SYSTEMS RESEARCH INSTITUTE
POLISH ACADEMY OF SCIENCES

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS

CONTRACTED STUDY AGREEMENT REG / POL / 1

# "CONCEPTS AND TOOLS FOR STRATEGIC REGIONAL SOCIO-ECONOMIC CHANGE POLICY"

## STUDY REPORT

## PART 2

# POLISH CASE STUDY REPORT

COORDINATOR, IIASA: A. KOCHETKOV
COORDINATOR, SRI PAS: A.STRASZAK

ZTS/ZPZC/ZTSW 1-36/85

WARSAW 1986

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Consisting of 3 Parts

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# III. AN LP STUDY OF CONDITIONS FOR TECHNOLOGICAL SHIFT IN THE REGIONAL AGRICULTURE

by J.W. Owsiński

## III.1 Introduction

As mentioned previously, this case study was not undertaken from scratch. It was based upon the body of experience and analysis, which had been built before 1985 and was thereafter reported, albeit only in a limited degree, in Owsiński and Hołubowicz (1985) and Owsiński (1985). An essential part of this experience was constituted by construction and development of the model meant to give indications as to feasible and preferable ways to be taken by the regional agriculture in view of the environmental and socio-economic changes brought about in this area by introduction of the large scale development in question. The model was a static one, but it could equally well yield results for the "start of the cycle" situation, i.e. in terms of the forecasting session described in Chapter V Part 2, over the period extending from NOW till BEGINNING, as for the "end of the cycle" (TERMINATION) conditions, see Fig. V.1.1, provided reasonable hypotheses concerning quantitative description of these situations could be forwarded. Such hypotheses would concern technical and economic parameters entering the model, as well as resources available, for the given time moment analysed.

One of the major motivations for this particular study was consciousness, gained through previous experience, that the hypotheses mentioned in fact already existed, although in very vague formulations, within the institutional setting related to the development and local authorities. The hypotheses did not only concern conditions for, but also outcomes of the future course of events, and they could be relatively easily attached to particular actor types within the institutional setting (see Chapter V). They can be worded as follows:

Hypothesis No. 1 : Through diversion of surplus labour force from agriculture and expansion of market (higher incomes and bigger urban population) development shall induce (force) agricultureal technological shift.

Hypothesis No. 2 : The above can occur only provided additional investment capital is made available for agriculture over the coming period of time.

Hypothesis No. 3 : In order for the proposition of Hypothesis 1 to come true not only additional capital would be necessary, but also the diversion of labour would have to be accompanied by an important reallocation (or flow) of labour force among the farm types.

In accordance with the analysis presented in Owsiński (1985) the preconditions evoked in Hypotheses 2 and 3 (H.2 and H.3) were, in the eyes of the present authors to necessarily occur in the build-up stage, i.e. between NOW and BEGINNING of the period considered. (H.3 was, in fact, generated as the result of the modelling study, and as such communicated to some of the actors in the institutional setting). Results here presented will, in a varying degree, refer to H.1 ÷ 3, primarily to conditions of H.2 and H.3, seen as well-defined and tangible, and of necessity preceding those of H.1.

In this short chapter results will be presented obtained from a modest study performed with the model mentioned, concerning the conditions and reach of technological change in agriculture in the first period of the new industrial development. Technological change in agriculture is regarded as necessary, see the results of the cross-impact forecatsing session from Chapter V, Part 2, in view of the new developments, but will certainly not occur automatically. That is why conditions for such an important technological shift in region´s agriculture had to be investigated, along with the possible depths and reaches of this shift.

First, the general outline of the model and the way it functions will be presented, followed by these features which relate to technology, then runs of the model meant to highlight the problems envisaged will be commented along with their results. Finally, a nubmer of summarizing conclusions will be offered.

III.2 Regional agricultural policy model

Whether this region will remain in the future agricultural or not, the problem structure, as seen now, is centered around energy and agriculture, for both the development cycle and afterwards.
In creation of agricultural policies related to the development in question the voivodship authorities may activate their proper policy (e.g. zoning, infrastructural instruments, certain supplies), highly augmented by the mining and energy compensation. Because of the complexity of situation the regional agricultural authorities have contracted a modelling study oriented at production structures and policies related to regional agriculture.

