's most important partners in industrial cooperation with the western countries (1975) were:

Italy	— 40%	(FIAT)
FRG	— 20%	Telefunken, Lurgi, Bosch, Mannesmann and others)
USA	— 12%	(International Harvester, Singer, Clark, Kohering)
Sweden	— 6%	(Facit, Alfa-Laval, Volvo, Saab)
France	— 4%	(Creuzot, Berliet, Sat-Serete)
Great Britain	— 4%	(Massey-Fergusson-Perkins and others)
Switzerland	— 3%	(Sulzer, Rotel, Brown-Bovery)
Austria	— 3%	(Steyr-Daimler-Puch, Voest-Alpine)

other (Norway, Denmark,
Holland, Canada, Australia,
India, Ethiopia) — 8%

Cooperation agreements with the leading industrial firms of the world have made it possible (apart from the already mentioned profits in the transfer of technologies and the scale of production) for Poland's industry to enter the markets of the third countries, in that of developed countries, which are difficult to penetrate.

Such conditions are met in a most complex way by, for example, contracts with FIAT (in the production of passenger cars) or a contract with the British firm Massey-Fergusson-Perkins (production of tractors). The latter, its value £ 190 mill. belongs to the biggest and most complex licence and cooperation contracts negotiated between the East and West.

Apart from this, Poland actively participates, too, in the recently increasing cooperation 'East-West-South'. According to data of UNCTAD (Zagórski, 1976) some 160 three-sided cooperation enterprises were recorded in the developing countries in 1975. Poland took part in 40 of them (25%), her chief partners being FRG, Austria and France from the 'West' and India, Indonesia, Malasia, Egypt, Marocco, Tunisia, Benin and Congo from the 'South'.

The line East-West is also marked by the ever-increasing cooperation of Poland with numerous firms owned by Poles living in North America and in Western Europe, chiefly in the small industry, trade and in some services.

Another form of international cooperation are joint-ventures. In western countries these contributed to 25–35% of the production of mother countries in 1970–71 (Vernon, 1972).

The earliest example of a joint-venture in the CMEA countries is a Polish-Hungarian joint-stock company 'Haldex' created in 1959. Its business is the recycling of coal from numerous wastes heaped up in the Upper Silesian Coal Basin. Annually 3.5 mill. tons of wastes containing some 10% of coal are processed, the coal regained being divided by halves between the two countries.

On the basis of an agreement of 1972 between Poland and GDR a cotton spinning mill was jointly erected at Zawiercie and since 1975 is jointly operated and managed. This is an inter-state entreprise in which each country contributes 50% both in capital expenditures, the supply of raw materials and in the final products.

Similar joint-ventures are, too, the factory of bearings at Leszno (Poland-GDR, 1974) and a cotton spinning mill in Iran (1977). Apart from these, Poland is a co-participant in a number of production-trading companies in Greece, Nigeria, Ghana, Ethiopia, Kenya, Iran, India and Brazil and in more than 100 trade organizations in the developed western countries.

Yugoslavia, Rumania and Hungary are also participants in this kind of capital cooperation with western countries, their share being respectively 140, 6 and 3 joint-ventures (1975).

There are still various troubles in financial settlement of accounts among individual CMEA countries, these due to lack of market prices, difficulties in the conversion of national currencies into transfer-roubles etc., which have impeded the creation of joint-ventures on a larger scale in these countries.

Rising international economic cooperation including expansion of the geographical range and multilateralization of cooperational links is reflected in specific associations and spatial patterns among individual countries of groups of countries. Within the CMEA countries the elements shaping those associations and patterns are, for example, the oil pipeline 'Friendship' from the Volga, USSR, to Poland and GDR, and to Czechoslovakia and Hungary, or the gas pipeline from the southern Urals (Orenburg) into the same countries. The above-cited oil pipeline has determined among other things the location of the largest petrochemical and oil refining plants in these countries, namely at Plock (Poland), Schwedt (GDR), Bratislava (Czechoslovakia) or Szazhalombatta (Hungary).

An equally important link integrating the power economy in the CMEA countries is a combined electro-energy system of these countries.

A characteristic pattern of links between Hungary, the USSR, Poland and Czechoslovakia has been created for example in the metallurgy of aluminium (Fig. 2).

Fig. 2.

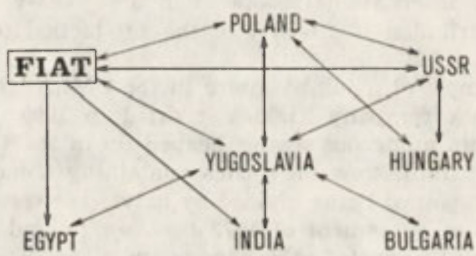

Fig. 3

This results from the situation in which only Hungary out of the four countries is in possession of aluminium raw materials, being at the same time devoid of major energy sources.

It the petrochemical industry of some CMEA countries in which the so-called olefin programme is carried out a kind of 'olefin ring' is being formed, this including Hungary and the USSR, Rumania and Yugoslavia as well as GDR and Czechoslovakia, now in the form of bilateral connections covering the consignment of olefin compounds varying in the degree of polymerization.

A good example of international spatial and cooperation associations is a new 'cooperation circuit' in Eastern Europe created as result of entering into the licence and cooperation contracts already mentioned with the firm FIAT by Yugoslavia, Poland and the USSR. This makes possible not only to cooperate with FIAT but also to enter more easily the markets of western Europe and of developing countries (Kołodziej, 1978; Fig. 3).

Poland is an important link in that 'circuit'. On the basis of the licence and cooperation contracts negociated with FIAT passenger cars FIAT 125p have been produced in Warsaw (since 1965) and FIAT 126p (since 1971) at Bielsko and Tychy, their total production being 250,000 in 1978. Out of this some 80,000 cars were exported. The production of some parts and assemblies to these cars involves by way of cooperation Yugoslavia, the USSR and Hungary in exchange for other spare parts supplied from Poland for the car industry of these countries and of complete Fiat 126p cars which are purchased by Yugoslavia and Hungary. Part of the licence costs of the firm FIAT are offset by the cooperation export of engines and of complete Fiat 126p cars. Also the factory in Warsaw exports some elements of the Fiat 125p cars to Ireland, Columbia, Egypt, Thailand, Malasia and Indonesia where they are assembled.

Equally active and widespread cooperation connections are displayed by the Polish car industry in the production of lorries and buses (Fig. 4). In addition, if we add cooperation contracts entered into during the past two years with the USSR and USA in the production of aeroplanes and with Great Britain in the production of ships, it must be acknowledged that the Polish industry of transportation equipment is in general of remarkable importance in the shaping of international associations of Poland's manufacturing.

Fig. 4.

On account of her medium-size in terms of population, availability of raw materials and production potential, Poland is all the more interested in international division of labour, in a profitable specialization and cooperation of production. This is reflected in Poland's economic policy since 1970 which was promoted a rising degree of openness in the Polish economy both in the relation of Poland—other CMEA countries and Poland—western countries. 55% of Poland's foreign trade in 1977 was with socialist countries and 45% with the remaining countries, of that 38% with the developed countries. Poland is now, after the USSR, the second largest trade partner of the EEC. The growing turnover with countries abroad brings about, among other things, a modernization of the Polish economy. For instance the amount of imports allocated for investment purposes was 15% in 1970 while it rose to 26% in 1975. Half of the machinery and installations installed as well as of means of transport over 1971–1976 were derived from imports.

Beside an increase in the traditional trade exchange the industry of Poland actively participates in various forms of international production and trade-financial cooperation in accordance with present-day world tendencies in this respect. This is accompanied by intense processes of the diffusion of innovations, a transfer of modern technologies and of the organization of production. On the whole Poland provides important links in the shaping of the system of spatial and cooperation linkages in Europe and in the World.

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SETTLEMENT CONCENTRATION AND INDUSTRIAL PRODUCTIVITY IN POLAND

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Spatial concentration as a phenomenon and process together with its consequences has long been attracting the interest of economic geographers, economists and spatial planners. The factors conductive to concentration and deconcentration and their impact on the effectiveness of production activities were the main substance of studies in the location of industrial activities. The classical works by A. Weber (1909), W. Sombart (1916), A. Lösch (1954) or E. M. Hoover (1948) furnished the groundwork for studies that demonstrated the economies of common location, that is, the benefits arising from several different industries localized in one place.

M. I. Webber (1972) attempted to recapitulate what the classical location theory had achieved. He did this by trying to explain location problems through an analysis of the concentration of industrial activity in spatial terms. Webber's study contains a comprehensive classification of the motivations and decisions that are possible in connection with the location of industries in various settlement systems.

Whenever the economies of concentration were studied it was mainly with reference to industrial activities. This problem has been explored in detail for the particular branches of the sector of industry. This involved mainly the analysis of investment effectiveness as recorded for the particular industries. Parallel to these, there appeared studies of industrial complexes. Soviet students of the problem have had notable achievements in analyses of what they termed territorial-productive complexes. These latter comprise a wide gamut of spatial units — from economic regions to agglomerations and urban centres.

The idea of territorial-productive complexes, a concept common in Soviet geographical and planning studies, is in its substance largely concurrent with the theories of growth poles. Originally devised in France and Italy, polarization concepts have by now been embodied into the planning practice of several countries and proved to be an adequate analytical method for the economic assessment of industrial concentration in spatial terms.

Results of studies on the processes of industrial concentration in territorial-productive complexes and in growth poles began to be used by planners in the derivation of policies for inducing certain desirable changes in space-economic structures. This involved, on the one hand, attempts to activate certain areas and, on the other, the necessity to raise productivity by concentrating a number of locations in selected urban centres.

In contrast to this, studies that would tackle the problem of how the size of a town as measured by its population potential affects the productivity of the industries localized in it are very few. There are still no studies that would disclose the actual relationships between the spatial concentration of settlements and industrial productivity or establish the effect of the degree of the concentration on the economic relations and interdependences in industrial production.

A theoretical recapitulation of settlement concentration in terms of cost-benefit analysis was given by W. Isard (1965) who studied the problems of industrial productivity above all from the angle of the degree of concentration. In addition to the locational benefits, Isard discusses the benefits to urbanization and regionalization, which he regards as economies of spatial concentration. To estimate this kind of economies one has to carry out a number of methodological and empirical studies which should comprise both the costs and economic benefits of concentration.

The study of the cost of growing concentration has been given considerable impetus by B. Malisz who developed the method of threshold analysis (1963). Malisz, however, did not intend to consider the economies arising with increasing concentration of settlements. His book marked the beginning of a series of studies dealing with the theoretical and practical uses of threshold analysis.

The study by W. Alonso (1971) is indicative of another line of research. His purpose was to establish the economic effects generated by the increasing spatial concentration of the manufacturing industries. Interesting attempts in this respect were made by Soviet researchers. Thus A. S. Akhiezier and A. V. Kochetkov (1972) analysed the gross output and investment outlays on industrial development made in Soviet towns of various sizes. The results they obtained disclosed that the biggest cities had recorded the highest productivity indices. The same problem was discussed by L. V. Kozlovskaja (1975) in a study which surveys the most recent studies by Soviet researchers concerning the economies and costs of the spatial concentration of settlements.

The way this issue will be solved is of great importance to any planned economy, not only theoretically but for practical purposes too. The relation between the degree of settlement concentration and the productivity of the industrial capacities installed may co-determine certain concrete planning decisions, because it is part of the choice of options for future development and for changes to be induced in urban settlement patterns. The feasible alternatives of this development either promote the growth of big agglomeration or provide for a more uniform development of the country and curbing the expansion of cities that have already gone through a process of industrialization. Data depicting the economic functioning of industries in agglomerations and towns of various sizes may be used as arguments in devising the concepts for the development of the country's settlement system. What has so far been proposed as forecasting procedures for urban settlements still lacks a solid enough economic justification. Hence the importance of an adequate method for assessing industrial productivity in various settlement units or groupings of different sizes and complexities which has yet to be developed.

In this study, we employed the analytical method referred to in the economic literature as the study of relations between capital, labour and output to define the productivity of industrial localized in Poland's towns and agglomerations. The behaviour of this relation has been studied mostly by economists working on the theory of economic growth. But studies in this latter theory are as a rule without the spatial dimension to them. Industrial activity is explored in the pattern of sectors or branches, with little regard to its regional characteristics. It is to be emphasized here that industrial productivity is largely determined by the spatial pattern of branch distribution. A joint branch-spatial effectiveness is hardly possible to assess, for the technical-economic features and dependences tend to take a bent different from that of the spatial trends. Moreover, the spatial pattern and the branch pattern are separate rather than complementary parts of one economic system.

Both a concentration of industrial activity in space and an industrial branch are economic aggregates each composed of some definite number of individual productive units. Each of such units belongs both to the sector-branch pattern and to the spatial pattern. The branch structure of industry is highly differentiated in spatial terms, whereas the productivity of the different branches varies from case to case. Relatively low productivity is a characteristic feature for some industrial branches but there are branches that as a rule display very good economic indicators.

Hence, to be fully comparable, the analysis of the capital-labour-output relation in spatial terms should comprise not only the industrial activity in its entirety but also individual industrial branches that may differ considerably by their production characteristics. This is what has been done in the present study. Eight different industries were included in the analysis so as to establish to what extent disproportions between the branches may affect data concerning the sector of industry as a whole. The present paper, which is part of a major study published earlier, focuses above all on the method employed and presents only aggregate data concerning the entire industry sector, while omitting the problems resulting from the differentiation of the branch structure.

One important point in analysing the capital-labour-output relation is which measures should be picked to characterize adequately each of the three components of this relation. In this study use has been made of the industrial census data collected by Poland's Central Statistical Office in 1965.

Capital, the first of the three components of the relation, has been defined through the gross value of the (enterprise's own) fixed capital installed or otherwise used in the production process. This includes buildings, constructions, machinery and technological equipment, means of transportation and such like.

The third component of the studied relation, the volume of output, was harder to assess. Gross output used to be the fundamental measure commonly applied in geographic studies in Poland up to now. But as an economic indicator this is inadequate for the purposes of spatial analyses dealing with economic relationships and all but prevents any realistic assessment of industrial activity. Gross output comprises not only the value of the output produced but also what is called the 'carry-over' value of raws and materials as well as fees for contractor deliveries or external services. To eschew this kind of mistakes, in the present investigation we take total net output as the indicator of the volume of industrial production; total net output is obtained by deducting the material cost of production from gross output. Material cost includes the use of raws, materials, energy and fuels. Total net output (hereafter referred to simply as 'net output') comprises above all accumulation, wages, and depreciation.

The industrial relationships between capital, labour and output permit to derive three extremely important productivity coefficients: capital-intensity, the capital-labour ratio, and labour productivity.

Capital intensity is the capital-output ratio and indicates the gross value of capital that must be used to turn out a unit of net output. The capital-labour ratio in turn is defined by the ratio of capital value to the number of employees. The third and last of the relationships of industrial production is the productivity of a single employee in the industry sector, or the ratio of net output to the number of employees.

The analysis of the three coefficients and their mutual relations is intended to yield a picture of the spatial productivity of Poland's industry. The purpose of the study, that is, the assessment of the effect of spatial concentration on industrial productivity, made it necessary to choose the territorial reference units. The author's intention was to furnish as broad a treatment as possible in this case and therefore all towns and settlements were taken as reference units. Next the analysis was repeated for all agglomerations of Poland. This faced the author with the important methodological problem of the huge difference in number of those units — whereas the number of towns and settlements totals 885 there are only 16 agglomerations in Poland. Hence the methodological procedure applied in the case of the agglomerations had to be different from that for the towns and settlements.

As already mentioned, the statistical set of towns and settlements consisted of 885 variables. The degree of spatial concentration was expressed in terms of population number. Data on population size were used to form a statistical sequence of settlement concentrations in the decreasing order. It this order, too, the data concerning settlement units were coded for computer processing. A code was supplied for each town comprising the afore-mentioned economic magnitudes and dependences connected with industrial productivity. This produced a clearly defined statistical set of the two components of the studied interdependence: the spatial concentration of settlements and industrial productivity.

The mathematical analysis was carried out in several steps. One of the first tasks was to determine the expected value (EX), also referred to as the value averaged for the chosen set of data. It is the sum of products of the probability of the given value of the variable x_k by the value of the variable, with the summing extending over all values of the variable. The expected value defines the most probable value the variable can achieve. Variance (WX) is the next parameter characteristic of the random variable. It is the expected value of the square deviation of the random variable from the mean value. Variance is a measure of the scatter of any given random variable around the expected value. The square root of variance is called standard deviation. The closer a set of values concentrates around the expected (mean) value, the lower the value of standard deviation. These parameters concern a one-dimensional random variable.

The next step was to calculate the covariances of a two-dimensional random variable which enabled us to calculate the correlation coefficient between two variables X and Y with realizations x_k and y_k ($k = 1, 2,...$), with estimators EX and EY, and with the following probability of occurrence of these variables, p_k:

$$\varrho = \frac{\sum_{k=1}^{n} x_k y_k p_{xy_k} - \sum_{k=1}^{n} x_k p_{x_k} \cdot \sum_{k=1}^{n} y_k p_{y_k}}{\sqrt{\sum_{k=1}^{n} (x-EX)^2 p_{x_k} \cdot \sum_{k=1}^{n} (y_k-EY)^2 p_{y_k}}},$$

where x_k, y_k denote the values of the random variables X and Y, EX and EY are the expected values of these variables, and p_k is the probability of occurrence of the two-dimensional variable XY.

If the correlation coefficient has the plus sign, the direction of change of the two variables is the same: higher values of one variable correspond to higher values of the other, and, conversely, with the minus sign before the correlation coefficient the direction of change of the variables is opposite to each other.

The estimators of the expected value, standard deviation variance and correlation coefficients were determined for each productivity coefficient for the series composed of all towns and urban settlements as well as for each group of towns distinguished on the ground of population size or industrial employment.

The determination of the relationships between the size of urban centres and the productivity coefficients was followed by the construction of an econometric model. The parameters of that model were estimated by means of models of two-dimensional relations, that is, $y = f(x, z)$. The estimation was carried out by approximating the statistical data using an algebraic polynomial. The structural-parameters of the polynomial were estimated on the ground of the following function:

$$y = \sum_{k=0}^{n} a_k x^k = a_0 + \ldots + a_1 x + a_n x^n.$$

The approximation was carried out by means of a first-degree polynomial: $y = ax+b$, a second-degree polynomial $y = ax^2+bx+c$, a third-degree polynomial: $y = ax^3+bx^2+cx+d$, and a fourth-degree polynomial: $y = ax^4+bx^3+cx^2+dx+e$. For this purpose the least-squares method was employed which consists in finding such estimates of the structural parameters (a, b, c, d, e) at which the function $\o$ — sum of square deviations of the actually observed values of the variable from the corresponding values found from the theoretical model — is the smallest.

To find the minimum of the function $\o$ it was differentiated with respect to all the coefficients. The differentiation yields $n+1$ determinate equations with $n+1$ unknowns (by a determinate equation is meant an equation for which a unique solution exists). The equations were solved in different ways — the linear equation was solved by the substitution method, the second- and third-degree equations were solved by the opposite coefficients method, while for the fourth-degree it was the Gaussian elimination method of solving systems of linear equations. The approximation procedure was carried out for three productivity coefficients, that is, for the capital-intensity of production, for the capital-labour ratio, and for labour productivity. A program was evolved to disclose the relationships between these coefficients and the size of the settlement units.

The computer-determined values enabled us to present certain interesting relationships graphically. For want of space, this paper does not furnish or interpret the correlation coefficients obtained, the changes and values of standard deviation that characterize accurately the relationships between the size of settlement units and the productivity of the industries localized in them. We only present diagrams showing the dependence between town size and some productivity coefficients in a general way.