It should be mentioned that, in view of the magnitudes of envisaged changes a number of other studies were also undertaken. These studies concerned geological and hydrological systems, soil changes, crop yield sensitivities, farm economies etc.
In particular, certain studies related to crop yield and farm organization and economy were undertaken and are continued within the Field Research Station of the Environmental Engineering Institute, located in Piotrków. Owing to these studies the data set necessary for the agricultural model construction was in fact ready prior to model development.

The regional agricultural policy and production structure model is meant for analysis of medium-term development alternatives, for choice of best structures and for evaluation of conditions of agricultural operations and their changes, including those related to technology. The time horizon of the model results from its linear form. In fact, it is an LP construct, relatively detailed, allowing quite precise balancing of resources and products. Thus, the model can presently help in policy setting for the initial stage of the cycle, taking into account such effects of mining development as labour force from agriculture, water deficit, land availability decrease and crop yield decrease, and their consequences (Fig.I.3.) . Hence, the model can represent most of the processes related to the development/ agriculture interface. Furthermore, if the model is run for the end-of-cycle scenario, it can also be used for the long-term policy analysis. In order, however, to obtain an internally consistent end-of-cycle scenario, another, dynamic model would have to be developed and run.

On the other hand, having in mind temporal scales shown in Owsiński (1985) one can easily see that even medium-term policies undertaken now shall be of strategic importance for the regional development over the whole cycle and beyond.

Model structure and functioning

The model called further on SEMORA B, resulting from a series of previous works on the subject, see Albegov et al. (1982), Owsiński (1982), Straszak et al. (1982), Owsiński and Zadrożny (1985), is constructed as a two-level LP problem. The lower level, composed of 7 submodels, represents individual subregions of the area. Subregions are delineated according to administrative breakdown, contiguity and location with respect to the mine i.e. volume of change imposed on a given territory (see Fig. III.2.1 for the scheme of breakdown). Each submodel describes in quite a detailed way agricultural economy of a subregion. The submodels contain approx. 1700 variables and approx. 500 constraints each. The main groups of variables describe:

1. Areas under crops grown,
2. Numbers of livestock kept,
3. Sales of crop products,
4. Own consumption of own crop products,
5. Own crop products for livestock feeding,
6. Sales of livestock,
7. Sales of livestock products,
8. Own consumption of own livestock products,
9. Livestock slaughter,
10. Purchase of crop products for human consumption,
11. Purchase of crop products for livestock feeding,
12. Purchase of livestock products.

These variables are subject to the following groups of constraining balances:

1. Land: general, crop rotation and secondary crop,
2. Crop product balances,
3. Herd balances,

4. Livestock product balances,
5. Feed balances,
6. Labour force balances,
7. Pulling power balances,
8. Fertilizer balances,
9. Water balances (annual and peak period),
10. Sales and purchase balances,
11. Capital investment limits,
12. Minimum income requirements.

Two objective functions were maximized, alternately:

1. Total agricultural net income from subregional agriculture;

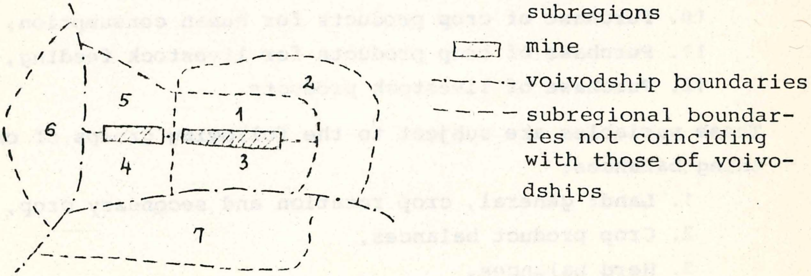
2. Total agricultural subregional production value.

Three other criteria (agricultural trade balance of the region, protein trade balance, diet content trade balance) were treated as reference indices.

The variables and constraints were classified according to the following aspects (numbers in brackets indicate the numbers of categories considered for each aspect):

a. crop types (16 various crops considered),
b. soil quality types (4 + permanent grassland),
c. crop technologies (3),
d. farm types (5),
e. animals (7),
f. husbandry technologies (2),
g. fertilizer contents (4),
h. sales and purchase markets (3).

Fig. III.2.1. Outline of the breakdown into subregions



With thus detailed specification the submodels are quite accurate, but, simultaneously, rather large. They communicate with the upper level, i.e. the master model, representing a regional policy centre, vis a coordination procedure, Owsiński and Zadrożny (1985), see Fig. III.2.2.

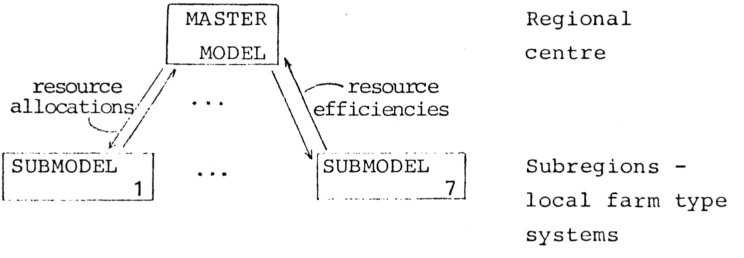



Fig.III.2.2 Scheme of cooperation of the master model and the submodels

The master model is much smaller than the submodels. Its dimensions, however, are not uniquel defined, since they are established through the working of the coordination procedure. The master model operates on the - linearized - resource efficiency functions of the submodels, thereby determining optimal resource allocations to subregions (farm type subsystems within subregions). Because of the model dimensions the coordination procedure is not iterative, i.e. the above information exchange between levels is not repeated. It occurs jut once and an approximate solution is obtained.

The master model contains descriptions of the subregional resource efficiency functions and certain constraints on regionally balanced resources, such as: infrastructural and productive investments, credits for credit schemes, and water. It is with respect to these resources that coordination is primarily performed.

Model application

SEMORA B is meant to provide infromation for policy analysis and construction. Directly, solutions of SEMORA B on the subregional level specify optimal production structures and product destinations. On the master model level values of "policy variables", i.e. certain resource allocations, are determined. Thus, it is possible to construct functions relating incomes and production levels to production and exchange structures and these to "policy variables". Evaluation of policies should also account for other aspects, especially related to these resources, which are affected by the development. Thus, besides coordination, some post-optimal analyses are of necesity performed.

The above results and analyses obtained with SEMORA B can serve for elaboration of both internal and external policies. Internal policies are those which lie entirely within the scope of control of the regional authority (notwitstanding their possibly varying efficiency). There are, however, also external policies, oriented at persuading other actors as to certain items of common interest. As mentioned, the main local partner considered is mining. Another important partner is the central planning body and central budget (finance ministry and planning commission). With respect to these two partners the local authority may, with the help of SEMORA B, determine potential losses or gains to regional agriculture, (see Fig. III.2.2), resulting from implementation of their respective policies. Thereby optimal directions of inducing both partners can be defined.

## III.3 Some remarks on model results

For the sake of shortness and clarity only main features of solutions and policy indications and chosen directions of analysis are presented here.

One of the main objectives of analysis, in view of the changes envisaged, was establishment of adequate agricultural income conditions. Their level is decisive for the further fate of local agriculture. Several scenarios were tested, differing by assumptions as to potential water deficit, crop decrease etc. It must be emphasized that simple maintenance of the present income levels is not sufficient to effectively limit labour force diversion from agriculture to mining, since wages in new industries are, on the average, 2-3 times higher than agricultural incomes. Thus, it was shown with

SEMORA B that some farm types may attain income levels comparable with those of industrial employment, while others cannot. Attainment of lower income levels does not imply, of course, that labour diversion shall occur automatically. The greater the difference, however, the more important this diversion. On the other hand, attainment of comparable incomes by some farm types is conditioned by adequate increase of capital investments in these farms, i.e. appropriate credits. For an overview of some results with this respect see Table III.3.1.

| DESCRIPTION OF SCENARIOS: | | CAPITAL INVESTMENTS IN FARMS | | |
|---|---|---|---|---|
| | | Present level, 100% | 150% | 200% |
| WATER DEFICIT AND CROP DECREASE | NONE | 2 | 2 | 4 |
| | A. | 1 | 2 | 4 |
| | B. | 0 | 1 | 2 |
| | C. | 0 | 0 | 1 |
| | D. | 0 | 0 | 0 |

Table III.3.1 Numbers of farm types, out of the total of 5, in which incomes comparable to those in industry jobs can be obtained under optimum conditions.