Figure 1 presents the approximations of two of the relationship. One of the approximation curves represents the relationship between industrial employment and urban population size while the other that between labour productivity and population size of towns and urban settlements. The former

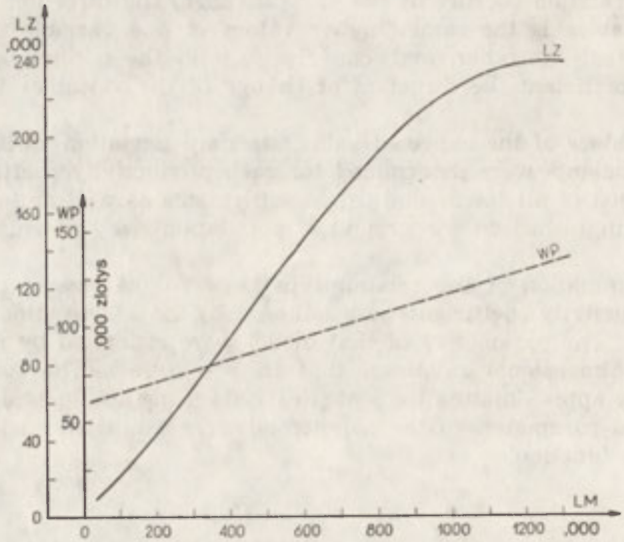

Fig. 1. Population size and employment as related to industrial productivity (for 885 towns and urban settlements)

LM — population size, LZ — employment volume, WP — labour productivity, KP — capital-intensity, TUP — capital-labour ratio

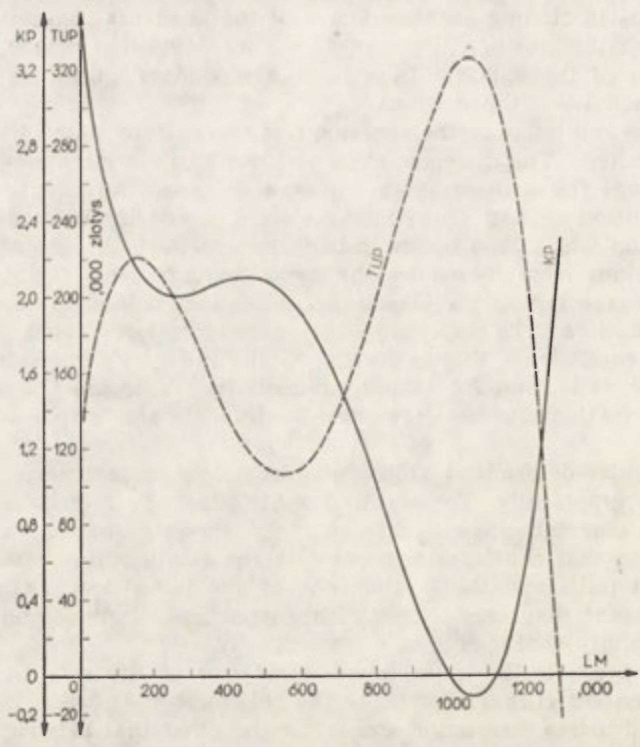

Fig. 2. Population size and capital-intensity as related to capital-labour ratio in the industry sector (for 885 towns and urban settlements)

curve represents a well-known relation and demands no interpretation. The dependence of labour productivity on the degree of spatial concentration as expressed by demographic potential is very interesting. With growing town size industrial labour productivity rises too. It is some 60,000 zlotys in a 50-thousand town, 70,000 zlotys in a 200-thousand town, and as much as 90,000 zlotys of net output per employee in a 500-thousand town.

The shape of the curve in Fig. 1, which represents the mean labour productivities for towns of various sizes, suggests that in Poland rising spatial concentration of socio-economic activity yields definite economies. The high labour productivity in the bigger towns is probably due to the exogenous economies of common location. The figures obtained from the analysis of the coefficient of labour productivity alone are unequivocal. In the case of the other two coefficients the results are more difficult to interpret. Figure 2 shows the relationship between the capital-labour ratio and the capital-intensity of production on the one hand, and urban population size of towns on the other. These coefficients correlate but very weakly. First-degree approximation was therefore ineffectual. It turned out that this relationship was best approximated by a fourth-degree function. The approximating curve does not represent the values of the variables. All it does is to disclose certain general trends in terms of probability.

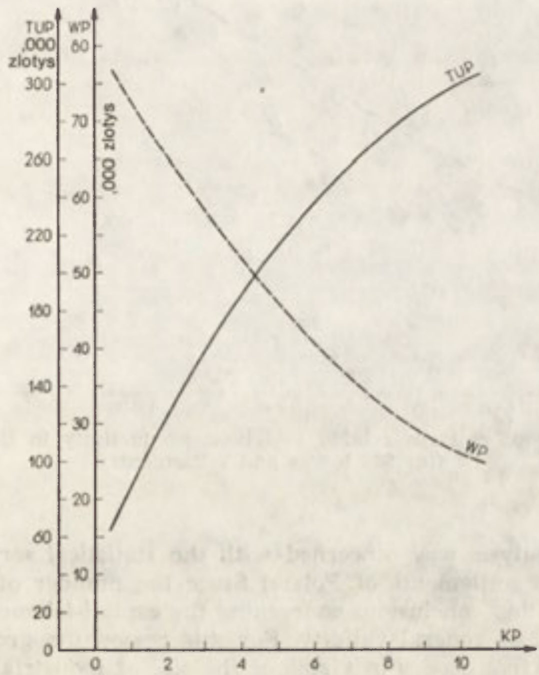

Fig. 3. Capital-intensity and labour productivity and capital-labour ratio (for 885 towns and urban settlements)

The shapes of the curves in Fig. 1 and 2 show the general relationships between the population size of towns and the three coefficients of industrial productivity. The production relationships seem to point to some economies resulting from concentration. This follows mainly from the rise in labour productivity while there is a weak downward tendency in the capital-labour ratio.

The capital-intensity of production does not depend on the spatial concentration of settlements.

The relationship between capital-intensity and labour productivity on the one hand, and the capital-labour ratio on the other is represented in Fig. 3. Since the results can be read off the diagram with high accuracy there is no need to comment on the shape of the curves. The trends are evident. With capital-intensity declining, labour productivity rises while the capital-labour ratio declines too.

Figure 4 illustrates the relationship between rising labour productivity and the capital-labour ratio. The relationship is constant and demands no interpretation. The higher that ratio the higher the value of labour productivity.

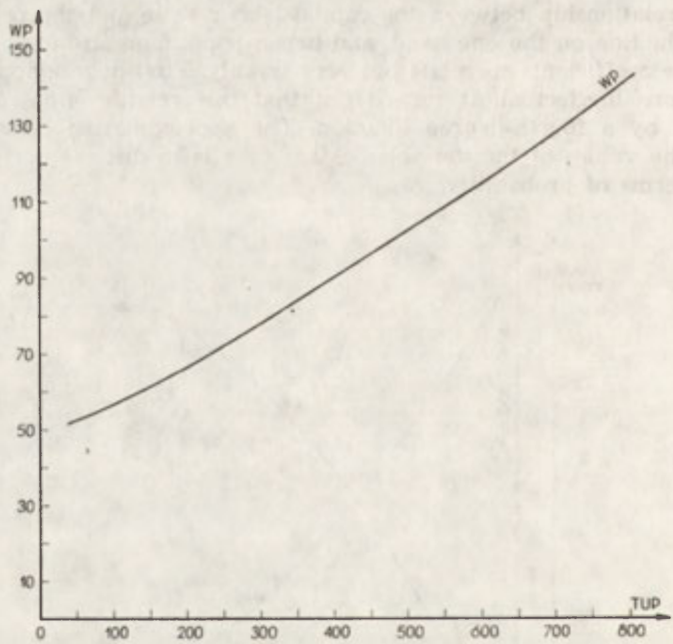

Fig. 4. Capital-labour ratio as related to labour productivity in the industry sector (for 885 towns and settlements)

So far the analysis was concerned with the statistical series including all towns and urban settlements of Poland Since the number of reference units is great the resulting conclusions concerning the capital-labour-output relationship can only be of general validity. For this reason the group of all towns was divided into five classes in virtue of the size of industrial employment in each case. The correlation coefficients characterizing the relationships between rising concentration of settlements and industrial activity against the productivity coefficients were determined for each of these classes. Next a program was evolved such that yields data for the diagrams concerning each of the five classes of size of industrial employment. Each of the five diagrams plotted (Figs. 5–9) concerns one category of employment size. The approximation method was used to plot three curves representing the size distributions of the coefficients of industrial productivity in a system of coordinates.

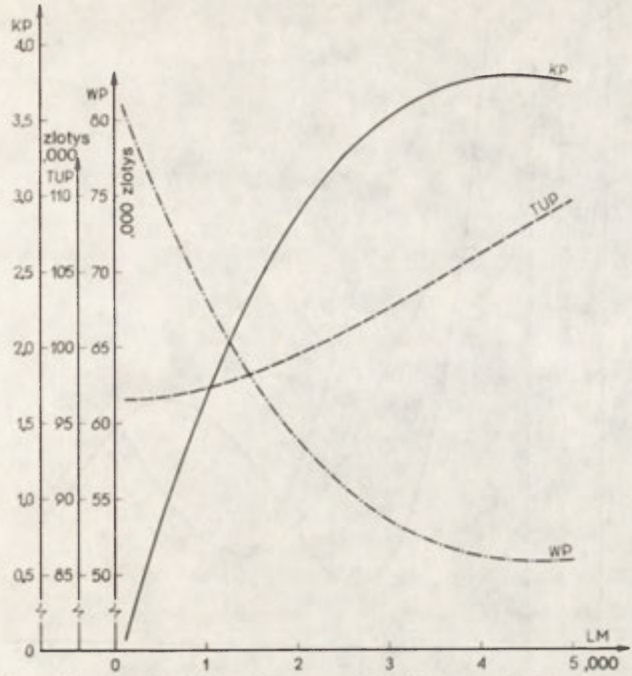

Fig. 5. Population size as related to labour productivity, capital-intensity and capital-labour ratio in the industry sector (for towns and settlements with employment figures above 1000)

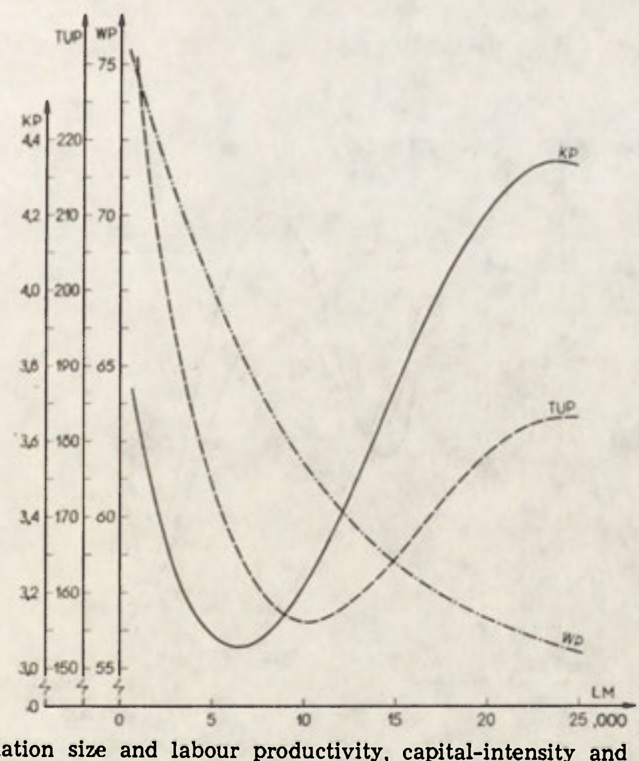

Fig. 6. Population size and labour productivity, capital-intensity and capital-labour ratio (for towns and settlements with population totals of 1000–5000)

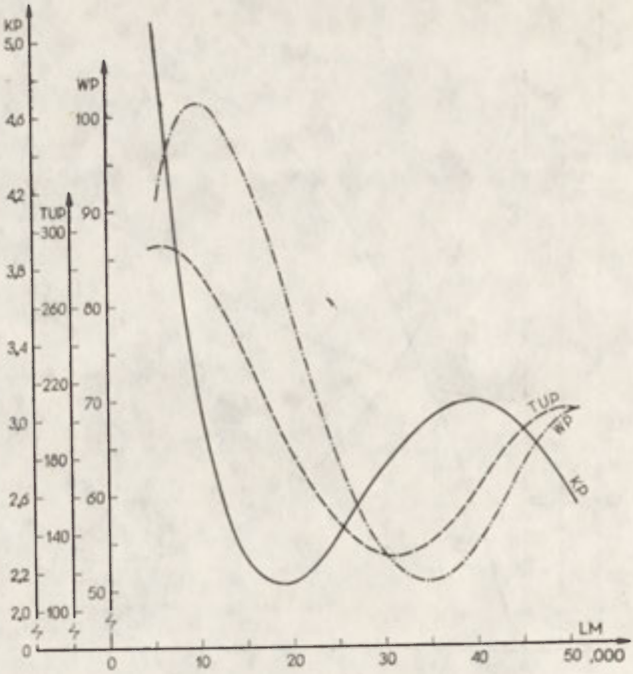

Fig. 7. Population size and labour productivity, capital-intensity and capital-labour ratio in the industry sector (for towns and with employment of 5000–10,000)

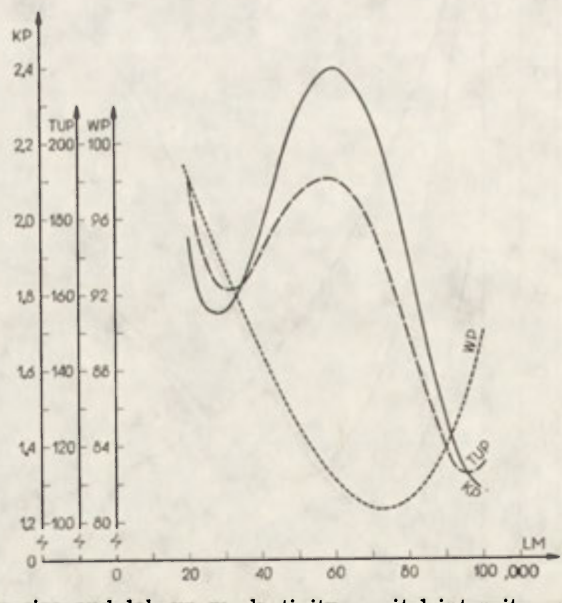

Fig. 8. Population size and labour productivity, capital-intensity and capital-labour ratio (for towns with employment of 10,000–20,000)

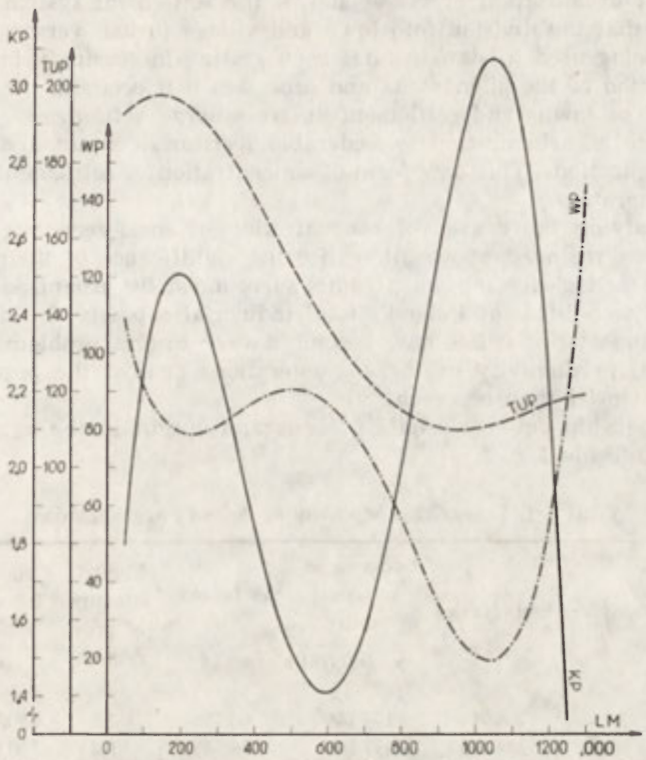

Fig. 9. Population size and labour productivity, capital-intensity and capital-labour ratio in the industry sector (for towns with employment above 20,000)

Note that the curves often have a regular shape, resembling a logistic curve that runs asymptotically up to some limit or to an exponential curve. The functions that tend downward to the abscissa indicate that, within the given class of industrial employment, growing town size involves a decline in the given coefficient; the opposite is true of curves representing the functions rising with respect to the x-axis.

When interpreting the diagrams enclosed (Figs. 5–9) we must bear in mind that by analysing individual diagrams only the results obtained may not be adequate enough. For instance, labour productivity displays a steady downward trend within some of the size classes, which indeed is the case of Figs. 5–7. Yet this does not invalidate the general upward trend of labour productivity within the entire collection composed of five classes. This means that smaller towns display higher labour productivity within a given class of size of industrial employment, and that towns with relatively high proportions of employment with respect to their population size are the most productive ones. But mean labour productivity takes higher values when we pass on to the next class of employment size.

By the same method we can easily carry the studies further and in a more detailed way by individual industries for various spatial systems. Such studies will help us to give a more precise definition of the relationship between the spatial concentration of settlements and the productivity of the industries localized in the towns.

Studies of urbanization processes and of the settlement system carried out so far show that the division into town and village (urban versus rural areas) that keeps being used in statistics has been getting increasingly inadequate as a representation of the phenomena and processes that occur in the real world. In the stead of towns and settlements there emerge settlement groupings of a high degree of urbanization, considerable territorial extent and diversified spatial configurations. This new form of concentration of settlement is referred to as agglomeration.

When studying the degree of concentration of socio-economic activity in agglomerations we must above all realize the significance of their productive potential. These big-city settlement units surrounded by urbanized zones have concentrated two-thirds of Poland's total industrial capacity. In view of their paramount importance it has now become a very urgent problem to estimate the industrial productivity of the agglomerations against the population and industrial potential they represent.

The relationship between capital, labour and output in the agglomerations are shown in Table 1.

TABLE 1. Industrial productivity in Poland's agglomerations

Agglomerations	Employment	Gross value of fixed capital	Net output	Capital intensity of production	Capital-labour ratio	Labour productivity
		,000,000 zlotys			,000 zlotys	
Katowice	708 916	177 744	60 756	2.9	250.7	85.7
Warsaw	283 495	37 107	26 545	1.4	130.0	93.6
Cracow	149 708	39 934	16 207	2.5	266.7	108.2
Łódź	250 647	27 303	18 475	1.5	106.3	72.0
Sudetes	155 668	37 037	12 900	2.9	237.9	82.9
Gdańsk	102 304	16 603	10 237	1.6	162.3	100.0
Old-Polish	116 528	15 593	8 092	1.9	133.8	69.4
Poznań	98 424	12 210	7 344	1.7	124.0	74.6
Wrocław	94 109	13 307	8 543	1.6	141.3	90.8
Opole	83 175	22 344	7 622	2.9	268.6	91.6
Bydgoszcz-Toruń	91 541	12 983	8 416	1.5	141.8	91.9
Bielsko-Biała	85 437	12 679	6 927	1.8	148.4	81.1
Częstochowa	74 512	13 054	3 852	3.4	175.1	51.7
Szczecin	47 775	9 867	4 082	2.4	206.5	85.4
Lublin	41 742	5 457	3 190	1.7	130.7	76.4
Białystok	25 371	2 936	1 177	2.5	115.7	46.4
Total	2 415 352	456 158	204 365	2.2	188.8	84.6
Remaining areas	1 240 803	214 554	80 410	2.7	172.9	64.8
Poland	3 656 155	670 712	284 775	2.35	183.4	77.9

Poland's agglomerations record a lower capital-intensiveness than the remaining areas. The difference is clear — it reaches 0.5. But the considerable disproportions within the pattern of agglomerations are still more remarkable a feature. The agglomerations situated in the central and northern parts of Poland have lower capital-intensity coefficients than those in the south of

Poland. These findings indicate that geographic situation, which determines the specific production profile, is the decisive factor rather than the degree of settlement concentraton.

As a whole the agglomerations record higher values of fixed capital per employee in the industry sector. This results primarily from the high value of the capital-labour ratio in the Katowice-Cracow agglomeration which concentrates the bulk of the heavy industries.

Another important question in considering the industrial productivity in agglomerations is how settlement concentration affects labour productivity. The data obtained have shown that labour productivity in industry in the agglomerations taken in their entirety much exceeds that in the remaining areas of Poland. This perhaps points to economies resulting from the size and complexity of settlement systems.

There is little point in discussing the empirical results of the study in any great detail here. More useful to the student of such problems may be the inquiry into further methodological possibilities that spring up from these basic considerations of the industrial productivity of agglomerations. The small number of variables vindicated the abandonment of the method based mainly on one-dimensional correlation which used to be the customary procedure in studies of urban units. The underlying assumption of the research method employed so far was that analysing pairs of elements alone will do, and thus penetrating the dependences of each production coefficient on the others is superfluous.