A: water cost increase with no deficit and crop decrease,

B: cost increase and water supply out by 30%,

C: as A, with 10% crop decrease, esp. in permanent grasslands,

D: as B, with 10% crop decrease, esp. in permanent grasslands.

The counterpart of the income situation is the labour force situation. Analysis of this aspect of the regional agricultural system is insofar important as the labour force diversion, already mentioned, is positively evaluated by some agricultural economists (H.1).

The reasoning behind: agricultural employments are inefficient and unprofitable and there is too much labour force in agriculture. These opinions are formulated on the basis of a global assessment od labour force number, its theoretical productivity and actual prices and levels of produce. The SEMORA B model applied the same parameters as those used in global assessments. Since, however, the model solutions represent optimal rather than average conditions, it could be justly suspected that the "idle manpower" would come out in these solutions even greater than in the global economic assessment. This would provide arguments for the mining side, which claims that labour diversion helps in rationalization of agricultural production. Actual results are schematically outlined in Fig. III.3.1.

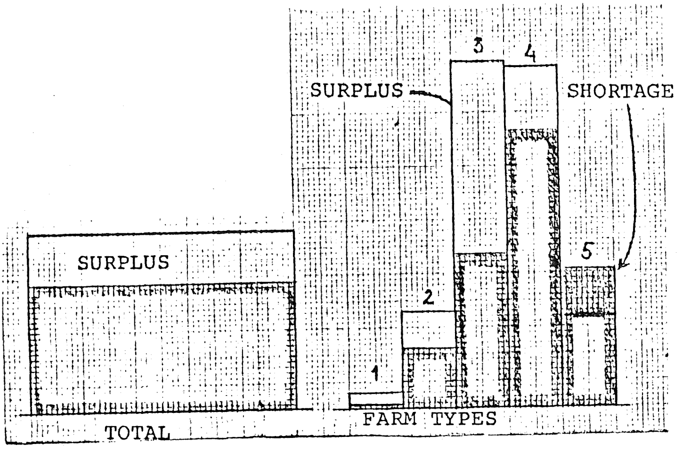



Fig. III.3.1 Comparison of actual manpower to manpower requirements in the regional agriculture, according to a SEMORA B result, Table III.6.4.
Farm types: 1: state farms,
2: cooperative farms,
3: private farms < 5 hectares,
4: private farms 5 to 10 hectares,
5: private farms > 10 hectares.

The diagram shows that virtually the whole labour margin comes out of one farm type, i.e. small private farms, in which already an important share of population are partly or wholly employed outside agriculture, while the most promising farm type (No. 5 in the diagram) is already suffering from the important lack of manpower. Furthermore,as was indicated, quite a share of manpower originating from and still related to the farm type 3 are so called double-professionals, i.e. are also employed outside agriculture, which is caused by income shortages in small, underinvested farms. Thus, the margin indicated here may in reality be even lesser.

Hence, while it seems almost sure that certain diversion will occur over the years to come, this diversion would certainly have a negative effect on local agriculture, unless appropriate policies are undertaken.

## III.4 Technological aspects

The above general considerations are obviously closely related to technological aspects of changes in regional agriculture, especially if such changes are connected with important shifts in labour and land productivity, unit costs, unit profits etc. In fact, technological changes intervene in the results outlined here, i.e. optimal solutions whose implications were reported, indicate a degree of technological shift with regard to the present state of affairs in the regional agriculture. In assessing the role played by technological changes in future development of this area one must, though, analyse also in more detail conditions for technological change, with special emphasis on these conditioning factors which, on the one hand, are policy--controllable and on the other hand are simultaneously sensitive to such controls. This kind of analysis could lead to determination of synergistic policy actions, aimed at broader and longer-term policy effects, ultimately also of strategic importance. Thus, for instance, price controls were excluded from the considerations related to model development and use from the very start, not only because they are regionally not manipulable (being either centrally established or quite freely formed), but also because they are of quite short-run significance, since other pressures may force their changes towards quite unexpected and not, from this point of view, advised, structures. (Price structure was, of course taken into consideration in the sensitivity analysis of optimal solutions).