When referring to correlation we spoke in fact of a relationship between two features only. By employing the methods of multiple correlation we can determine the multiple dependences there may be between any variable and others. Multiple correlation techniques are very rarely used in economic-geographical studies. Its techniques are very involved and the results obtained by means of EDP techniques are extremely cumbersome in interpretation.

On the methodological plane, the most difficult problem is to find a one-equational econometric model such that would take account exclusively of relationships between elements which are permanent rather than contingent while the situation is encumbered by the circumstance that one element affects significantly all the others.

In such a case, the econometric model can be chosen by estimating the stochastic parameters of the models as precisely as it is possible. Which specific estimation method will be applied depends on the class of the model in each case. The model's attributes can be defined by considering the behaviour of the variation in parameters representing employment, capital value, net output, capital-intensity, the capital-labour ratio, and labour productivity. The model representing the variation of these factors and coefficients of industrial productivity has the following three properties. First, the set of parameters characterizing industrial production is not complete because there are other parameters not taken into account and besides not all factors are connected by a cause-effect relationship. Viewed from the theoretical point of view, the model has thus the attribute of symptomaticity. Secondly, the model is statical, for all data concern one and the same time interval. Thirdly, the model can be classed as simple because it is reducible to a single equation.

Once we know the class of the model — ours is asymptomatic, statical, and simple — we can choose a suitable method of calculation and then to determine the stochastic values of the model. This cannot be done with absolute accuracy since random factors affect the endogenous variables so as to make them deviate from their expected values (those assumed in the model of functions of the explanatory variables). If we have chosen the most adequate estimation method, all we can be sure of is that errors will not be systematic. Thus, by increasing the number of statistical observations, we can reduce the probability of significant error to zero.

Optimization analysis has shown that the best way to estimate the stochastic parameters of a one-equational model with an arbitrary number of explanatory variables is the classical method of least squares. The equation of the model is taken in the following form:

$$Y_t = \sum_{i=1}^{n} \alpha_i X_{it} + \xi_t ,$$

and we assume that the following conditions are fulfilled:

(a) the variables X_{1t}, X_{2t}, ..., X_{kt} are nonrandom variables and they are not colinear,

(b) the expected value of the random component ξ_t is zero and it has a constant finite variance σ^2,

(c) the observations are independent of one another and the sequence $\{\xi_k\}$ is a sequence of independent random variables,

(d) the ξ_t component does not correlate with the explanatory variables.

To estimate the parameters we employ the matrix calculus. It is assumed that n observations of the variables Y_t, X_{1t},..., X_{kt} have been made. Let $y(n \cdot 1)$ denote the vector of the observed values of the endogenous variable Y_t; $X(n \cdot K)$ the matrix of the explanatory variables observed, and $a(k \cdot 1)$ the vector of estimates of the structural parameters α_i.

The estimation of the structural parameters by means of the least-squares method consists in finding values for them such that the sum of square deviations of the actually observed values of the endogenous variable Y_t from the corresponding theoretical values should be minimum. In the matrix notation this reads

$$\Psi(y - Xa)(y - Xa) = \min .$$

After some transformations in the matrix calculus we find that:

if the matrix X is of the order k, then ψ takes the smallest value when the vector a of estimates of the model's structural parameters is found according to the formula:

$$a = X' \cdot X^{-1} \cdot X' \cdot Y,$$

where X is the transported matrix, and X^{-1} is the reciprocal matrix of X, that is a matrix such for which $X \cdot X^{-1} - E$ holds, where E is a unit matrix.

In the computer-processing of the formula of vector a, use was made of an algorithm of elementary transformations. The description of the algorithm is omitted here as too involved to be readily apprehended by nonmathematicians.

To determine the relationships between the different variables describing the model, we estimated the matrix of variation and covariation of the estimators of the parameters σ_t according to the formulae:

$$D^2 \cdot (a) = \sigma^2 \cdot (X' \cdot X)^{-1},$$

$$s^2 = \frac{1}{n-k} u' \cdot u,$$

where $u = y - Xa$.

After some transformations we get

$$s^2 = \frac{1}{n-k}(y' \cdot y - y' \cdot X(X' \cdot X)^{-1}X' \cdot y).$$

On substituting s^2 for σ^2 we obtain the approximate values of the matrix D^2.

In keeping with the foregoing interpretation, to determine the correlation coefficients between the estimators of the parameters a_i and a_j we found the symmetric matrix E in which

$$E_{ij} = \frac{d_{ij}}{\sqrt{d_{ii} \cdot d_{jj}}}.$$

To establish the accuracy of the results it is necessary to determine what is called the convergence coefficient from a sample according to the formula:

$$\varphi^2 = \frac{\sum_{t=1}^{n_1} (y_t - y_t^*)^2}{\sum_{t=1}^{n} (y_t + \bar{y})^2},$$

where y_t^* denote the expected values of the endogenous variable estimated on the ground of the estimated model, and $\bar{y}$ is the arithmetic mean of the observed values of y_t.

The values of φ^2 are easily seen to oscillate between 0 and 1, that is, $0 \leqslant \varphi^2 \leqslant 1$. The closer the value of φ^2 to zero, the more accurate the estimation of the model's parameters.

The determine the effect of agglomeration size as expressed by population or industrial employment on the behaviour of the productivity coefficients, three models have been constructed.

Model A

Endogenous variable: capital-intensity (*KP*)

Variant A1

Explanatory variables: employment size (*LZ*)
capital-labour ratio (*TUP*)
labour productivity (*WP*)

Variant A2

Explanatory variables: population size (LM)
capital-labour ratio (*TUP*)
labour productivity (*WP*)

Model B

Endogenous variable: capital-labour ratio (*TUP*)

Variant B1

Explanatory variables: employment size (LZ)
capital-intensity (*KP*)
labour productivity (*WP*)

Variant B2

Explanatory variables: population size (*LM*)
capital-intensity (*KP*)
labour productivity (*WP*)

Model C

Endogenous variable: labour productivity (*WP*)

Variant C1

Explanatory variables: employment size (*LZ*)
capital-intensity (*KP*)
capital-labour ratio (*TUP*)

Variant C2

Explanatory variables: population size (*LM*)
capital-intensity (KP)
capital-labour ratio (*TUP*)

The coefficients for each explanatory variable were estimated and the free term determined for these three econometric models. As the next step, a matrix was composed of the correlation coefficients that disclose the reciprocal effect of changes in the behaviour of one variable on another. To check the correctness of results we calculated the mean relative error which indicates to what extent the model estimates the reality it describes.

The results obtained in the part of the study concerned with Poland's agglomerations are shown by way of example in Figs. 10–12. As these figures illustrate accurately the mutual relationships between the particular parameters it would be superfluous to provide any extensive textual interpretation or tables of correlation coefficients.

The two variants of Model A show that the closer the given urban unit is to becoming an agglomeration the more downward the trend of capital-intensity of production. This is evidence of economies springing up from rising spatial concentration, with growing industrial potential being more important than population growth.

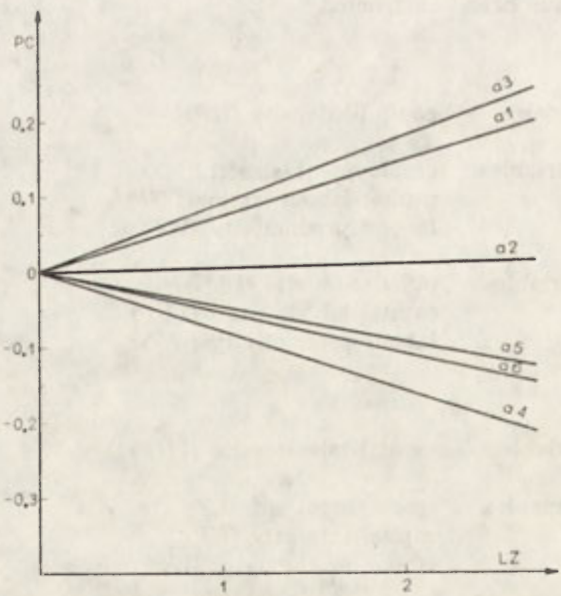

Fig. 10. Behaviour of industrial employment in the agglomerations versus aggregate net output

a1 — all agglomerations, a2 — agglomerations of the southern macroregion, a3 — seaport agglomerations. a4 — eastern agglomerations, a5 — central agglomerations, a6 — other agglomerations

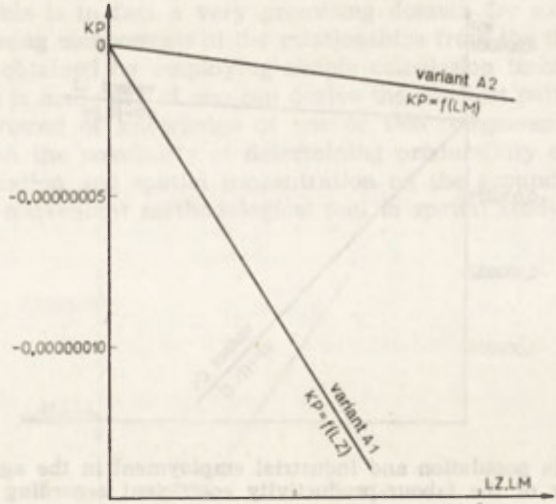

Fig. 11. Increase in population and industrial employment in the agglomerations and the behaviour of the capital-intensity coefficient according to Model A

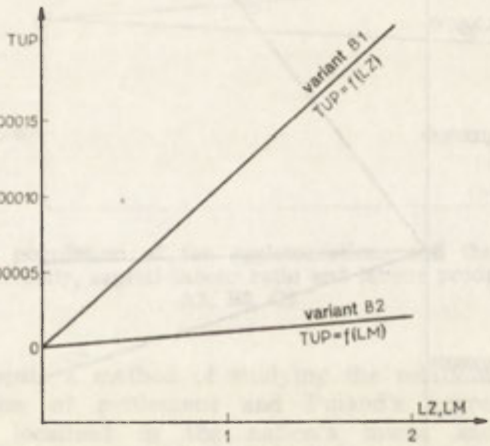

Fig. 12. Increase in population and industrial employment in the agglomerations and the behaviour of the capital-labour ratio according to Model B

From the two variants of Model B it follows that the growth of the capital-labour coefficient in the agglomerations depends more strongly on the increase in employment than on population increase.

The results obtained from the two variants of Model C are rather surprising. With increasing population size the labour-productivity coefficient in the agglomeration tends to rise. But if we rank the agglomerations by the size of industrial employment then mean labour productivity displays a downward trend.

The last two figures (13 and 14) represent the relationships between the productivity coefficients with rising industrial employment (Fig. 13) and with rising population size in the agglomerations (Fig. 14). Rising spatial concentration has the strongest effect on the behaviour of the capital-labour coefficient.

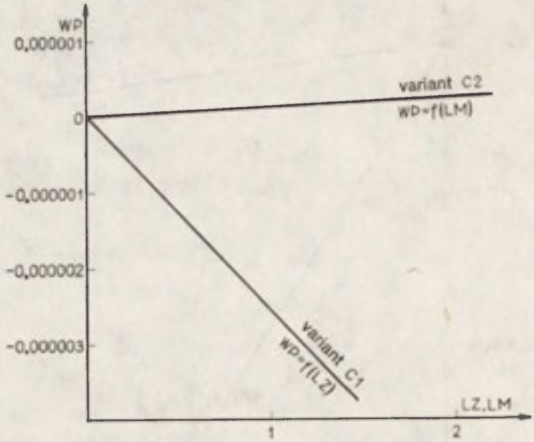

Fig. 13. Increase in population and industrial employment in the agglomerations and the behaviour of the labour-productivity coefficient according to Model C

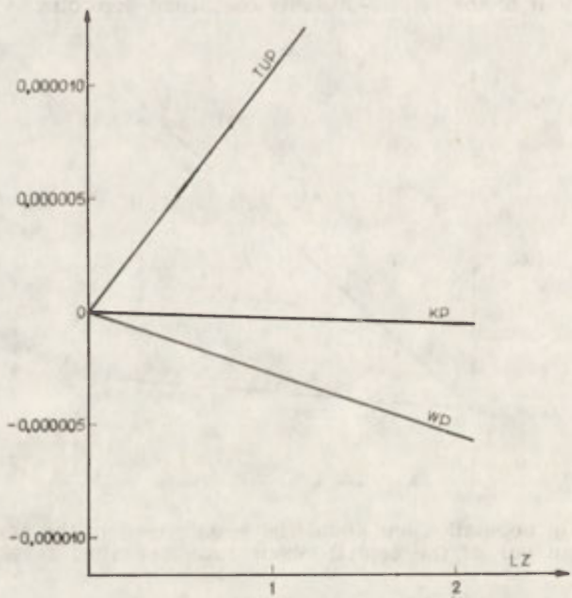

Fig. 14. Increase in industrial employment in the agglomerations and the behaviour of the coefficients capital-intensity, capital-labour ratio, and labour productivity for variants A1, B1, C1

Capital-intensity is the least-varying coefficient, which indicates its poor correlation with the degree of spatial concentration. The coefficient of labour productivity in the agglomerations declines more strongly at rising employment than with growing population size.

So far we have been discussing the relationships between spatial concentration expressed either by population size or industrial employment on the one hand, and the three productivity coefficients on the other. For want of space we have not discussed the relationships between the coefficients of industrial productivity. This is in fact a very promising domain for extensive analysis. Each of the missing components of the relationships from the three econometric models can be obtained by employing simple calculation techniques. If probabilistic calculus is made use of one can derive the likeliest patterns of relationships on the ground of knowledge of one or two components. Theoretically, this may furnish the possibility of determining productivity on the ground of spatial concentration and spatial concentration on the ground of productivity. This may be a convenient methodological tool in spatial studies.

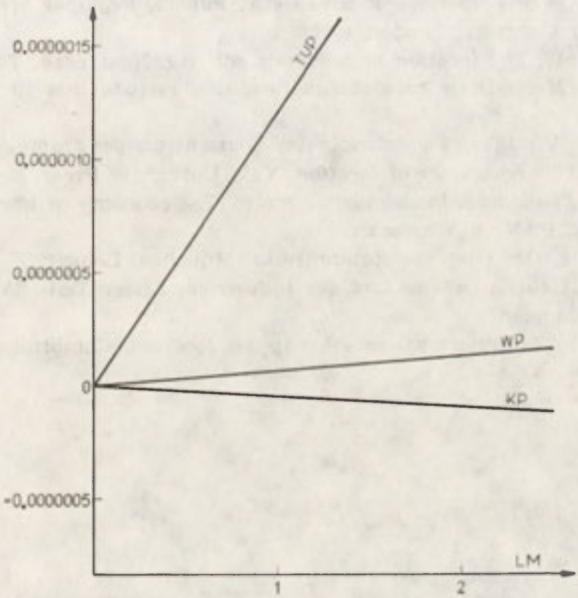

Fig. 15. Increase in population of the agglomerations and the behaviour of the coefficients capital-intensity, capital-labour ratio and labour productivity for variants A2, B2, C2

This paper presents a method of studying the relationships between the spatial concentration of settlement and Poland's aggregate productivity of all industries localized in the nation's towns and agglomerations. Both one-dimensional and multiple correlation should be applied to study the productivities of the various groups of industries or even of individual establishments and firms in various regional patterns. This type of analyses based on capital-labour-output relationship will show to what extent industrial productivity is sensitive to changing settlement size and geographic situation and to what extent by the branch and size structures.

Parallelly to studies devoted to the relationships between the spatial concentration of settlements and productivity and next industrial effectiveness researchers should focus on a still more difficult research task. Sectors III (services) and IV (science) still have not been quantified in settlement patterns. It is only by the joint analysis of material production and services that we can arrive at a more comprehensive picture of the socio-economic effectiveness of settlement concentration within the nation-wide spatial structure. This may furnish the point of departure for preliminary considerations on the economic costs and benefits of various settlement patterns. Such results, if used by planners, would probably help them to evaluate and control current location policies as well as to construct the economic foundations for the space-economic plan for Poland.

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THE CENTRALITY OF TOWNS AS REFLECTED BY THE TRANSPORT INDICES

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For the hinterland which surrounds towns they constitute, as a rule, central places. The centrality can be measured not so much by the number of population, or the position in the administrative hierarchy, but rather by the range of services rendered to the population of the hinterland. The measures can be, for example, the number of institutions rendering services, the number of people employed by them, or the number of served clients. The last measure seems to be the most appropriate, but it is a very hard task to express it quantitatively.

It seems therefore advisable to base the index of centrality on transport relations, as close links bind them with services rendered to the population of the hinterland. In general, the higher a given town's position in the hierarchy of transport nodes, the more developed is the predisposition towards fulfilling the functions of a central point. There are, of course, certain exceptions to that rule, especially as the size and significance of transport nodes can be assessed by means of various measures.

The present study is concerned with the hierarchy of Poland's transport nodes. It is a result of the investigation of 108 bigger and medium towns (including all voivodship towns), which have been compared with the number of inhabitants and the number of people employed in services. Conclusions as to the correlation between the functions of services and transport have been drawn subsequently. In the course of the analysis five towns were eliminated because of their position at the border, or a partly satelitary character.

As regards their transport indices the towns' centrality has been differentiated as follows:

(1) centrality of position,

(2) centrality of traffic,

(3) centrality of links.

The hierarchies of towns in relation to every one of those centrality forms are different, and this makes it possible to differentiate various types of central places.

CENTRALITY OF POSITION

Centrality of position is an effect of the town's situation in relation to the transport network. Rail and road (interurban buses and coaches) networks have been taken into account as the two basic forms of public transport, rendering services to over 90% of passengers in interurban traffic. Only 15% of house-holds own a motor car, which they utilize economically because of the high exploitation costs.

Railways and interurban buses operate in all investigated towns. However, the ranges of services differ greatly owing to an unequal development of the transport networks, in the course of which not always the needs of the town and of the population living in the neighbourhood have been taken into consideration.

Out of 103 analysed towns 90 are railway nodes, i.e. railway lines from at least three directions converge in the town (local lines which have their termini within the town's boundaries, or lines carrying only freight cargoes have not been included). Out of the remaining towns that are not railway nodes as many as 7 are voivodship towns. In the past four towns used to be the railway nodes, or still are, but only for freight traffic. The worst situation has the town of Łomża, as it is a terminus of a blind branch line of a secondary line. The town of Wroclaw has the maximal number of railway lines, namely ten. The average number of railway lines, running from those central places, amounts to 4.2, and from the voivodship towns to 4.4.

The voivodship towns are not in any better situation, as far as the railway networks are concerned, than the remaining central places. This is particularly true of the towns which became voivodship capitals in 1975. In as many as 16 voivodships (of which 13 were newly established) the voivodship capital is not the most important railway node in the area.

The number of bus lines is much bigger, as the interurban bus network is four times denser than the railway network. All investigated towns are the nodes of the bus lines, from which on the average 9.2 directions are served by regular lines. Their minimal number is three (in the towns of Chorzów, Jaworzno, and Sosnowiec, lying in the Upper Silesian agglomeration), and the maximal is 22 (Wroclaw). Lines branching out up to 5 km outside the town's boundary were classified in the study as separate routes, when their length exceeded 5 km.

The voivodship capitals are usually better situated as regards bus lines network, and are, as a rule, principal bus nodes in their regions. The average number of directions is 10.7.

If railway and bus lines are treated as equal and summed up, the average number of public transport lines from the investigated central places is 13.4. The least number (6–8) of lines was found in the Upper Silesian agglomeration (Chorzów, Sosnowiec, Ruda Śląska, Jaworzno, Będzin); the industrial area in the valley of the Kamienna river follows (Skarżysko-Kamienna, Starachowice, Ostrowiec Świętokrzyski). The maximal number was found in big cities and certain medium towns with a particularly well developed transport network (Wroclaw 32, Poznań 26, Warsaw 23, Opole and Legnica 21 each, Olsztyn 20, Cracow and Toruń 19 each).

Altogether, no association is evident between the centrality of the situation and the number of inhabitants, or of people employed in services. The correlation analysis has revealed that the correlation coefficient of the number of the railway lines is only 0.387 in relation to the number of inhabitants, and 0.390 in relation to the number of people employed in services. The number of bus lines is more strongly correlated: 0.445 in relation to the number of inhabitants and 0.440 in relation to the number of people employed in services. Altogether, the correlation coefficient of the number of public transport lines (railways and bus lines) is 0.498 in relation to the number of inhabitants and 0.495 in relation to the number of people employed in services.