As previously mentioned, in SEMORA E three kinds of crop raising technologies, indexed s, s=1,2,3, are distinguished, and two kinds of livestock breeding technologies, indexed s´, s´= 1,2. Thus, all variables representing areas under various crops are classified, in addition to other aspects such as crop type, land quality and farm type, according to technologies s . Similarly for variables representing numbers of animals bred.

The various technologies indexed s and s´ can be shortly characterized as follows:

Crop raising technologies:

s=1: "traditional" technology, i.e. the one with which the present levels of crop yields are attained; it assumes statistically given levels of use of chemicals (fertilizers, pesticides,...), labour force, pulling power, fixed assets, current costs etc.,

s=2: "intensive" technology, i.e. the one in which such factors as energy (chemicals, pulling power, other equipment) and fixed assets are used in a more intensive way, incurring also higher costs, and which, simultaneously, requires less manpower and gives higher yields;

s=3: "irrigated" technology, which shares most of its numerical characteristics with s=2, except for introduction of irrigation of a given intensity and minor changes in other coefficients so as to account for the differences in operations related to irrigation.

Livestock breeding technologies:

s´= 1: "traditional" technology, i.e. the one with which livestock breeding activities are conducted nowadays, with statistically given yields;

s´= 2: "new" technology, i.e. the one which is more intensive than the traditional, with more intensive resource use and higher yields.

It should be noted that parameters characterizing these technologies are not the same across other classifications, e.g. crop technology s=1 has various parameters for various farm types, in accordance with their present performance. For s=2 and s=3 there is more homogeneization of the parameter values across farm types, but identity could not be assumed. Especially big differences occur for $s' = 1$, where some farm types almost entirely conduct livestock breeding on a subsistence level (less than 5, most often 1-3 dairy cows and some calfs thereof, as well as less than 5 bulls fed for meat as far as cattle is concerned, and/or altogether not more than 10 pigs, often a horse as pulling power), while other farm types have since several decades turned towards larger-scale livestock operations (e.g. 2000 dairy cows on one state farm).

On the other hand such discrete treatment of technologies, instead of a possibility of applying continuous, say-linear, functions of resource use and product yield, is justified not only by the modelling and computational facility, but also by the existing agricultural planning practice, in which it is assumed that various resource uses and resulting yields are correlated in a certain "optimum" manner. This "optimum" is defined by the existing economic and natural conditions and farms for which such an "optimum" or "optima" are defined, shall in deed try to approach one of the potential "optimum" levels. Thus, for instance, when tractor is bought by a private farmer who owned a horse before, new machines have to go with, and with these machines more intensive operations become profitable.

In the optimal solutions provided by the model, either as a whole or for its lower level submodels, choice is made as to the technologies with which activities entering such solutions are performed. Choice of technologies is conditioned by differences of parameters related to various technologies, by availability of resources and by objective function efficiencies of these technologies. Thus, by varying parameters and right hand side values (e.g. resource volumes) one can obtain sets of solutions differing by the shares of various technologies along with differences in other choices, e.g. of crops, land qualities, animal types.

## III.5 Analysis of conditioning of technological shifts

Shares of various technologies in optimal solutions obtained for the region or for its subregions change with most of the coefficients appearing in the SEMORA B model. Not all of these coefficients are interesting from the policy formation point of view. Having analysed sensitivities of a number of optimal solutions, see Owsiński and Romanowicz (1985) for methodology, it was established that technological aspects of variables entering optimal solutions are primarily related to economical parameters in general, to availability of in-farm investment capital and to labour force. An example of influences exerted by various conditions on individual aspects of a variable appearing in an optimal solution is illustrated in Fig. III.5.1. Such an illustration cannot

| BASIC VARIABLE: | CHANGE OF CONDITIONS | CORRESPONDING CHANGE OF VARIABLE: |
|---|---|---|
| Area under forage crops in farm type 3, land quality 3, s=2 (intensive technology) | 1. Additional land area | 1. Increase activity (up to a certain level) |
| | 2. Decrease of land area | 2. Partial shift to other crops |
| | 3. Additional water | 3. No change |
| | 4. Additional capital | 4. Increase activity (up to a certain level) |
| | 5. Less capital | 5. Shift to technology s=1 (traditional), and to some other crops |

Fig.III.5.1 Some changes related to a variable appearing in an optimal solution.

provide the full idea of interactions among the variables through the intermediary of coefficients. This system of interactions is revelated via the sensitivity analysis.