The centrality of situation is associated more closely with the geographical situation in relation to main transport routes, rivers, valleys, mountains, sea coast, etc., and with the historical past which has influenced the current shape of the transport nodes. In Poland, therefore, there are cities with a 'very central' situation which are not very important (like Toruń, Leszno, Legnica, Opole, Piła, Olsztyn, Głogów, Nysa, Ełk), and much bigger and more important towns, less conveniently situated as regards the transport network (e.g., Łódź, towns in the Upper Silesian Industrial District, Gdańsk, Gdynia, Wałbrzych).

CENTRALITY OF TRAFFIC

The term 'centrality of traffic' denotes here the convergence of transport means and passengers on a central place. The measures used to compute the traffic are: the number of passenger trains and interurban buses, as well as the number of passangers arriving at or departing from a given place within 24 hours. The number of trains and buses were computed on the basis of timetables for the 1975/76; both the trains and buses which terminate their journeys in the given towns, or those which pass through them, were included. As no statistics provide the number of passengers, respective figures were assessed on the basis of the number of trains, their length (measured by the number of axes), and the average number of passengers per axis (9 people). The number of bus passengers was assessed in a similar way, that is on the basis of the average number of passengers per bus (32 people).

The average number of passenger trains departing from a central place is 82 per 24 hours (seasonal and additional, holiday trains are not included). The traffic range is very wide. Maximal numbers of trains were found in the towns situated within the agglomerations with suburban electric trains, characterized by a great frequency (Warsaw 584, Gdynia 395, Gdańsk 319, Katowice 298 trains per 24 hours). Towns situated along the side railway lines, for which the principal means of transport is the bus, have minimal numbers of trains (Łomża 5, Zamość 12, Suwałki 16, Lubin 19 trains per 24 hours). Railway services in the voivodship cities are not better than in the other towns, the average number of trains departing from them is 87. A big difference exists, however, between the former 17 voivodship capitals (the average of 151 trains) and those newly established 32 voivodships (the average of 53 trains).

The frequency of bus traffic is four times bigger, as the average number of public transport vehicles, departing from the town, is 324 per 24 hours. As bus services operate almost exclusively between 5 and 22 hours, the average frequency is one departure per three minutes. Big cities occupy the leading place in the hierarchy of the bus traffic (Warsaw 1166, Cracow 976, Lublin 976, Wrocław 654 departures); however, some smaller voivodship capitals and the industrial centres of southern and central Poland, where rail networks are not sufficiently developed and to which commuting to work is on a mass scale, play also an important role (Rzeszów 652, Kielce 594, Bielsko-Biała 592 departures). As far as this group of towns is concerned, central places in the new industrial districts where almost all passenger traffic is carried by bus lines are of special significance (Rybnik 791, Konin 685 departures per 24 hours).

The bus lines in the towns situated in the central part of the Upper Silesian agglomeration (Katowice excluded) are characterized by the smallest traffic; traffic between towns is carried by tramways and town buses there, as well as in the railway nodes with a high frequency of trains (Skierniewice, Gdynia), or a big number of railway lines diverging in all directions (Malbork, Lębork, Elk).

As regards bus transport the voivodship cities are in a better position than as regards the number of trains. The average number of buses, departing from every voivodship capital, is 410 per 24 hours. In the 17 former voivodship capitals the average index is 566, whereas in the 32 newly established ones it amounts to 327 per 24 hours. The ratio between those figures is only 1.7:1, whereas as far as the number of trains is concerned it is 3:1. Those ratios point to the fact that bus transport has adapted itself very quickly to the town's new administrative functions and that bus service in the new voivodship cities is more developed than that in the old capitals, which traditionally have been important railway nodes.

In order to obtain the total number of occasions for arrivals in the town, or departures from it, the numbers of trains and buses were added together. Though their capacities differ largely and trains carry many more passengers, in the present case it is only the frequency of traffic which is of interest. Altogether, the daily average of public transport means which arrived in the investigated towns is 406 trains and buses. The maximal number was discovered in Warsaw (1750), subsequently — though after a long interval, in Cracow (1136), Lublin (1022) and Wrocław (816). Other big cities (Łódź, Poznań, Gdańsk, Katowice, Bydgoszcz) are on almost the same level as the much smaller industrial centres which employ commuting labour (Rybnik, Konin, Opole, Rzeszów and Kielce).

The correlation coefficient of the number of trains with the number of population living in the central places is rather high: 0.751, in the same way as that referring to the number of people employed in services: 0.739. No closer connection has been revealed in relation to the number of railway lines converging in the central places (0.370). The correlation coefficient of the number of buses with the number of population and the number of people employed in services is lower (0.594 and 0.616 respectively), whereas it is higher than in the case of the trains as regards the number of lines (0.572). The intensity of traffic carried jointly by public means is more closely associated with the number of population (0.770) and employment in services (0.782) than with the number of transport lines (0.512).

To eliminate the incomparability of trains of various capacities with buses the number of passengers, estimated on the basis of the average number of passengers carried by trains and buses, has also been taken into account. Thus, the probable number of passengers who arrive at every central place has been estimated per 24 hours. Unfortunately, the number of passengers who terminate their journeys in those places, and of those who only pass through them, or change into another means of transport, are not known. It seems correct to assume that a great majority of bus passengers terminate their journeys in the investigated places, in a similar way as the passengers of local trains, whereas those travelling in long-distance trains, usually continue their journeys to reach a higher rank place.

On the average, approximately 31 thousand people come daily to each investigated place by train or bus. This index for the voivodship capitals is slightly higher (36 thousand). If the division into old and new voivodship capitals is introduced, the difference is very big: approximately 60 thousand people commute to the old capitals, and only approximately 24 thousand people to the new ones. The correlation coefficients as regards the number of their inhabitants (0.832) and as regards the number of people employed in services (0.831) are high, whereas in relation to the frequency of public transport means the coefficient is lower (0.763). There is almost no correlation, however, with the number of transport lines (0.309).

THE CENTRALITY OF LINKS

Another important centrality index, besides the number of lines and traffic intensity, is the number of direct connections which link a given central place with its hinterland and other places. To obtain statistical data the author counted up direct connections by trains or direct buses (seasonal lines excluded) of the central places with the voivodship capitals and former powiat towns, as the central places of microregions which had developed during the period of the three-rank administrative division.

In Poland there are 49 voivodship capitals. Poland's capital, Warsaw, is however the only city which is connected with all the voivodship capitals by direct trains or bus lines. The remaining big cities are directly connected with 37 (Łódź), 35 (Wroclaw), 33 (Poznań, Cracow), or 30 (Katowice, Szczecin, Lublin) voivodship capitals. The lowest number of intervoivodship connections is in the eastern part of the country (Łomża 5, Chełm and Suwałki 6, Zamość 7), as well as in the southern border zone, which lies away from important routes (Racibórz, Wodzisław Śląski, Jastrzębie and Żywiec — 7 each).

On the average, every one investigated central place, out of the total of 103, is directly connected with 17 voivodship capitals. The latter are in a slightly better situation, as the average number of their connections is 19. Former voivodship capitals are evidently privileged in this respect, as their average is 27, whereas that of the new capitals is only 15.

The number of the former poviat towns, which have not been raised to the status of a voivodship capital, is almost six times bigger than that of the voivodship capitals. The investigated central places are directly connected with 49 former poviat towns on the average. The voivodship capitals are in a better situation (connections with 57 former poviat towns), among them the former voivodship cities have the greatest number of connections (the average is 88). The difference with the new voivodship capitals (the average of 40 connections) is striking.

The maximal number of direct connections with the former poviat towns is in Warsaw, namely 190. The capital is followed by Katowice (124), Łódź (118), Poznań (117), Cracow (113) and Wrocław (109). The minimal number of connections was found in the new voivodship capitals in eastern Poland (Chełm 13, Biała Podlaska 16, Suwałki 18, Łomża 19, Zamość 21) and in certain smaller localities, situated along secondary routes (e.g., Racibórz, Stalowa Wola, Chojnice, Żywiec).

If the voivodship capitals and the former poviat towns are approached as equal in rank, the number of direct connections oscillates between 19 (Chełm) and 238 (Warsaw). The correlation of the number of connections is quite high with the number of inhabitants (0.792) and with the number of people employed in services (0.765), as well as with that of passengers (0.777) and of trains (0.738); it is much lower as regards the number of buses (0.401) and transport lines (0.482). In all the cases the correlation of direct connections with the former poviat towns is much stronger than that with the voivodship capitals.

Smaller towns which lie along the routes leading to the biggest cities have also a big number of direct connections, as they are conveniently situated (e.g., Tczew on the route to Gdańsk; Stargard Szczeciński on the route to Szczecin; Gliwice and Jaworzno on the route to Katowice). The same is true of places lying along the main railway lines with a big number of express trains running. For example, Leszno, situated on the main line Poznań-Wrocław, is directly connected with 28 voivodship capitals and 67 former poviat towns. The town of Oświęcim, though of the same size as Leszno but lying on a less important route, is connected with only 8 voivodship capitals and 21 poviat towns, whereas Zamość, which is a voivodship capital of the same size as the former two, is connected with only 7 voivodship towns and 21 poviat towns. The centrality of connections depends therefore to a very high degree on the importance of routes converging on the given place.

CONCLUSIONS

In the light of the results described above, the hierarchy of transport nodes or of central places is hardly homogeneous from the point of view of transport. Every aspect leads to an identification of a different gradation and puts every place on another position. Of course, an integrated coefficient can also be sug-

TABLE 1. The hierarchy of the most important central places in Poland according to transport indices

Central places	Rank according to the number of inhabitants	the number of transport lines	the number of trains and buses	the number of passengers	the number of direct connections[a]
Warszawa	1	3	1	1	1
Łódź	2	9/12	12	11	2
Kraków	3	7/8	2	5	5
Wrocław	4	1	5	7	6
Poznań	5	2	17	6	4
Gdańsk	6	36/46	8	3	9
Szczecin	7	9/12	75	40	7
Katowice	8	60/71	10	2	3
Bydgoszcz	9	9/12	14	21	24
Lublin	10	13/16	3	17	8
Gdynia	12	95	19	4	15
Częstochowa	13	25/35	30	18	12
Białystok	14	17/24	16	35	39
Gliwice	17	13/16	15	9	20
Radom	18	17/24	23	38	25
Toruń	19	7/8	25	34	21
Olsztyn	26	6	20	41	18
Rybnik	27	9/12	4	23	91
Opole	28	4/5	9	15	30
Rzeszów	29	25/35	7	25	33
Tarnów	33	17/24	44	39	31
Jelenia Góra	43	17/24	18	46	17
Kędzierzyn-Koźle	47	13/16	24	29	34
Konin	53	36/46	6	20	69
Leszno	69	13/16	32	36	16

[a] Voivodship capitals and former poviat towns included.

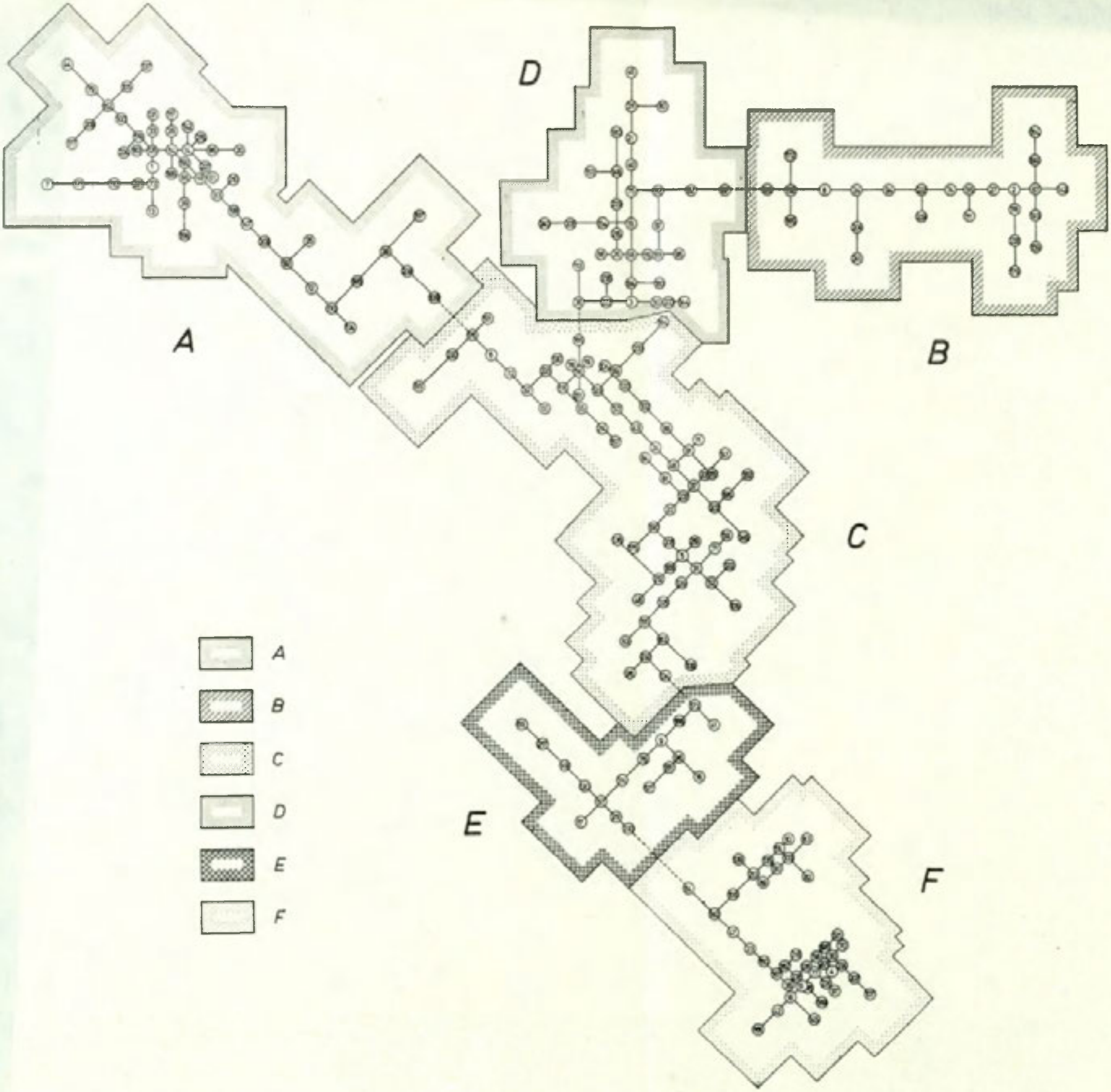

Fig. 3. Arrangement of distinguished climatic seasons of selected localities in North-West Poland by means of the 'Wroclaw dendrite' method (A–F — typological classes)

gested, which would be the resultant of all the elements investigated in the study, but it is debatable whether or not they should be treated in an equal way. This depends on the research objective. If, for example, we wish to plan the size of the service infrastructure in a central place, the number of incomers is important. For the inhabitants of a given place the frequency of transport means and the number of direct connections are more important. If we want to locate a technical infrastructure the number of lines and intensity of traffic seem to be more important, etc.

The author has not therefore proposed any single index but he has presented a hierarchy of central places according to various measures. Table 1 shows 25 central places which occupy the highest position in that hierarchy; they are arranged according to the number of population, and their rank as regards the separate measures is shown. As it can be seen the ranks do not tally, and deviate also as regards the number of inhabitants.

On the basis of the deviations from their average positions all the places can be put into separate classes of types. For example:

— places with rather equally developed features of centrality (e.g., Wrocław, Cracow, Bydgoszcz);

— places with an excessive centrality of the position, which has not been used up to intensify traffic and to develop direct connections (e.g., Toruń, Olsztyn, Opole);

— places with a very high frequency of traffic, though the numbers of lines and direct connections are rather low (e.g., Rybnik, Konin, Lublin, Rzeszów);

— places with a very big number of passengers, exceeding the ranks of other measures (e.g., Katowice, Gdańsk, Gliwice, Gdynia);

— places with very well developed direct connections, which point to their all-national significance, or their situation along a main far-distance routes (e.g., Katowice, Częstochowa, Leszno, Jelenia Góra).

Certain places occupy a high position as regards two or three features of centrality. There are types of places with various combinations of those features. To present the diversity of central places and their individual properties Fig. 1 shows the distribution of investigated places and their four principal properties (the number of public transport lines, the frequency of trains and buses, the intensification of passenger traffic, and the number of direct connections with the voivodship capitals and former poviat towns). Because of graphic reasons 11 places in the Upper Silesian and Rybnik agglomerations, which fulfil lesser central functions, are not shown. The pattern of graphic signs shows the type of the place (the so-called Uhorczak's typogram). The average value of every property is presented by a segment of the same length (see the explanatory notes).

Places with a better developed network of lines and connections are presented by the signs of a bigger horizontal length; places with a big intensification of traffic are marked by the signs of a bigger vertical length. The signs with equal sides symbolize places with evenly developed centrality features. The size of the sign shows, to a certain extent, the importance of the given node for passenger traffic. The selection of properties and the average of the 103 investigated places as an equivalent value for every property can of course be debatable. The method is, however, convenient because it makes it possible to take into account various aspects of transport which emphasize the centrality of the place. Each property, taken separately, does not characterize sufficiently the central character of the place.

Correlation coefficients between the investigated transport indices and of every coefficient with the numbers of inhabitants and with people employed in services are given in Table 2. The correlation coefficients with the numbers of inhabitants and people employed in services are the highest (with the exception of the number of lines), which proves that the selected transport indices are also proper measures of the centrality of places. Their mutual correlation is, however, weaker, with the exception of that between the number of passengers and the number of trains and buses as well as with the number of connections and that of passengers.

TABLE 2. Correlation coefficients between the transport indices of the central places

	Number of railway and bus lines	Number of trains and buses	Number of passengers	Number of connections[a]
Number of inhabitants	0.498	0.770	0.832	0.792
Employment in services	0.495	0.782	0.831	0.765
Number of railway and bus lines		0.512	0.309	0.482
Number of trains and buses	0.512		0.763	0.604
Number of passengers	0.309	0.763		0.777
Number of connections	0.482	0.604	0.777	

[a] Voivodship capitals and former poviat towns included.

The assumptions that various transport indices are characteristic of the various types of central places and that it would be difficult to select a single one as being the most adequate for a town to be identified as a central place of a given region, have thus been corroborated.

ORIGIN AND PROBLEMS OF SOCIAL TRANSPORT GEOGRAPHY

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INTRODUCTORY REMARKS

To say that transport geography has been (and still is) continuously transformed, in the same way as every other scientific discipline, seems to be almost a truism. Transformations are i.a. bound up with changes in the research paradigm.

Except for research into location theory most studies were descriptive until the late 1950s. Among the few existing exceptions one may quote E. L. Ullman's (1957) and W. L. Garrison's *et al.* (1959) studies in which statistical-mathematical methods were used. The turning point was reached in the first years of the 1960s, when purely descriptive work gave way to studies using quantitative methods especially gravity models, graph theory, factor analysis and linear programming. From the turn of the 1960s a new trend has been observed which was first developed by American geographers and later adopted in certain European countries. This trend focuses attention on man, his behaviour and the social constraints of movement.[1] According to M. E. E. Hurst (1973) geographers should not only be concerned with outlining economic and social structures in space, and investigating networks and nodes but also they should examine the social consequences of transport. Neither the collection of facts, referring to transport network themselves, nor a search for optimal solutions or abstract spatial analyses will help us to understand and explain these consequences.

This trend, which was subsequently named social transport geography by P. O. Muller (1976), has developed in parallel with quantitative studies, in the same way as the latter have not completely ousted typical descriptive studies. Though the name of this new trend has not always been used specifically, it is quite easy to single out such research. The study presented below is an outline of the origin and problems concerned with social transport geography.

ORIGIN OF THE TREND

What is the set of constraints which contributed to the development of social transport geography? I believe there were at least three closely interconnected constraints.

Firstly, there was a reaction to the widely applied morphometric analysis

[1] A different division is used by J. O. Wheeler (1976a), who singles out the following periods: (1) pre-revolution (prior to 1959); (2) revolution (1959–1963); (3) the aftermath (1963–1970); and (4) early maturity (post-1970).

and spatial statistics. Morphometric analysis, as one of the ways which provides explanations in transport geography, has recently been discussed (cf. M. Potrykowski and Z. Taylor, 1978), so there is no need to raise this problem here. It is only worth while remarking that an analysis of transport systems entirely in geometrical-topological categories may lead to superfluous simplifications and distortions of the reality that surrounds us. Actually, it is relatively easy to describe quite complicated patterns in transport geography by means of mathematical terminology even if the basic process is not understood (M. E. E. Hurst, 1973). The morphometric analysis and spatial statistics say very little, or almost nothing, about current spatial processes, so geographical theory has had to borrow from other social sciences for explanations of man's behaviour in space.

We can define both internal and external constraints. The first is embedded in transport geography itself, whereas the second lies outside this discipline altogether. The most important external role is played by behaviourism, widely adopted in psychological and sociological research, and known to us thanks to the activity of the American geographical school and Hägerstrand's Swedish school. Interest in behaviourism has arisen i.a. because of a need for developing methods based on less rigorous assumptions than those used in the classical economic approach, and of a wish to free oneself from earlier deterministic doctrines in economic geography (I. Cullen and V. Godson, 1975). The behavioural approach can most generally be determined as an attempt to obtain sets of empirically substantiated statements regarding the behaviour of individuals or social groups (F. E. Horton and D. R. Reynold, 1971). It is obvious that the development of behavioural studies has influenced the development of the profile of transport geography, i.a. because certain hopes have been associated with the former in studies of spatial processes (K. R. Cox and R. G. Golledge, 1969). There is no doubt that the behavioural approach has had a strong influence on the selection of research problems.

The third constraint is of a mixed character for it applies to geography in general as well as transport geography in particular. There is a general tendency to shift the centre of gravity in researchers' interest from purely economic analyses to socio-economic research. Social phenomena are more and more often included in traditional economic geography. To put a special emphasis on this process the Anglo-Saxon literature (cf. J. A. Jakle, S. Brunn and C. C. Roseman, 1976) has introduced the notion of social geography, which considerably exceeds the range of problems with which traditional population geography has been concerned.

However, as regards the patterns (e.g., network patterns) a need has arisen to develop a new approach, namely the holistic one. This possibility has been opened up i.a. within studies of the shifts of separate social groups, subsequently taken over from sociologists by geographers. Incidentally, close relationships can be observed here with the first two constraints mentioned above. I believe that this set of constraints has contibuted to the development of social transport geography in the early 1970s.

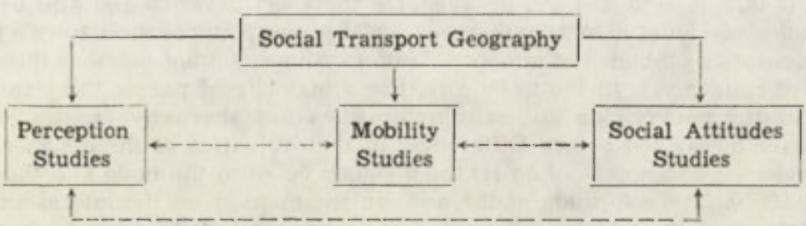
RESEARCH PROBLEMS

Most research work within transport geography has so far been concerned with either a static analysis of the network pattern or of its changes, or with flows in the network. Many examples are given by P. Haggett and R. J. Chorley (1969), or E. J. Taaffe and H. L. Gauthier (1973).

The approach adopted in social transport geography is quite different. It represents not only a shift of emphasis but a completely different way of looking at problems within our sub-discipline. Let us explain the problem by the following example. R. Borgstrom (1974) in his analysis of the pattern of air transport between the American mainland and Hawaii focuses his attention on the investigation of perception principles of separate modes of transport by actual and potential passengers instead of the traditional description of carriers, or an attempt at explaining various conceptions of distances (physical, temporal, economic, etc.). Knowledge of perception principles makes it possible for him to propose certain conclusions regarding spatial behaviour of an individual, and also to analyse his attitude towards various transport innovations. This is therefore an analysis at a micro level (micro-analytical approach), contrasting with the macro scale used previously. Both scales of the analysis do not compete with one another. The micro approach offers interesting possibilities for the expansion of research.

Problems outlined so far prove that strong interrelationships exist between social transport geography and other disciplines. For example, social transport geography is associated with population geography by the same research subject, though, as a rule, the scale of the analysis is different: in social transport geography population is analysed from the point of view of an individual. Knowledge of behavioural motives of an individual makes our subject very close to social psychology. The most common area of research — the urbanized area — is the domain of urban geography. To sum up, it seems that social transport geography is a good example to illustrate the thesis that the current division of economic geography into subject branches has become more and more deceptive and anachronistic. In my selection of problems, discussed in the subsequent part, I apply the subject criterion, though in certain cases it was not unequivocal. It is believed that transport geography is above all interested in the distribution and development of transport networks, facilities and means, as well as in the transport of cargo and passengers.

The range of subjects with which social transport geography is concerned is relatively wide. It is possible that in the near future further developments will occur in this research field trend. For the purpose of this study the already recognized subjects can be subdivided as follows:



This division is arbitrary because particular studies are supplementary one to another and they are interlinked.

PERCEPTION STUDIES

Perception studies have become an object of interest because of the need to construct operational models, which will make it possible to introduce spatial generalizations on the basis of a small amount of data. Those data can be obtained from the spatial behaviour of individuals or social groups. An individual evaluation of the transport network and of the resulting behaviour of individuals is of special interest for social transport geography.

A potential set of locations, found usually though not necessarily, in the area of a town about which the individual possesses some information obtained in any way (autopsy, mass media, friends, etc.). Which he somehow utilizes, or to which he gives a certain preference, is called the *action space*. Images and action spaces resulting from them, are to a high degree shared by the groups of inhabitants living in a particular geographical neighbourhood. From this point of view the action space may be characterized as (1) spatial dimensions determined by a set of locations, and (2) a generalized space in which utility, or the level of preferences to be found in every place, is taken into consideration. (F. E. Horton and D. E. Reynolds, 1971), while a subset of all locations with which an individual is in direct contact following a frequent (e.g. everyday) activity is called an *individual's activity space*. The introduction of the notion is well motivated because an individual — though he has access to various information — utilizes only some of it. The dimensions of the action space are naturally bigger that those of an individual's activity.[2]

Much attention has been paid to the studies of the activity space in towns (i.a. F. E. Horton and D. R. Reynolds, 1971; J. O. Wheeler, 1972; F. P. Stutz, 1973; D. Höllhuber, 1974; M. E. E. Hurst, 1974; R. F. Wiseman, 1975). The following assumptions are usually adopted for urban areas: (1) every individual makes his own peculiar picture of the structure of the environment in which he operates (this subjective and generalized picture of the spatial structure, and sometimes its presentation in a cartographic way is known in the Anglo-Saxon literature as *mental map*); (2) the framework of the mental map is made by the axes joining together the place of residence with certain more important destinations of the individual;[3] (3) mental maps present reality more or less distinctly; whether the map provides the minutest details or not, depends on the frequency with which information on the given territory is supplied: places which are closest to our point of departure will as a rule be known best; (4) the extent of the mental map is determined by the town sector which is orientated towards the CBD; (5) the individual's decision on location is not objective but influenced by the sector about which he has most information.

As is shown by D. Höllhuber (1974) the form and intensity of the activity space is largely reflected by the available transport network and also by conceptions underlying it. A homogeneous social group pictures their town's transport network as a bunch of streets or tramway lines, joining together their own place of residence with the town core. For a majority of people the transverse links of the network do not exist unless they are alternative routes joining the above mentioned points. Differences in the evaluation of the distance from or to selected nodes depend on (1) the distance between the node and the place of residence, (2) the location of the node on the main or on the lateral axis; (3) the location of the node in relation to the town core; (4) the directness of the connection; and finally, (5) the accessibility of the node in the urban transport network.[4]

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[2] Another division is given by R. E. Lloyd (1976, p. 243), who uses the following terms: cognitive space, preference space, and behavioural space.

[3] Potentially 'mental maps' provide three types of spatial information: (1) on the existence of objects or places; (2) on distances separating those places; and (3) on direction relationships. Cf. J. A. Jakle, S. Brunn and C. C. Roseman (1976), p. 76.

[4] 'Accessibility' denotes here a relative degree of easiness with which an individual or a group can reach a given place.

The behaviour of an individual in space is in accordance with his own mental map. Many factors influence it, such as the utility of place, the style of life, the system of value, and the geographical situation. All these factors influence the structure of the journey, the selection of the transport means and the selection of the route. (R. Borgstrom, 1974). Studies of the differences in the activity spaces of various ethinic and socio-economic groups, for example, in towns, are very important therefore, in the same way as comparative studies of communities inhabiting contrasting environments: urban — rural, suburban — town centre, etc. The extent to which a person's activity space coincides with the town's spatial structure depends i.a. on the ease with which data are gathered and absorbed (F. E. Horton and D. R. Reynolds, 1971).

The most general regularity which can be detected in activity spaces is the distance decay function,[5] which suggests that most journeys are made to places in the vicinity, and more and more rarely as the distance from the journey starting point increases. This dependence between mobility and distance may however be more complex in the case of separate individuals.

Research into man's spatial behaviour cannot be limited to an analysis of mental maps only. M. D. Menchik (1974) puts forward a suggestion of another approach. He starts from the assumption that this behaviour is rational and tries, using linear programming, to determine the so-called *psychic transport costs*. The observed behaviour will, of course, be influenced by these psychic transport costs. It is, however, worth while to observe that Menchik's approach is exclusively an attempt to specify spatially the behaviour of individuals; it does not lead to the estimation of the spatially utilizable transport costs. It may be because of that that Menchik's proposal has not been further developed as yet.

MOBILITY STUDIES

Perception studies are usually a preliminary step in researching the mobility of individuals and social groups. They are regarded predominantly as a source of information of the transport behaviour of people inhabiting urbanized areas and form a basis enabling to draw conclusions which can be used in planning practice. Material thus obtained has, for example, been used to organize public transport while simultaneously limiting private transport in western Holland (L. H. Klaassen, 1973). The problem of commuting to work has been dealt with in a majority of studies; less space has been reserved for analyses of journeys undertaken for other purposes (e.g. J. O. Wheeler, 1972), social trips to relatives, friends, and neighbours (F. P. Stutz, 1973), or religious journeys (P. L. Hinshaw and F. P. Stutz, 1976)

When differences in the social mobility in space are taken into consideration it is no wonder that no general model has yet been constructed which makes it possible to understand and forecast all forms of human movements. In the literature there are many models referring to the movement of individuals, but the so-called 'general' model usually possesses only one or two variables. There have been some attempts which may be treated as a certain approximation to build a general model, e.g. S. M. Golant (1971) constructed a behavioural model facilitating the understanding of all movements of the human beings, and

[5] Most often it is an exponential function. A good synthesis of views held on this subject in relation to various types of activity is provided in a study by R. M. Haynes (1974).

P. Burnett (1976) made mathematical models presenting the behaviour of passengers in space and time. H. Hensel and P. A. Macke (1977) believe that human behaviour in time and space, as well as the choice of route, can be modelled as a cybernetic system with some negative and some positive feedbacks, initiated and controlled by the planner.

In mobility research the most common assumption is that of perfect mobility, which is a result of expanding motorisation. All departures from this assumption are typical deviations and refer to people in a disadvantageous position. Many geographers in their analyses of population mobility have dealt with the movements of particular social groups. Much attention has been paid to people in a disadvantageous situation for various reasons: the Negroes, the urban poor, old people, handicapped, females, children, and also rural population (cf. P. O. Muller, 1976).

STUDIES OF SOCIAL ATTITUDES

Spatial analyses of attitudes towards transport innovations taken by inhabitants, predominantly in urbanized areas, are directly associated with perception studies. The introduction of transport innovations of a linear character, such as: urban freeways, additional linkages in transport networks, or a new bridge, cause many controversies between planners and population (J. Wolpert and R. Ginsberg, 1969; P. Burnett, 1977), and also varied attitudes in local communities (A. J. Mumphrey and J. Wolpert, 1973; P. Burnett, 1975; J. O. Wheeler, 1976b). These problems are undoubtedly something new in the spatial transport research.

Let us assume that a new investment is being contemplated in a certain region, for example whether or not to construct an urban freeway. The inhabitants of the neighbouring territorities may expect that this investment will bring them certain advantages (better accessibility) or that they will suffer certain disadvantages (increased noise, greater air pollution, etc.). The attitude of the inhabitants towards the proposed urban freeway will depend entirely on the degree to which this innovation affects them personally. J. O. Wheeler (1976b) explains that (1) a decisive role in shaping human attitudes is played by the distance from the place of residence to the freeway; (2) those who support the project are living at a certain distance from the freeway and hope to gain certain benefits as regards transport possibilities and not suffer any harmful effects; (3) the strongest opposition comes from people living in the immediate vicinity of the proposed freeway.

Both positive and negative features of the project to build a new artery have, of course, their geographical aspect. Usually, environmental costs are highest adjacent to the road itself and fall extremely rapidly away from the line of the road. Economic and social advantages, however, expand more regularly over the area of the whole town, though they are also the greatest in the vicinity of the contemplated investment. People living in the vicinity of the freeway will gain most advantages from improved accessibility; the effectiveness of the whole urban transport system is theoretically higher. Increased noise, denser pollution of man's environment, disruption of the neighbourhood, and other negative phenomena will be mostly felt by the closest neighbours of the freeway.

There is also a fundamental conflict between the interests of users and non-users of the road. The first, especially those living in the close neighbourhood, respond positively to the project because they can see benefits from better accessibility. And *vice versa*, the non-users become even greater advocates of the plan as the distance separating them from the road increases. This is an indirect effect of the expectation that future positive changes in land use (situated within the range of the road influence) may occur while simultaneously environmental conditions will be preserved.

The attitudes may very not only in relation to the proposed freeway but also as regards the selection of alternative transport linkages (P. Burnett 1975, 1977), or as a controversy on the location of a new road bridge, as, for example, in the case of New Orleans (A. J. Mumphrey and J. Wolpert, 1973). In similar cases social transport geography is primarily interested in the spatial distribution of the attitudes of investigated communities and in its implications for planning practice.

STATISTICAL MATERIAL AND RESEARCH METHODS

The need for a high degree of detailed statistical data, which is associated with the scale of phenomena and processes investigated, means that in a predominant number of cases one cannot rely exclusively on published material. This is, however, not an isolated case: the inadequacy of data which are available has often been a barrier in the preparation and development of many spatial analyses. Among several scores of studies, read by the author, only that by R. F. Wiseman (1975), which investigated two particular cities in the USA used data published in the National Census. In the remaining cases data were collected by means of questionnaires, compiled specially for the particular purpose.

The development of social transport geography has in no way hampered the use of quantitative methods and models. On the contrary, in studies carried out by the followers of the new trend, a great number of known techniques have been applied (cf. Table 1).

AN ATTEMPT AT AN EVALUATION. POSSIBILITIES OF THE DEVELOPMENT OF SOCIAL TRANSPORT GEOGRAPHY

Most studies carried out so far have been concerned with analyses of urban problems under North-American conditions. This, however, does not mean that certain problems of man's mobility, the development of attitudes towards transport innovations, etc. might not be similar in socialist or the Third World countries, though the nature of those problems may be quite different. Some recent observations on the subject of man's mobility (cf. L. H. Klaassen, 1973, pp. 19–20) are becoming more and more topical also under Polish conditions. For example, information in the transport behaviour of the urban population may be used in the reorganization of public transport. Undoubtedly, this is a problem which we will have to solve in the near future, if we want to avoid trouble associated with a rapid expansion of car ownership in Poland.

The question of attitudes also looks similar. An almost classical example is provided by the case of a new motorway from Cracow to Zakopane in the 1970s. Diametrically different views of the population living around Myślenice meant that the investment was stopped. An earlier analysis of the population's attitudes might have eliminated such a development entirely. The above example shows that irrespective of certain fundamental differences in the political systems, we are facing here an analogical situation with that described

TABLE 1. Selected methods in social transport geography

Method	Examples of research objectives	Application
Factor analysis and principal components analysis	Investigation of common dimensions of variability in action space structures of two populations;	Horton and Reynolds (1971)
	Singling out of essential properties of the socioeconomic groups setting on a journey — the preliminary stage of investigations;	Wiseman (1975)
	Determination of the fundamental structure of interaction — the preliminary stage of investigations;	Wheeler (1972)
	Differentiation of components of the process of a complex social interaction on the basis of data referring to social trips;	Stutz (1973)
	Determination of components of environment perception under conditions of optional alternative transport systems (modified principal components analysis — INGRID algorithm);	Burnett (1977)
	Establishing of standard attitudes occurring in neighbourhoods and of relations between the variables and the standards.	Wheeler (1976b)
Correlation analysis	Identification of relationships and dependences: between individuals' behaviour and their socioeconomic variables;	Wiseman (1975)
	Frequency of interactions and individual evaluation of the distance;	Hollhuber (1974)
	Frequency of interactions and evaluation of single nodes.	Hollhuber (1974)
Markov chains	Determination of the mean first passage time (MFPT) in journeys to numerous destinations	Wheeler (1972)
Graph methods	Determination of time accessibility and hierarchy of the nodes of the urban transport network	Höllhuber (1974)
Multidimensional scaling	Scaling of accessibility and environmental attitudes as regards the proposed urban freeway	Wheeler (1976b)
Linear programming	Determination of the so-called psychic transport costs	Menchik (1974)

by J. O. Wheeler (1976b). Studies of the population bahaviour may also be accompanied by the preparation of interesting implications which could be utilized in planning practice and which are based on social discussions as to the improvement of transport services, a subject entirely neglected in our research work.

P. O. Muller (1976) believes that the social factor influencing accessibility plays a decisive role in the diffusion of agricultural, sanitary and other innovations in the urban areas of Third World countries, and also that it exerts an effect on migration and the planning of new growth centres. This subject still awaits geographical research.

The author believes that studies in social transport geography should be further developed, for three main reasons: (1) for the sake of planning practice (problems not yet brought to light in our country), (2) for the sake of cognition: a supply of new, interesting subjects which could be investigated within transport geography, (3) for the sake of theory: collection of new material necessary for generalisations of the spatial behaviour of an individual or a social group. The main difficulty in the development of research into problems outlined above lies in a need to collect each time statistical data, a task which undoubtedly will make research workers less interested in undertaking such studies.

The development of each discipline depends, of course, mainly on some well-grounded theories, which also make quantification possible. R. F. Abler (1974) believes that in the case of transport geography the theories can be built on the basis of the analyses of man's behaviour in space.

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TYPOLOGIE FONCTIONNELLE DES VILLES DE ROUMANIE À LA LUMIÈRE DE L'ANALYSE FACTORIELLE

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Au cours des vingt dernières années, de nombreux travaux de la littérature géographique mondiale et polonaise ont été consacrés à l'étude de la structure et de la typologie fonctionnelle des villes (Dziewoński, 1967). Le présent travail réunit l'étude des fonctions de 183 villes de Roumanie, toutes celles qui, en 1966, jouissaient du statut juridique de cité. Le but visé est de définir, au travers de l'identification et de la caractéristique des fonctions, les fonctions dominantes en liaison avec la grandeur et la dynamique de la ville, pour aboutir à l'établissement d'une typologie fonctionnelle des villes roumaines. La méthode de recherche adoptée est celle de l'analyse factorielle (*factor analysis*, Thurstone, 1931). Dans la géographie roumaine, les méthodes quantitatives sont en général peu connues, et aucune d'elles n'a trouvé des applications dans l'étude des fonctions des villes. Ce travail constitue donc une tentative de résoudre le problème de la classification et de la typologie fonctionnelle des villes roumaines, au moyen de la méthode quantitative d'analyse factorielle. Les matériaux utilisés proviennent du recensement de la population de 1966 (*Recensămîntul populaţiei din 15 martie 1966*).

Comparée à l'Europe Occidentale hautement urbanisée, la Roumanie est un pays d'un indice moyen d'urbanisation. En 1966, la population urbaine constituait 38,2% de la population totale (y compris les localités de type urbain); dans les villes habitaient 35,5% de la population totale. Sur les 183 villes existantes, les plus nombreuses (119 villes) étaient les petites villes, jusqu'à 20 000 habitants (Tabl. 1): en dépit de leur nombre, elles réunissaient cependant la part la moins importante (20,4%) de la population par rapport à tous les autres groupes quantitatifs. Le potentiel humain le plus élevé était réuni par les villes moyennes (de 20 000 à 100 000 hab.): 29,1%, 51 villes. La population de Bucarest, la plus grande ville de Roumanie, s'élevait à 22,0% de la population totale des villes [1]. Le rôle le plus important dans le développement du nombre de la population des villes à la période étudiée, incombait à la migration, conséquence du développement économique de la Roumanie, et surtout de l'industrialisation socialiste.