Thus, with regard to technology, economic parameters, investment capital and labour force would have to be looked at. In accordance, however, with previous remarks, it was deemed proper for the purpose of strategic policy analysis to look at the more long-term acting and stable factor which can influence the technological changes more deeply, excluding e.g. short-term price movements. Hence, primary emphasis in the analysis was ultimately put on availability of investment capital and on relations with labour force situation, which seems crucial for the system at hand.

First, a base-line solution shall be commented upon, and then results of appropriate parametrizations, together with conclusions therefrom. Analysis shall be performed on two of the seven subregions forming the overall region. As it turns out, results were in their general shape similar for all of the subregions, and therefore also for the region as a whole. In fact, they may be characteristic for Polish agriculture throughout larger regions of similar nature.

## III.6 Results

Out of the two objective functions primarily used by SEMORA B, i.e. net agricultural income and gross product (in fact: net of imports), the first one was taken as leading in the analysis, the second one not being indicative for the proper dynamics of the system, especially with regard to technological advancement, since this objective function reflects rather the wishes of upper decision centres and not the "summary" objective of actual economic agents. Thus, it may only be used as a background - showing the feasible extent of technological change, against which the efficient solutions are presented.

### III.6.1 Baseline solutions

This short section is devoted to a description of two basic solutions, attained for one of the subregions, subregion no. 2, and for two main objective functions mentioned, i.e. total net agricultural income (denoted DRR) and gross product, net of import (GPR). Some basic features of these two solutions are shown in Tables III.6.1 and III.6.2, presenting, respectively, general summary characteristics of the two solutions, and some more detailed ones, primarily specialization directions and intensities. Technological features are not shown in detail, since they will be presented against a broader spectrum of results further on.

Some of the differences between the two solutions are intuitively obvious, e.g. greater employment propensity in the case of GRP. Some other, however, have to be explained. Generally, DRR pushes harder towards cereals, while GPR towards cattle and poultry raising. This, together with the cost of labour explains why DRR prefers the advanced technologies in more activities than GPR.

Note also that the solution obtained for GPR does not appear as more stable than that for DRR: the value of DRR, when maximized, is 7.33 times greater than that attained when GPR is maximized, while value of GPR when maximized is only 2.52 times greater than its level attained when DRR is maximized. Moreover, specializations determined for GPR, as compared with those for DRR, show altogether a bit more of diversity with regard to crops, but less with regard to livestock breeding. Thus, besides the questions of representation of reality, other considerations do also indicate DRR as the more proper objective function for the study.

With regard to the more intensive technologies, s=2 and s=3, and s´=2, they are relatively clearly "located" in the activities vs. farm types space for both the main

| Item | Farm types | | | | | Total |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Land use,% | 100 | 100 | 100 | 100 | 79.5 | 95.7 |
| Land duals, max/min,$10^3$zl$^1$/ha | 122.9/7.4 | 114.8/5.3 | 114.8/3.8 | 114.8/3.8 | 107.0/0 | |
| Labour force use/availability, fte | 74/125 | 468/730 | 1090/2580 | 2103/2520 | 685/685 | 4420/6640 |
| Labour force duals,$10^3$ zl per fte. month | 0 | 0 | 0 | 0 | 34.3 | |
| Shares of crops* raised/dominating technology: | | | | | | |
| cereals | 60**/1 | 60**/1 | 60**/1 | 60**/1 | 49/1 | 57.7/1 |
| potatoes | 30**/1 | 30**/1 | 30**/2 | 30**/2 | 30**/2 | 30/2 |
| forage | 10/1 | 10/1 | 10/1 | 10/1 | 0 | 7.9/1 |
| grassland | 0 | 0 | 0 | 0 | 0 | 0 |
| Numbers of livestock bred/ dominating technology: | | | | | | |
| cattle | 281/2 | 1781/2 | 1824/2 | 4045/2 | 2090/2 | 10 022/2 |
| pigs | 251/1 | 1586/1 | 1633/1 | 3546/1 | 1861/2 | 8 877/1 |
| sheep | 555/1 | 3511/1 | 3571/1 | 7912/1 | 4120/2 | 19 669/1 |
| poultry*** | 95/1 | 599/1 | 533/1 | 1189/1 | 706/2 | 3 122/1 |