La structure spatiale de l'urbanisation de la Roumanie fait toujours apparaître des différences considérables. Les zones le plus fortement urbanisées, que l'on peut considérer comme se trouvant au stade initial de formation d'agglomération, sont surtout les suivantes: le bassin pétrolier de Ploieşti avec la

[1] La deuxième ville pour le nombre d'habitants, Cluj, était en 1966 sept fois plus petite que Bucarest.

TABLEAU 1. Classification des villes roumaines par groupes de grandeur en 1966

Groupe de grandeur des villes d'après le nombre d'habitants	Nombre de villes	% du nombre total des villes	Population	% du nombre total de la population des villes
1. Villes petites				
au-dessous de 5000	12	6,6	42 917	0,7
5000 — 9999	48	26,2	366 953	5,9
10000 — 19999	59	32,2	859 554	13,8
2. Villes moyennes				
20000 — 49999	43	23,5	1 273 398	20,5
50000 — 99999	8	4,4	532 104	8,6
3. Grandes villes				
100000 — 149999	6	3,3	792 484	12,7
150000 — 199999	6	3,3	985 962	15,8
4. Villes très grandes				
au-dessus de 1000000	1	0,5	1 366 684	22,0
Total	183	100,0	6 220 056	100,0

Elaboré à partir du *Recensămîntul populaţiei 1966*, Direcţia Centrală de Statistică, Bucureşti 1969.

région industrielle de Braşov, le bassin houiller de Petroşani, y compris la région sidérurgique de Hunedoara, le bassin houiller et sidérurgique de Reşiţa et l'ensemble urbain de Constanta. En Roumanie les plans économiques influent sur l'évolution des processus d'urbanisation. Le développement de l'urbanisation se fait au travers de l'agrandissement des villes existantes et de la construction de villes nouvelles (p. ex. Victoria, Gheorghe Gheorghiu Dej, Bicaz, Vulcan), principalement grâce à leurs fonctions industrielles. Ceci entraîne des modifications dans la structure de l'emploi de la population des villes. La Roumanie d'avant-guerre, agricole, était caractérisée par des centres agroforains peu importants, alors que l'industrie employait un pourcentage modique de la population urbaine. En 1966, la moyenne nationale d'emploi de la population des villes dans le secteur primaire s'élevait à 9,6%, dans le secteur secondaire — à 51,1%, dans le secteur tertiaire — à 39,3% (Cucu, 1970; Kremky-Saloni, 1973, 1975; Şandru 1975).

Le problème de la classification des villes avait retenu l'attention des géographes roumains qui le faisaient à partir de différents critères. La première typologie fonctionnelle des villes faite en Roumanie, fondée sur les critères quantitatifs à partir de la structure professionnelle de la population dans les trois secteurs principaux de l'économie, avait été faite par I. Şandru en collaboration avec V. Cucu et P. Poghirc (1961) de l'université de Iaşi. Les auteurs ont résolu le problème d'une manière graphique à l'aide du triangle d'Ossan, en dressant des nomogrammes pour 1930 et 1956. Ils ont ainsi abouti à distinguer 4 types principaux de villes (1. industrielles, 2. services, 3. agricoles, 4. de structure mixte), répartis en sous-types, ce qui, dans la classification définitive, donne un schéma de 10 types de villes. Pour les années 1930 et 1956 également, une classification fonctionnelle des villes avait été établie par V. Karteva et V. Sofalvi (1963) de l'université de Cluj. Les auteurs ont distingué 12 types fonctionnels de villes à partir d'un groupement simple en fonction de la structure professionnelle de la population, l'emploi dans l'industrie ayant été retenu par eux comme principal critère de la distinction des différents groupes de villes. Le problème de la classification fonctionnelle avait également intéressé l'équipe d'auteurs de l'Institut de Géographie de l'Académie Roumaine à Bucarest: V. Mihăilescu, C. Herbst et I. Băcănaru (1962, 1964, 1965). Ces auteurs considèrent que la classification fonctionnelle des villes devrait tenir compte des critères géographiques (site), démographiques (structure professionnelle de la population) et économiques (valeur de la production).

Dans les conditions économiques actuelles, les villes de la Roumanie se répartissent en deux grands groupes fonctionnels: 1. les villes aux fonctions complexes; 2. les villes à une fonction prédominante (industrielle, tertiaire, transports, curative-balnéaire, agricole).

Il est significatif que, portant un si grand intérêt au problème de la classification des villes, les géographes roumains n'aient entrepris aucune tentative pour mettre au point et soumettre à une vérification empirique un modèle méthodologique fondé sur les méthodes mathématiques quantitatives, universellement employées dans l'étude des phénomènes spatio-économiques (Czyż, 1971; Chojnicki, 1977). Il semble d'autant plus juste et opportun d'introduire un des modèles d'analyse factorielle pour procéder à la typologie fonctionnelle des villes de Roumanie.

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Parmi les nombreux modèles d'analyse factorielle au sens général, on a retenu pour l'étude de la structure fonctionnelle des villes roumaines l'algorithme de l'analyse des principales composantes (*component analysis*). H. Hotelling (1933) est considéré comme l'auteur de ce modèle. Ce modèle a été reconnu comme une bonne méthode pour résoudre les problèmes de classification (Racine, Reymond, 1973). L'analyse des principales composantes consiste essentiellement en une transformation des variables (des attributs primaires) z_n caractérisant p unités étudiées, en de nouvelles variables F_m appelées principales composantes, celles-ci servant de base à la caractéristique essentielle des villes, puis à leur typologie. L'algorithme utilisé des principales composantes adopte la forme d'un modèle mathématique exprimé par l'équation:

$$z_i = a_{i1}F_1 + a_{i2}F_2 + \ldots + a_{im}F_m$$

où

z — variables primaires (1, 2...n),
F_1, F_2...F_m — principales composantes (1, 2...m),
a — coefficients de saturation (de la composante m à la variable n).

L'ensemble des 183 villes soumises à l'étude a été caractérisé au moyen d'une série d'attributs quantifiables, leurs valeurs étant exprimées en nombres. Sur les 19 attributs choisis pour la caractéristique des villes, 11 se rapportent à la structure professionnelle de la population, les autres décrivent la ville sous le rapport de sa grandeur, du rythme de croissance, de la position sociale de la population et des conditions de logement (Tabl. 2). Les données fondamentales ont été présentées sous forme de matrice originelle A d'information spatiale, de l'ordre 183×19, qui sert de point de départ à la procédure de recherche.

La première chose à faire est de transformer la matrice originelle A en matrice standardisée Z de même ordre. Les valeurs titrées de tous les attributs

TABLEAU 2. Attributs originels caractérisant les villes

N° de l'attribut	Nom de l'attribut et unité de mesure
1	Grandeur de la ville — nombre d'habitants de la ville en 1966
2	Rythme de croissance — accroissement de la population dans la période 1956–1966
3	Population active — pourcentage de la population active par rapport au total de la population de la ville
4	Industrie — pourcentage de la main-d'oeuvre industrielle par rapport à la population active
5	Industrie minière — pourcentage de la main-d'oeuvre minière par rapport à la population active
6	Bâtiment — pourcentage de la main-d'oeuvre du bâtiment par raport à la population active
7	Agriculture et sylviculture — pourcentage de la main-d'oeuvre dans l'agriculture et la sylviculture par rapport à la population active
8	Transports et communications — pourcentage de la main-d'oeuvre dans les transports et les communications par rapport à la population active
9	Commerce et finances — employés du commerce et des finances en % de la population active
10	Economie communale — pourcentage de la main-d'oeuvre des services communaux par rapport à la population active
11	Education, culture, arts, science — travailleurs de l'éducation, de la culture, des arts et de la science en % de la population active
12	Protection de la santé — travailleurs du service de santé en % de la population active
13	Administration — employés de l'administration en % de la population active
14	Artisanat — pourcentage de la main-d'oeuvre artisanale par rapport à la population active
15	Position sociale — ouvriers en % de la population active
16	Position sociale — travailleurs intellectuels en % de la population active
17	Position sociale — paysans en % de la population active
18	Logement — nombre de personnes par pièce habitable
19	Logement — nombre de m² par habitant

originels ont été soumises à la standardisation d'après la formule de W. Isard:

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma}$$

où

x_{ij} — attribut j de l'objet i,
$\bar{x}_j$ — moyenne arithmétique de l'attribut j,
σ — écart type de la distribution.

Les attributs ramenés ainsi à une forme comparable restent, les uns par rapport aux autres, dans la même relation que les valeurs titrées correspondantes. L'opération suivante est de calculer la corrélation des variables (attributs) d'après la formule de K. Pearson:

$$r_{1,2} = \frac{\sum_{i=1}^{N} (x_{ij} - \bar{x}_j)(x_{ik} - \bar{x}_k)}{\sqrt{\sum_{i=1}^{N} (x_{ij} - \bar{x}_j)^2 \sum_{i=1}^{N} (x_{ik} - \bar{x}_k)^2}}$$

où

i — unités observées (villes),
j, k — attributs (variables).

Les coefficients de corrélation des variables ont été présentés sous forme de matrice *K* des corrélations des variables, de l'ordre 19×19.

L'analyse de la matrice des corrélations par la méthode du dendrite a permis de distinguer trois groupes de liens réciproques variables (Fig. 1). Le premier groupe englobe les attributs caractérisant l'emploi dans les services (secteur tertiaire) et la catégorie sociale des travailleurs intellectuels; à ce groupe est reliée aussi la grandeur de la ville. Le deuxième groupe est composé des attributs correspondant à l'emploi de la population dans l'agriculture et l'industrie (secteurs primaire et secondaire) ainsi qu'à la catégorie sociale des agriculteurs et des ouvriers: entre les deux secteurs d'emploi, comme entre les deux groupes sociaux, interviennent des corrélations négatives. Le troisième groupe ne contient que deux attributs qui définissent les conditions de logement. Le dendrite présenté peut servir à formuler une hypothèse préliminaire sur l'existence de systèmes convergents de structures spatiales. Se fondant sur lui, on peut distinguer 3 systèmes spatiaux essentiels, déterminés par les indices des attributs: un pour le secteur tertiaire et deux systèmes opposés du secteur primaire et du secteur secondaire, et on peut admettre qu'ils interviendront comme critères fondamentaux de classification.

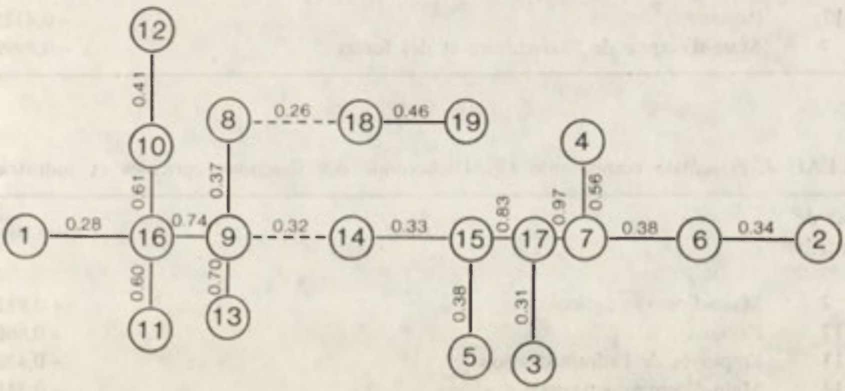

Fig. 1.

La partie la plus importante de l'analyse des principales composantes est la réduction de l'espace multidimensionnel, qui consiste à remplacer les variables orginelles par des composantes principales[2] nouvellement calculées. La procédure mathématique a été conduite d'après la méthode de la principale composante avec l'algorithme de Hotelling (Harman, 1960). Trois composantes principales C_1, C_2, C_3 ont ainsi été distinguées. La matrice des principales composantes (matrice des saturations) *C* de l'ordre 19×3, ainsi obtenue, est le point de départ de l'analyse et de l'interprétation. Les principales composantes accusent des valeurs propres supérieures chacune à 1 et expliquent 49,23% du

[2] Appelées aussi, mais improprement, facteurs: ce terme en effet se rapporte au modèle de l'analyse en facteurs communs et spécifiques (l'analyse factorielle au sens plus étroit).

poids cumulé de la variance. La relation entre les principales composantes et les variables est exprimée par la grandeur des coefficients de saturation. Les diverses composantes C diffèrent entre elles par une part variable des attributs originels. Chacune des composantes est expliquée par ceux des attributs auxquels correspondent les poids de saturation les plus élevés.

L'analyse des saturations de la composante principale C_1 a démontré que 6 attributs fortement corrélés positivement avec cette composante concernent l'emploi dans les services et les travailleurs intellectuels, alors que les saturations négatives de la composante C_1 ont les atributs qui déterminent la position sociale — paysans et travailleurs employés dans l'agriculture. La composante principale C_1 détermine donc les fonctions tertiaires des lieux centraux (Tabl. 3).

TABLEAU 3. Principale composante C_1. Fonctions tertiaires des lieux centraux

N° de l'attribut	Attribut	Saturations
16	Travailleurs intellectuels	+0,9081
9	Main-d'oeuvre du commerce et des finances	+0,8370
10	Main-d'oeuvre des services communaux	+0,7623
13	Employés de l'administration	+0,6780
11	Travailleurs de l'éducation, de la science, de la culture et des arts	+0,6440
8	Main-d'oeuvre des transports et communications	+0,4669
17	Paysans	−0,4525
7	Main-d'oeuvre de l'agriculture et des forêts	−0,3999

TABLEAU 4. Principale composante C_2. Dichotomie des fonctions agricoles et industrielles

N° de l'attribut	Attribut	Saturations
7	Main-d'oeuvre agricole	+0,8872
17	Paysans	+0,8619
13	Employés de l'administration	+0,4309
14	Main-d'oeuvre artisanale	+0,3435
15	Ouvriers	−0,9492
4	Main-d'oeuvre industrielle	−0,6121
6	Main-d'oeuvre du bâtiment	−0,4984
2	Rythme de croissance	−0,3244
5	Main-d'oeuvre minière	−0,3175

La principale composante C_2 manifeste une deuxième structure des relations variables. C'est une composante bipolaire: elle oppose en effet les fonctions agricoles à coefficients de saturation positifs très élevés aux fonctions industrielles exprimées par des coefficients de saturation négatifs. La principale composante C_2 s'identifie en tant que dichotomie des fonctions agricoles et industrielles (extra-agricoles) (Tabl. 4). On voit nettement apparaître ici la convergence des groupements précédemment analysés du dendrite du système des composantes C_1 et C_2. Vu le caractère pilote des attributs positivement corrélés caractérisant la population active, le rythme de croissance, le nombre de la population et l'emploi dans le bâtiment, la principale composante C_3 est définie comme représentant le dynamisme du développement (Tabl. 5).

TABLEAU 5. Principale composante C_3. Dynamisme de développement

N° de l'attribut	Attribut	Saturations
3	Population active	+0,7232
2	Rythme de croissance	+0,4491
12	Travailleurs de la protection de la santé	+0,3660
1	Nombre d'habitants	+0,3603
6	Main-d'oeuvre du bâtiment	+0,3150
5	Main-d'oeuvre minière	−0,4016
8	Main-d'oeuvre des transports et communications	−0,3073

Pour ensuite procéder à la classification des différentes villes et à leur typologie, l'on a calculé les poids locaux des principales composantes C_1, C_2, C_3, pour chacune des 183 villes étudiées. Ainsi a été obtenue la matrice W d'information spatiale réduite de l'ordre 183×3, chaque ville étant ainsi caractérisée par 3 composantes principales au lieu des 19 attributs précédents.

L'utilisation des composantes principales dans la solution du problème de la typologie a concerné trois catégories: la classification à partir d'une composante principale, de deux composantes principales et de trois composantes principales. La classification à partir d'une composante a été faite en fonction des poids locaux répartis en 3 classes: 1. poids locaux +2 et plus; 2. poids locaux de +2 à −2; 3. poids locaux −2 et au-dessous. La typologie à partir des poids locaux C_1 caractérise les villes sous le rapport de leurs fonctions tertiaires. Sur les 59 villes accusant les poids locaux C_1 les plus élevés, donc villes éminemment tertiaires, 24 sont des centres administratifs de districts et, en même temps, les plus grandes villes de Roumanie (p.ex. Bucarest, Cluj, Iaşi, Ploieşti, Timişoara). Le deuxième type de villes aux fonctions tertiaires, administratives, moyennement développées réunit 67 villes, dont 14 seulement sont des centres administratifs de districts et toutes sont des villes plus petites. Les villes du troisième groupe, distinguées au moyen de la composante C_1, ne remplissent pas de fonctions administratives; ce sont des centres agricoles (p.ex. Siret, Panciu, Zimnicea), ou des villes industrielles et minières (p.ex. Hunedoara, Victoria, Anina, Petrila). La typologie à partir des poids locaux C_2 donne en principe une répartition en villes à fonctions agricoles (54 villes) et extra-agricoles (54 villes) ainsi qu'un groupe de 75 villes aux fonctions différenciées. La classification selon les poids locaux C_3 donne une distribution spatiale des types évolutifs des villes. Cette composante se caractérise par une proportion très peu élevée des villes dans les groupes aux poids locaux les plus élevés et les plus bas, donc caractérisés par un grand dynamisme (p.ex. Bucarest, Braşov, Bicaz) ou accusant la stagnation (p.ex. Fetesti, Abrud). La grande majorité des villes accuse un dynamisme de développement moyen et c'est un groupe très différencié quant à la grandeur des villes et leur structure fonctionnelle.

Dans la classification à partir de deux composantes principales, quand ces composantes sont au nombre de trois, les combinaisons possibles se répartissent en systèmes binaires: C_1, $-C_2$; C_1, $-C_3$; C_2, $-C_3$. La classification à partir de

TABLEAU 6. Types fonctionnels des villes de Roumanie en 1966. Tableau classificatoire

Type	Ordre de grandeur de la ville d'après le nombre d'habitants	Type fonctionnel	Portée	Dynamisme de développement	Nombre de villes
		A. Multifonctionnelles			123
I	Grande ville au-dessous d'un million	Fonctions diversifiées avec une dominante des tertiaires et industrielles	Capitale nationale et supranationale	Grand	1
II	Grande ville v. 100 000 et au-dessous	Fonctions diversifiées avec une dominante des tertiaires et industrielles	Nationale et régionale, lieux centraux	Grand et moyen	16
III	Moyennes et petites au-dessous de 100 000	Fonctions industrielles avec une sous-dominante tertiaire	Nationale et régionale	Moyen et grand	15
IV	Moyennes et petites au-dessous de 60 000	Fonctions tertiaires avec une sous-dominante des industrielles	Régionale et locale, lieux centraux	Moyen et faible	38
V	Moyennes et petites au-dessous de 40 000	Fonctions tertiaires-agricoles, à industrie faiblement développée ou embryonnaire	Régionale et locale, lieux centraux	Moyen	53
		B. Monofonctionnelles			60
VI	Moyennes et petites au-dessous de 100 000	Fonctions industrielles	Nationale et régionale	Différencié: grand, moyen, stagnant	30
VII	Petites au-dessous de 20 000	Centres agricoles	Régionale et locale	Moyen et faible	21
VIII	Petites au-dessous de 20 000	Fonctions tertiaires (stations de cure)	Supranationale et nationale	Grand	9

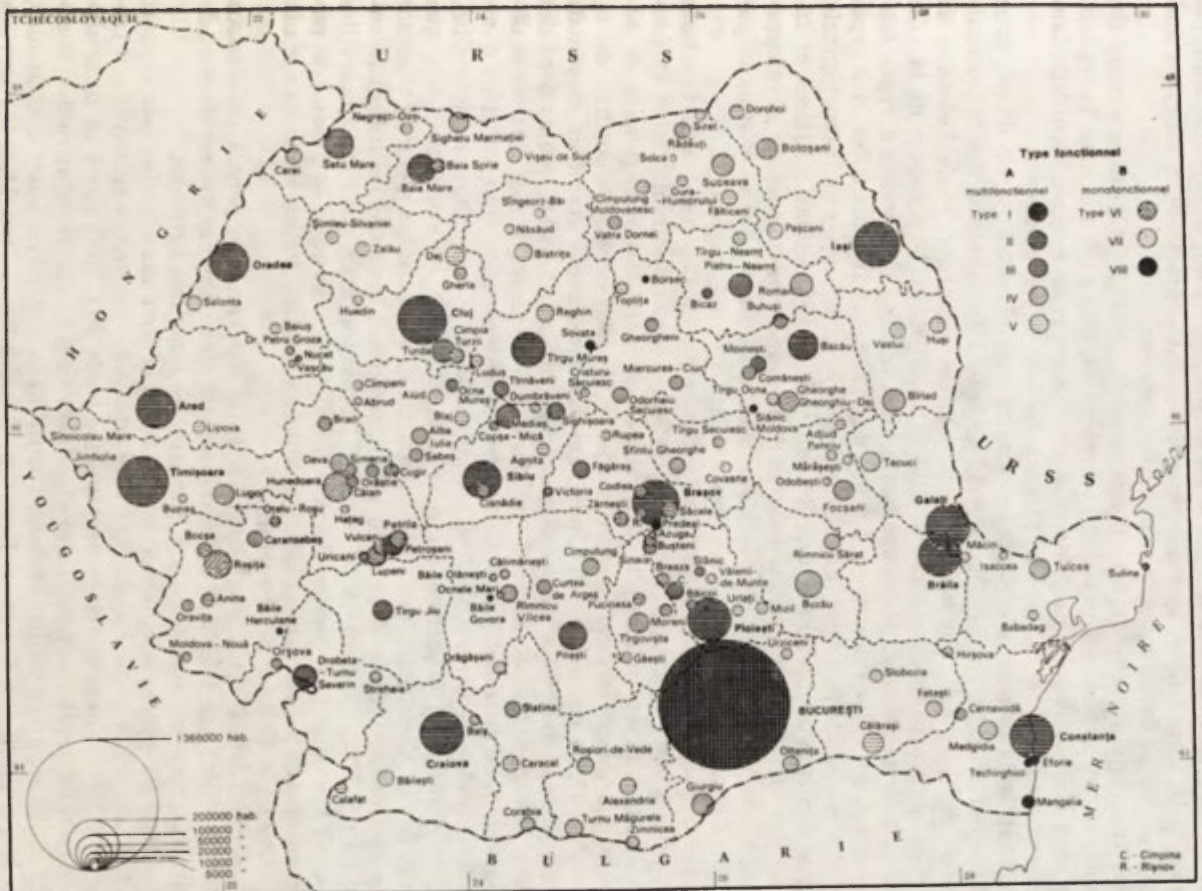

Fig. 2.

deux composantes a été faite compte tenu, pour chaque composante, de la répartition en 3 classes de poids locaux[8]. Ainsi, pour chacune des paires de composantes on a obtenu 3 types principaux divisés en 3 sous-types, soit au total 9 types. Le plus essentiel est le système C_1, $-C_2$ qui différencie les types fonctionnels, alors que les systèmes à composante C_3 caractérisent les types sous le rapport de la dynamique de leur développement.

La typologie à partir de trois composantes C_1, $-C_2$, $-C_3$ est la somme des typologies obtenues à partir de deux composantes. Elle a permis, dans la répartition en 3 classes d'après les poids locaux, de classer les 9 types identifiés dans la classification C_1, $-C_2$ sous le rapport de leur développement.

L'analyse faite par voie de classifications successives à partir d'une, deux et trois composantes principales, a servi de base à la définition des types fonctionnels des villes de Roumanie. En plus de leur fonction et de l'étendue de celles-ci, on a pris en considération dans cette typologie la grandeur de la ville et le dynamisme de son développement. Ainsi ont été déterminés 8 types fondamentaux de villes roumaines: 5 types de villes polyfonctionnelles et 3 types de villes monofonctionnelles (Fig. 2, Tabl. 6). Parmi les types multifonctionnels, le type I distingué comprend une grande ville aux fonctions tertiaires et industrielles, de portée supranationale et d'un grand dynamisme de développement, notamment la capitale de la Roumanie, Bucarest, qui se distingue par des poids locaux très élevés: positif pour C_1 et C_3 et négatif pour C_2.

Le type II comprend les grandes villes (env. 100 000 hab.) aux fonctions diversifiées, mais avec une dominante tertiaire, surtout administrative et éducativo-culturelle et industrielle diversifiée, de portée suprarégionale et régionale. Les poids locaux de la composante C_1 sont élevés et positifs, de C_2 tous négatifs, la composante C_3 indiquant un dynamisme grand et moyen de développement des villes. Dans ce groupe se situent 16 villes, toutes sont des centres administratifs de districts. Les fonctions tertiaires y sont fortement développées, tant pour ce qui est des services matériels (ce sont en effet d'importants centres commerciaux et des noeuds de communication, tels Cluj, Braşov, Ploieşti, Timişoara — ou des ports fluviaux et maritimes, tels que Galaţi, Brăila, Constanţa), que des non matériels: dans chacun d'eux se trouvent des écoles supérieures ou des instituts de recherche. L'industrie est très différenciée, p.ex. à Cluj, Craiova, Arad, Oradea, Timişoara, mais dans quelques villes certaines branches sont prédominantes: à Galaţi la sidérurgie et l'industrie navale, à Braşov l'industrie mécanique, à Sibiu les textiles, à Baia Mare les métaux non ferreux, à Ploieşti la pétrochimie.

Les types III, IV et V englobent les villes moyennes et petites (au-dessous de 100 000 hab.) aux fonctions diversifiées avec prédominance des services ou de l'industrie, mais on voit aussi y apparaître les fonctions agricoles.

Le type III accuse une prédominance des fonctions industrielles par rapport aux tertiaires. Les poids locaux de C_1 sont positifs, moyens et relativement faibles, de C_2 très élevés et éléves négatifs, les poids de C_3 indiquent un dynamisme moyen de développement. La prédominance des fonctions industrielles intervient d'une manière particulièrement nette dans des villes telles que Medias, Satu Mare, Petroşani, Cîmpina, Tîrnaveni, Moineşti et autres. Mais les services sont aussi importants pour la structure fonctionnelle de ce groupe, certaines d'entre elles (les villes moyennes) assument les fonctions de centre administratif du district (Piatra Neamţ, Satu Mare, Turnu Severin, Tîrgu Jiu).

Le type IV, tertiaire-industriel, beaucoup plus nombreux que les précédents (38 villes), a des poids locaux C_1 positifs très élevés et élevés, C_2 moyens né-

[8] Tout comme dans la classification à partir d'une composante.

gatifs, la composante C_3 accusant un dynamisme moyen et faible. Il se caractérise par la prédominance des fonctions tertiaires, correspondant à leur rang central, alors que l'industrie, quoique différenciée, est représentée principalement par les branches de l'industrie légère depuis longtemps développées (p.ex. Botoşani, Focşani, Alba Iulia, Lugoj, Caransebeş et autres). Seules quelques villes se distinguent comme des centres des industries lourdes et chimiques (à côté de l'industrie légère) développées depuis peu, telles Bîrlad, Roman, Slatina, Buzău. Une partie des villes rangées dans ce type manifeste dans le secteur tertiaire une fonction de transports et de communications bien développée, dont Simeria, Caransebeş, Sulina, Giurgiu, ou de repos et de cure, telles Sinaia, Breaza, Vatra Dornei, mais ce sont des villes où l'industrie occupe une si grande place qu'elles n'ont pas pu être reconnues comme monofonctionnelles — transports ou stations de cure.

Le type V englobe le groupe le plus nombreux (53 villes) de tous les autres types. C'est donc en 1966 le type le plus représentatif des villes roumaines. Sous le rapport fonctionnel, ce sont des villes tertiaires-agricoles avec une proportion relativement élevée de la population employée dans l'agriculture. Les poids locaux C_1 et C_2 sont moyens et élevés, positifs, C_3 moyens. Ce sont des centres régionaux ou locaux moyens et petits (au-dessous de 50 000 jusqu'à 5 000 hab.), d'un développement moyen, avec une industrie faiblement développée, surtout alimentaire (e.a. Huşi, Vaslui, Tecuci), du bois (p.ex. Reghin), des matériaux de construction (Babadag, Măcin). Certaines villes de ce groupe entrent actuellement sur la voie d'une industrialisation plus intense, comme Călăraşi, Turnu Măgurele, Bistriţa.

Parmi les villes monofonctionnelles on a distingué 3 types. Le type VI englobe les villes industrielles spécialisées, moyennes et petites (au-dessous de 70 000 jusqu'à 2 000 hab.), donc d'un écart assez grand; elles ont des poids locaux négatifs très élevés pour C_1 et C_2 et une dynamique de développement (C_3) très différenciée. Prédominent les villes spécialisées dans la sidérurgie (Hunedoara, Reşita, Cugir, Călan, Oţelu Roşu), l'industrie chimique (Gheorghe Gheorghiu Dej, Victoria, Copşa Mica) et minière (Lupeni, Petrila, Vulcan, Anina, Uricani, Baia Sprie), beaucoup moins dans l'industrie légère (p.ex. textile à Buhuşi, Cisnădie).

Le type VII groupe les centres agricoles. Ce sont des villes petites, de moins de 20 000 hab., liées à l'arrière-pays agricole. Elles ont des poids locaux C_1 élevés négatifs et des poids locaux C_2 très élevés positifs, et accusent une dynamique (C_3) relativement faible de développement. L'industrie y est strictement et exclusivement liée à l'agriculture, p.ex. Panciu, Odobeşti, centres d'une région viticole et de l'industrie de transformation qui s'y rattache. Certaines villes de ce groupe ont récemment (en 1948–1966) obtenu les droits de cité du fait de l'attention accordée à la possibilité d'utiliser les sources d'eau minérale et de les développer en tant que stations de cure (p.ex. Sîngeorz-Băi, Băile Olaneşti, Buziaş, Covasna) et on peut supposer qu'à l'avenir elles passeront dans le type VIII, mais en 1966 leur caractère fonctionnel était absolument déterminé par l'agriculture.

Le type VIII englobe un petit groupe de villes spécialisées dans les services: stations de cure et balnéaires maritimes. Ce sont des villes petites (moins de 15 000 hab.), mais accusant une très grande dynamique de développement, surtout Eforie, Mangalia, Băile Govora, Băile Herculane. Ce groupe, très petit en 1966, augmentera en nombre du fait du développement planifié des stations de cure et de tourisme en Roumanie.

Appréciant les résultats obtenus, on peut constater que, après avoir soumis à l'analyse multidimensionnelle les villes roumaines et découvert les différences et les ressemblances entre les diverses unités étudiées, on a déterminé les fonctions dominantes à partir desquelles ont été définis les types fonctionnels fondamentaux des villes roumaines contemporaines. En même temps, grâce à la methode d'analyse des principales composantes et la succession des composantes dégagées, l'on a d'emblée établit dans la classification des villes le rang des fonctions urbaines, déterminées par la composante. Dans le système des principales composantes, au premier rang de la structure fonctionnelle des villes roumaines se sont situées les villes aux fonctions tertiaires des lieux centraux et ensuite les villes aux fonctions agricoles et industrielles. Indépendamment de la détermination des types, il s'est dégagé un certain système structural des villes, caractéristique de la Roumanie: immense prépondérance d'une grande ville — Bucarest, existence d'un petit groupe de grandes villes, très inférieures cependant à Bucarest (assumant les fonctions de centres et possédant une industrie différenciée), nombreux groupe de petits centres agricoles possédant une industrie encore faiblement développée. Le tableau des types fonctionnels des villes roumaines ainsi obtenu est beaucoup plus complet en comparaison avec les résultats auxquels on parvient par l'utilisation des méthodes statistiques simples. Dans l'analyse des principales composantes on utilise un grand nombre (19 dans la présente étude) d'attributs. Leur réduction aux 3 composantes fondamentales se fait par la procédure mathématique; elle est donc objective. Toutes les relations les plus essentielles sont en même temps dégagées. La méthode permet donc de bien montrer la réalité et, en tant qu'un des modèles des méthodes quantitatives, elle semble convenir aux études modernes des fonctions des villes.

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AN ATTEMPT TO APPLY THE METHOD OF TAXONOMIC CLASSIFICATION OF LINEARLY ORDERED SETS TO THE DELIMITATION OF ZONES OF LAND USE IN CRACOW

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One of the important problems common to various studies in urban spatial structure is how to divide the space-economically differentiated area of a town into zones differing by the intensity of land use, by demographic potential, function etc. There are several methods of delimiting regions or zones within larger territories.

In this study the author attempts to delimit the zones of land use for the city of Cracow by the method of taxonomic classification of linearly ordered sets (Grabiński, 1975). The zones are delimited in virtue of the structural features of a profile running from the city core (the Main Market place — *Rynek Główny*) to its western boundaries for which a detailed survey of land use had been made to the scale of 1:1000 in 1972–1973. This 6.5 km long profile has been divided into twenty-three block aggregates (n) each characterized by the same set of ten weakly correlated features (M):

1 — index of intensity of building developments,
2 — percentage of areas for technical uses,
3 — percentage of building-covered areas in the group of technical uses,
4 — percentage of building-covered areas with one-and two-storey houses,
5 — percentage of building-covered areas with houses of non-dwelling functions,
6 — percentage of building sites in the group of technical uses,
7 — percentage of non-agricultural green areas,
8 — percentage of agricultural green areas,
9 — percentage of orchards and gardens in the group of agricultural green areas,
10 — percentage of vegetable gardens in the group of agricultural green areas.

Thus the determined profile, which was composed of block aggregates and characterized by the above-listed collection of features, was a linearly ordered set. The linear order of the set's elements results from objective criteria — in our case, from the distance to the Main Market place which had been taken as the point of origin (time too can be such a criterion).

The main purpose of this study is to distinguish groupings relatively homogeneous from the point of view of the adopted features from the profile, which is a set of linearly ordered aggregate blocks. The author identified those groupings with zones of land use. This problem can be solved by means of the abovementioned method of taxonomic classification of linearly ordered sets. This method enables us to divide a set (linearly ordered according to the respective distances to the city core) of n elements characterized by M features into more homogeneous subsets (zones) without translocating them in space. The method consists in an accurate determination of the courses of boundaries between the zones so as to ensure that the collections of features are similar to one another within one zone and different from those of other zones. In addition to delimiting the boundaries, this method enables us to check their significance as it discloses at which points the given boundary is significant.

Thus the method is reduced to a verification of a series of zero hypotheses on the equivalence of distributions of several multidimensional random variables. From the point of view of multidimensional statistics, the recorded values of the M features of the n objects are individual realizations of M-dimensional random variables X_j ($j = 1, 2, ..., M$). The ordered series of the random variables X_j constitutes an n-element set in the space X^M. The space X^M is regarded as homogeneous if all of its constituent multidimensional random variables X_j have identical distributions:

$$|F_{j'}(X) - F_{j''}(X)| = 0,$$

where $F_j(X)$ is the M-dimensional distribuant of the distribution of the random variable X_j.

In what follows we assume that the space X^M is a normal space and thus the homogeneity condition can be written as follows:

$$\left| f_{j'}\left(X; \mu_{j'}, \sum\nolimits_{j'}\right) - f_{j''}\left(X; \mu_{j''}, \sum\nolimits_{j''}\right) \right| = 0,$$

where $f_j(X; \mu_{j'} \sum_{j'})$ is a function of density of the multidimensional normal distribution of the random variable X_j with the vector of mathematical exceptations μ_j and the covariance matrix $\sum_j$.

Since normal distributions are completely determined by the two parameters μ_j and $\sum_j$ the homogeneity condition can be replaced by two series of equations:

$$\begin{aligned} \mu_{j'} &= \mu_{j''} \\ & \qquad (j', j'' \in J) \\ \sum\nolimits_{j'} &= \sum\nolimits_{j''} \end{aligned}$$

In effect, the problem of studying the homogeneity of the space X^M reduces to the verification of a series of hypotheses on the equality of the vectors of mathematical expectations and the matrices of multidimensional covariances of normal distributions.

The method discussed here can be employed in solving the problem of periodization; to do this we can use the following numerical algorithm of periodization. The linearly ordered set of n objects is dichotomically divided into $n-1$ different ways so as to produce two multidimensional random samples containing n_1 and n_2 observations in each such division. For each case we verify the hypothesis of identity of the two multidimensional distributions to which the random variables belong. This can be done by verifying the hypothesis H_1: $\mu_1 = \mu_2$ and assuming that the covariance matrices of the distributions compared are equal to each other, or else by verifying first the hypothesis H_2: $\sum_1 = \sum_2$ and, when it turns out that there are no reasons for refuting it, then the hypothesis H_1. The most correct procedure is to verify the composite hypothesis H_3: $\mu_1 = \mu_2, \sum_1 = \sum_2$ on the simultaneous equality of the vectors of mathematical expectations and the matrices of covariance of the distributions compared.

These hypotheses are verified by using the empirical statistics determined by the following equations:

$$V_1 = \frac{|A|^{1/2n}}{|B|^{1/2n}}$$

$$V_2 = \frac{|A_1|^{1/2n_1}|A_2|^{1/2n_2}}{|A|^{1/2n}}$$

$$V_3 = \frac{|A_1|^{1/2n_1}|A_2|^{1/2n_2}}{|B|^{1/2n}}$$

where:

A_1, A_2, A — matrices of squares and mixed products of the individual features for the first, second and whole samples, respectively,

n_1, n_2, n — the respective numbers of elements in the first, second and whole samples,

B — a matrix defined as

$$B = A + \frac{n_1 n_2}{n_1 + n_2}(\bar{X}^1 - \bar{X}^2)(\bar{X}^1 - \bar{X}^2)^T,$$

$\bar{X}^1, \bar{X}^2$ — vectors of arithmetical means of features in the first and second samples,

These statistics have a χ^2 distribution of M degrees of freedom (Anderson, 1958).

When we find no reasons for refuting the hypothesis on the equivalence of the given multidimensional distributions in each case, then the space X^M is regarded as homogeneous. If hypotheses H_1 or H_3 are to be refuted even in a single case, then the space X^M is non-homogeneous and thus it can be divided into at least two different subspaces. The boundary of the division is fixed in a point to which correspond the maximum values of statistics V_1 or V_3 which is, in a sense, a generalized measure of the distances of the random samples compared. This procedure is repeated for each subspace we obtain to fix further boundaries till the moment all subspace turn out to be homogeneous.

In order to prevent delimiting 'false' boundaries, which may appear, for instance, as a result of the dychotomic division, we verify a series of hypotheses on the identity of the spatially adjacent multidimensional distributions obtained in the procedure so far. If there appears no justification for refuting either of the hypotheses H_1 or H_3, then the pertinent aggregates of objects (in our case, block aggregates) are connected to one another whereas the boundary between them is recognized as statistically insignificant. The verification of the significance of the boundaries is continued until all block aggregates will have displayed significant differences between one another. In view of the interpretation of the statistics V_1 and V_3 and considering the circumstance that hypotheses H_1 or H_3 have been refuted, the values of those characteristics indicate the relative importance of the given boundary. In this situation, the values V_1 or V_3 have been utilized for grouping the boundaries according to their relative degrees of significance.

The analysis, which has been carried out on a Honeywell-3200 computer, has disclosed the following five zones of land use in Cracow: I — the Central Zone, II — the Transition Zone, III — the Outer Zone, IV — the Fringe Zone, V — the Suburban Zone.

I — The Central Zone comprises an area which had been identical with Cracow city before 1800. It displays a domination of technical uses (74.3%), the main bulk of which are buildings from before 1900. Within the group of traffic areas, which is characterized by the prevalence of the transport-line pattern inherited from the past, pavements claim more area (57.8%) than roads (36.9%). Green areas, which cover 25.6% of the total area in this zone, are represented almost entirely by non-agricultural forms. This zone concentrates hardly any functions but those specific for city-centres; its population density reaches as much as 16,889 persons/km².

TABLE 1. Detailed structure of land utilization zones in percentages of total area

Type of land use	Zone I Central	Zone II Transition	Zone III Outer	Zone IV Fringe	Zone V Suburban
Houses	35.6	32.0	11.3	2.8	0.6
Utility shacks	0.4	0.2	0.1	0.5	0.2
Garages	0.1	1.1	0.7	—	—
Shanties	0.7	0.4	0.3	0.1	0.1
Goods yards	—	—	0.6	0.9	0.7
Market places	0.1	—	0.1	—	—
Backyards	8.0	14.1	4.6	2.1	1.1
Sport areas	0,1	1.3	3.6	1.1	0.4
Building sites	2.3	0.9	4.3	12.9	3.0
Roads	10.0	13.0	10.3	6.4	2.1
Railroad lines	—	—	3.2	2.4	1.1
Tramway lines	—	—	0.2	—	—
Parking places	1.4	0.6	0.5	0.7	—
Pavements	15.6	10.7	7.9	0.4	0.2
Green plots of parks and squares	19.7	0.8	5.3	—	—
Playing-ground parks	—	0.7	0.6	0.2	—
Greeneries	2.5	3.5	12.9	3.4	1.3
Greeneries + trees	1.1	4.7	5.3	3.7	0.3
Greeneries + flowers	1.0	1.6	1.8	0.4	0.1
Allotment gardens	—	—	—	8.7	—
Orchards and gardens	1.3	11.7	5.2	10.9	4.7
Vegetable gardens	—	0.7	3.1	8.2	3.0
Berry-bearing plantations	—	—	—	0.3	1.6
Flower plantations	—	—	0.1	1.6	1.6
Fruit-tree nurseries	—	—	0.1	—	0.1
Nurseries of other than fruit-trees	—	—	—	0.1	—
Garden frames	—	—	0.1	0.4	—
Glasshouses	—	0.2	0.1	0.2	—
Arable land	—	—	3.4	22.5	52.7
Meadows	—	—	0.1	2.0	11.4
Pastures	—	—	—	0.8	7.9
Fallow land	—	—	0.7	0.9	1.2
Special areas	—	—	7.8	—	—
Waters	0.1	1.4	—	0.6	0.6
Wastes	—	0.4	5.7	4.8	4.0
Total	100.0	100.0	100.0	100.0	100.0

TABLE 2. Detailed structure of land utilization zones — according to main groups of grounds in percentages of total area of the groups

Type of land use	Zone I Central	Zone II Transition	Zone III Outer	Zone IV Fringe	Zone V Suburban
Technical uses					
Building-covered areas	49.4	45.5	26.0	11.2	8.6
Traffic areas	36.3	32.8	46.3	32.6	36.7
Goods yards	—	—	1.3	3.1	7.1
Market places	0.2	—	0.2	—	—
Building sites	3.2	1.2	9.0	42.5	32.0
Backyards	10.8	18.7	9.6	7.0	11.4
Sport areas	0.1	1.8	7.6	3.6	4.2
Non-agricultural green areas					
Green plots of parks and squares	80.8	6.7	20.5	—	—
Playing-ground parks	—	6.3	2.3	2.3	—
Greeneries	10.3	30.7	49.6	44.3	70.1
Greeneries + trees	4.6	42.1	20.5	47.6	20.9
Greeneries + flowers	4.3	14.2	7.1	5.8	9.8
Agricultural green areas					
Allotment gardens	—	—	0.2	15.3	—
Orchards and gardens	99.7	92.9	40.5	19.2	5.6
Vegetable gardens	0.3	5.8	24.5	14.5	3.6
Berry-bearing plantations	—	—	—	0.5	1.8
Flower plantations	—	—	1.0	2.9	1.9
Fruit-tree nurseries	—	—	0.3	—	0.1
Nurseries of other than fruit-trees	—	—	—	0.1	—
Garden frames	—	0.3	0.9	0.7	0.1
Glasshouses	—	1.0	0.4	0.4	—
Arable land	—	—	26.5	39.8	62.5
Meadows	—	—	0.5	3.5	13.5
Pastures	—	—	—	1.5	9.4
Fallow land	—	—	5.2	1.6	1.5

II — The Transition Zone stretches over an area of 0.4–1.2 km off the city core. Technical uses account for 74.3% of this zone, and of these 45.5% are represented by building-covered areas. Apart from their recreational functions, the green areas in this zone are utilized for production (mainly orchards and gardens run by monasteries — 12.6%). This is a residential-type zone (25,139 persons/km²) with well-developed trading and service functions.

III — The Outer Zone is primarily one of technical land uses (47.7% of its total area), yet there has been a remarkable rise in the proportion of green areas (38.8%) in it, and these in turn are dominated by non-agricultural forms of land use (26.0%) because most of the city's green and recreational areas concentrate there. It comprises areas situated 1.2–3.9 km off the city core which fulfill several functions: from the residential (12,266 persons/km²) through the research-cultural (higher schools and research centres concentrate in that zone) to the recreational function.

IV — The Fringe Zone is dominated by agricultural land use (56.6%), some 50% of which are represented by intensive cultivation forms (allotment gardens, orchards and gardens, vegetable growing). Owing to the considerable reserves of areas suitable for cultivation, the group of technical uses which claims but 30.3% of the total area of this zone is clearly dominated by building-site areas (42.5% is the result of investment activities connected mainly with the construction of housing estates). It stretches over areas situated 3.9–5.5 km off the city core. Population density reaches here 1151 persons/km^2.

V — The Suburban Zone is absolutely dominated by agricultural green areas (84.2%) most of which are forms of extensive cultivation (62.5% arable land). This zone, which stretches around the city over areas situated more than 5.5 km off the city core, constitutes together with the Fringe Zone an important supply base of food for the city.

The structure of land use in the different zones is given in detail in Tables 1 and 2.

By employing the method of taxonomic classification of linearly ordered sets and utilizing detailed research materials we can accurately delimit the zones of land use as well as to get a good knowledge of their internal structures of economic development. The results obtained by means of this method confirm both that it can be usefully employed in profile studies and that the features picked for the delimitation of the area into zones of land use have been chosen correctly.

This method of classification can be employed in the division of any multidimensional set displaying a linear order defined by time and distance. The method described here can in practice be used for sets of no more than 300 elements.

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THE GEOGRAPHY OF DEVELOPMENT

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The changes in the organization of the world's socio-economic space induced by processes of development on a global scale have compelled geographers to look for some new approaches that would enable them to deal adequately with the new problems. Such new approaches have recently been emerging within the scope of geographic research.

Socio-economic geography has long been studying problems of development. Development problems have belonged to the stock issues in the various special branches of geography, such as population geography, the geography of resources, agriculture, industry or of transports, though the extent of interest differed from case to case. The studies carried out within each of these special branches have brought a lot of interesting materials, both of analytical and generalizing value.

Recently, special studies have begun to appear of development problems on world-wide scale. This results from the 'globalization' of a number of economic, social and political processes. The rising universal validity of those processes has made specialists in various disciplines realize that it is not enough to approach development problems from the angle of industrial branches alone or in their local, regional or national boundaries only; nor is it justifiable to analyse them as reduced to economic aspects exclusively. "The growth of the world's economy as a technological-economic category as well as that of its constituent parts is governed by definite rules common to all, regardless of the social order in any individual case."[1] For this reason, the world's economy has begun to be viewed as an independent research category.[2]

The above position shared by the economic scientists with regard to the problem in question, which we present in necessary shorthand, must not be disregarded in geographic research, including studies on the organization of the world-wide socio-economic space and its development. The world-wide economy viewed as an entity together with the processes taking place in it

[1] J. Kleer, *Gospodarka światowa i prawidłowości rozwoju* (World economy and regularities of development). Warszawa, PWE, 1975, p. 8.

[2] "The specific nature of world economy as the subject-matter of economic analysis consists in that strictly economic phenomena in that system do not constitute some relatively autonomous fragment of reality but are only one aspect of a complex, diversified and ordered consistent whole, a fragment that cannot be explained unless on the ground of the whole, that is, on the basis of the mutually crossing overlapping and interacting relations of economic, political, social, natural, cultural and demographic factors." Cf. B. Kamiński, M. Okólski, *System gospodarki światowej. Problemy rozwoju* (The system of world economy. Problems of development). Warszawa, PWN, 1978, p. 6.

find their manifestation precisely in the organization of space. It is certainly true that "... any economic activity, just as any economic space, is necessarily bound up with geonomic space (that is, the geographic and geodetic spaces), even though it may be phrased in the most abstract terms, for each economic activity involves some material activity — production, exchange or consumption — which takes place within a definite material context, a context that is basically confined to the Earth's surface, and thus to the geographic environment." [3] To put it differently, "... all economic activities have their place in geographic space" and hence "changes in the functional space ... may be projected, and indeed manifest themselves, in geographic space." [4]

In the light of these facts it is clear that the processes of world-wide development are bound to affect the shape of the global space, that they mould it and affect its evolution. It is this scope of problems that should become the primary object of research within the discipline that we call 'the geography of development'. However, it is certainly a hard task to define exactly the research problems this discipline of geography should explore. Any listing of such problems, whatever it may include, is bound to be subjective and arbitrary in character. We could, for instance, name problem groups such as, say, energy, raw materials, food, population, environmental protection, industrialization, yet each of these is the subject-matter of separate studies, including geographic studies, already. Often they continue, in a sense, the branch-oriented studies that have been carried out so far. Viewed from the angle of their 'global scale', they doubtlessly belong to the scope of interest of the geography of development. Nonetheless it seems justifiable to demand that the effect of the co-occurrence (as well as the 'confrontation') of the basic socio-economic systems and the many forms of interdependence and interaction between them on the global organization of space should be seen as a primary research task for this discipline. The prospective studies should deal with the basic groupings — the system of socialist countries, the advanced capitalist countries, and the Third World countries — and with the role each of them plays in the organization of space. Another important problem is the significance of multinational and supranational economic associations, such as the CMEA, the EEC, the OECD and others, or of the big international corporations.[5] The role each of these groupings plays today in international specialization, and thus in the organization of the global space, is now significant. The study of existing and emerging functional links within each such grouping and between them must take account of the fact that in reality we have to do with the co-occurrence and overlapping of a number of different patterns of spatial organization of different scale and varying scope of influence.

Studies of problems of Third World countries were the first to envisage this type of comprehensive approach in socio-economic geography. I do not mean here the many branch-oriented or regional studies. What I wish to indicate are studies concerning the consequences of underdevelopment to the organization of socio-economic space in that group of countries, including tentative treatments of the problem of underdevelopment as a geographic phen-

[3] K. Dziewoński, Teoria regionu ekonomicznego (The theory of economic region), *Przegląd Geograficzny*, vol. XXXIX, No. 1, 1967, p. 37.

[4] T. Hermansen, *Development poles and related theories — a synoptical review*. Conference on Growth Poles — Hypotheses and Policies, UNRISD/71 c. 76 August 1971, Geneva 71-18208.

[5] One example of geographic studies in the problem of multinationals is the paper by J. Rees, On the spatial spread and oligopolistic behaviour of large rubber companies. *Geoforum*, vol. 9, 4/5, 1978, pp. 319–330.

omenon.[6] Fewer attempts have also been made at studying the problem of the causes of underdevelopment; these latter, however, helped to extend the scope of geographic research by the factors that determine as well as differentiate with time the global space, thus integrating functionally areas that are often distant from one another.[7]

Those studies that deal with problems of underdevelopment in the wide sense, with their causes and effects, enabled researchers to realize one important fact. It has become clear that underdevelopment is essentially a process, that it evolves in time and space, and that it is a major aspect of the development of the world today.[8] Those studies further helped to expose the specific nature of spatial organization and to identify the characteristic features of spatial evolution typical of the Third World countries.

Such studies have dealt with the evolution of agrarian areas, urbanization processes, industrialization and others. They furnished the basis for subsequent investigations concerning the global disproportions in development or polarization processes; one result of these was the concept of central vs. peripheral space [9] which is, in a sense, a derivative of theories of unbalanced development and dual development. These in turn served as the foundation for time-space analyses of development processes while yielding additionally interesting comparative data for studies on the diffusion of development processes.[10]

The studies of underdevelopment in a broad sense have also shown that, as mentioned before, this is one of the principal aspects of the development of today's world. It is emphasized that the problem of underdevelopment, as occurring in a majority of countries today, must not be considered in isolation. Hence the understandable effort on the part of the students of the problem to place it within a context wider than merely that delimited by the 'boundaries' of the Third World and to view the problems specific to the developing countries as world-wide problems. This is exactly what UN Secretary General Kurt Waldheim had in mind when he said that "there is no real difference between the problems of the Third World and ours, they are essentially one and the same issue." [11] This opinion has been increasingly paving its way to scientific publications, and it is less and less frequently confined to purely economic problems such as production or trade alone. It has been gaining a much wider dimension, one which embraces ethical and humanistic aspects. This idea of the problems of world development being essentially one is perhaps best phrased by M. P. Torado, who has pointed out that "in the latter part of the twentieth century and in the twenty-first, there can no longer be 'two futures' — one for rich and the other for the very many poor. In the words of

[6] The first attempt by a geographer in this domain was the study by Y. Lacoste, *La géographie du sous-développement*. Paris, PUF, 1965. The third extended edition of this book appeared in 1975.

[7] One example of this type of studies is the article by M. Santos, Dimension temporelle et systèmes spatiaux dans les pays du Tiers Monde, *Rev. Tiers-Monde*, 50, 1972, pp. 247–268.

[8] In this sense the "géographie du sous-développement" becomes part of the "geography of development".

[9] J. Friedman is the principal name in this line of study. Cf. his work *The general theory of polarized development*, Ford Foundation, Urban and Regional Development Advisory Program in Chile, Santo Domingo 504, Op. 81, Santiago, August 1967.

[10] These problems have been discussed at length in the studies by J. Hinderink, La géographie, le sous-développement et la modernisation, *Rev. Tiers-Monde*, 62, 1975, pp. 267–293, and H. C. Brookfield, *On the geography of the Third World*, Inst. Brit. Geogr., Transaction 58, 1973, pp. 1–20. These studies contain important bibliographies of the problem.

[11] Interview in the Polish daily *Życie Warszawy*, 24 of 9–10 Sept., 1978.

a poet 'there will be only one future, or none at all'".[12] This view implies of course the conclusions from studies carried out by the Club of Rome as well as the tenets of the discussion on a 'new international economic order', no matter what the actual effects of such studies or discussions may in fact be.

The research objectives of the geography of development may now help to disclose new regularities that are of significance to the organization of the global space. But not merely this. It may also provide a more adequate understanding of the factors that currently determine spatial organization in territorially small units, it may enable geographers to disclose the changes in that organization that are under way together with the emerging mutual links on local, regional as well as global scale.

The radically altered position in the world's economy of the oil-producing countries is a near-classical example of this. It took place within less than ten years. If we disregard the occasionally significant differences between them, all the oil-producing countries in the Third World were toward the end of the 1960's and in the early 1970's marked by essentially external functional links. They were all enclave-type dependent territories in the full sense of this term.[13] The year 1973 marked a turning-point for them. The oil countries then began having a considerable influence on the character, rate and even the general directions of evolution in the advanced countries. This is true both of the changes called forth by the altered terms of trade for oil imports (by both advanced and underdeveloped countries) and of the exports of goods to the oil-producing countries. While they had formerly been 'objects' in the world's economy, they now became important 'subjects' in it that superseded the previous system of dependence by one of interdependence.[14] Though this example applies above all to the afore-mentioned problems of raw materials, it is equally true of the evident changes in spatial organization both on local and regional as well as global scale.

The advance of industrialization in some Third World countries is perhaps another illustration of the current important changes that are conducive to alterations in the relative importance of some areas. One result of that industrialization is the rising competitiveness of definite industrial goods (for instance textiles) from the developing countries, which in turn necessitates often significant changes in the industrial structure of the advanced countries. Consequently, we are witnessing a gradual degradation of certain areas or centres in the advanced countries that used to house the industries now jeopardized by the competition from Third World producers. These processes should be expected to be gaining in force with time, and the net result may be a significant alteration of international specialization.

Do the above examples vindicate the contention that the advanced countries are now entering a phase of interdependent development in their relations with Third World countries, a type of development that is regarded as a necessity by Waldheim and Torado? A definitely affirmative answer to this question seems still to be too rash a reply. We must realize that the links of dependence, which are responsible for disproportions in development in space, still continue

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[12] M. P. Torado, *Economic development in the Third World*, Longmans, London-New York, 1977, p. 17.

[13] The organization of space in the Third World is discussed by M. Rosciszewski, Organization and typology of socio-economic space in Third World countries, *Norsk Geogr. Tidsskr.*, 28, 1974, pp. 41–52.

[14] M. Rościszewski, The role of areas with predominance of external functional links in development of the Third World, in: *Development Countries: Problems of the Spatial Structure of Economy.* Moscow, 1978, pp. 152–162.

to be strong. They are the heritage of the entire historical process up to now as well as the product of the current structure of world-wide economy. The forms of dependence obviously undergo changes. Some of them are on the decline, while others begin to emerge; these latter are qualitatively new and they result from the actual socio-economic developments and from the economic or political power of individual countries or groups of countries. At any rate, those processes do generate (sometimes even considerable) alterations in the existing pattern of international specialization, which in turn manifests itself in the world-wide organization of socio-economic space.

Geography must see one of its tasks in monitoring such changes and including them into its scope of research. The processes of globalization of economic relations constitute a new quality whose effect on the organization of space must be taken into account.[15] On the other hand, we must bear in mind the fact that the present development has failed to reduce economic imbalances on a world scale.[16] The scale of these problems is such that entirely new methodological approaches are indispensable, if not even essential reformulations of the existing view.[17] The field of research will have to be extended to embrace noneconomic interdependences in addition to economic ones.[18] Apart from the purely theoretical aims, geography may serve practical purposes by taking up development problems and their consequences for the organization of space. This applies primarily to studies on regional development and space economy. In the case of these studies, when global assessments are supplemented with a knowledge of processes and possibly with the possibility to forecast the directions of their evolution, we may perhaps be able to wage a policy of regional development on national scale to some extent. Another important problem on the social and culture-generating level is the promotion of the knowledge of the spatial aspects of global development for educational purposes.

The discussion on the range of problems to be studied within the geography of development has now become a major task of geographic sciences. The geography of development may contribute a lot to the integration of geographic sciences.

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[15] This type of attempts have been frequent in recent geographic literature, including tentative definitions of the geography of world economy: "The geography of world economy is a section of economic geography studying development and the distribution in space of world economy as a whole as well as its constituent parts from the angle of socio-economic formations, individual countries and big regions. It also studies the regularities in definite trends of development and in the distribution of world economy taking account of the coexistence of two basically different social systems — the socialist and the capitalist systems." Cf. M. S. Rosin, V. V. Pokshishevskiy, M. B. Volf, L. Y. Vasilevskiy, *Sovremennaya geografia mirnogo khoziaystva.* Moskva, 1977, p. 15.

[16] C. Mendes (ed.), *Le mythe du développement.* Seuil, Paris, 1977.

[17] H. Isnard, *L'espace géographique.* PUF, Paris, 1978.

[18] The call for a "geography of non-economic interdependences" has been made by Y. G. Saushkin, V. S. Preobrazhenskiy, Differentsiatsia i integratsia geograficheskikh nauk v perspektive, *Voprosy Geografii*, 100, 1976, pp. 16–27.

INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION OF THE POLISH ACADEMY OF SCIENCES: THE LIST AND DESCRIPTION OF RESEARCH UNITS

1. DEPARTMENT OF GEOMORPHOLOGY AND HYDROLOGY OF MOUNTAINS AND UPLAND AREAS (CRACOW)

Study of the evolution of landforms under the impact of the changing climate and human activities with particular reference to Carpathian Mts. and uplands. Methods of geomorphological and hydrographical mapping. Methods of study of hydrological cycle and present-day geomorphological processes as well as their interrelations with the changing environmental conditions. Methods applied to the study of the evolution of abiotic components of the environment, as well as of the paleogeographical reconstruction of the Pleistocene and Holocene.

Evaluation of environmental components for land use and regional planning. Physico-geographical studies in Mongolia (in co-operation with the Mongolian Academy of Sciences).

The Department maintains three field stations: research station at Szymbark, and data-collection stations in the Tatra Mts. (Hala Gąsienicowa) and at Homrzyska near Nowy Sącz.

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Studies on the heat balance of the interface earth—atmosphere on a local and regional scale. The structure of heat balance and its differentiation over the territory of Poland and its neighbouring countries. Methods of topoclimatic mapping. Bioclimatic studies of areas heavily transformed by human activity, in particular the industrial and recreational areas.

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Studies on the spatial structure of individual economic sectors, in particular the industry and transportation.

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