Table III.6.1 Outline of baseline optimal solution for the DRR objective function. Value of DRR: $4.4.10^9$ zl, of GPR: $2.3.10^9$ zl.
fte: full time equivalent; *,**,***: see next page

Notes to Table III.6.1:

*: aggregate groups of crops

**: at upper limits

***: x 100

objective functions. For DRR it is potatoes and cattle and farm type p=5, while for GPR it is grasslands, pigs and also farm type p=5. Why this farm type so persistently recurs in technological advancement shall be commented upon further on, but can already be guessed when looking at the results regarding use and marginal cost of labour available. Namely, while generally there seems to be a certain margin of superfluous manpower, this certainly is

| Item | Farm types | | | | | Total |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Land use, % | 100 | 100 | 100 | 95 | 73 | 92.2 |
| Land duals, max/min, $10^3$ zl/ha | 72.9/16.5 | 100.3/49.2 | 38.5/21.7 | 32.0/0 | 22.1/0 | |
| Labour force use/availability, fte | 100/125 | 599/730 | 1465/2580 | 2529/2529 | 685/685 | 5378/6649 |
| Labour force duals, $10^3$ zl per fte. month | 0 | 0 | 0 | 28.4 | 31.7 | |
| Shares of crops* raised/dominating technologies: | | | | | | |
| cereals | 32.5/1 | 35/1 | 32.8/1 | 42.9/1 | 27.5/1 | 36.3/1 |
| potatoes | 30**/1 | 30**/2 | 30**/1 | 30**/2 | 23.6/1 | 28.7/1 |
| forage | 15**/1 | 12.3/1 | 15**/1 | 0 | 0 | 5/1 |
| grassland | 22.5/1 | 22.7/2 | 22.2/1 | 22.1/2 | 21.9/2 | 22.1/2 |
| Numbers of livestock bred/dominating technology: | | | | | | |
| cattle | 359/1 | 1965/1 | 3441/1 | 6490/1 | 2319/1 | 14 565/1 |
| pigs | 0 | 0 | 133/1 | 140/2 | 38/2 | 311/2 |
| sheep | 0 | 0 | 0 | 0 | 0 | 0 |
| poultry*** | 613/1 | 3416/1 | 5960/1 | 11 288/1 | 4063/2 | 25 340/1 |

Table III.6.2 Outline of baseline optimal solution for the GPR objective function. Value of GPR: 5.8 · $10^9$ zl; of DRR: 0.6 · $10^9$ zl. *,**,***: explanations as to Table III.6.1.

not so for the farm type p=5, and perhaps also for p=4, see Fig. III.3.1. Moreover, the dual values of labour, per month, show indices at the level of present wages, i.e. this additional labour could effectively be hired (DRR: p=5, dual labour value $34.3 \cdot 10^3$ zl per employee per month; GPR: p=4, $28.4 \cdot 10^3$ zl per employee per month and $31.7 \cdot 10^3$ zl per employee per month, while average monthly wage is approximately $20 \cdot 10^3$ zl per month).

### III.6.2 Influence of capital availability

This aspect was analysed by performing a series of parametrical runs of the subregion 2 submodel. The runs consisted in changing of available capital volumes over a certain range for all the farm types, and they differed by assumptions as to some other resources and their availability.

The results of the fundamental parametrical run, in which all the other resource availabilities were kept at their initial level, i.e. as of 1982, that is, start of mining, and the capital availability was changed for all the farm types parallelly over the range of 50% to 250% of the initial values of capital available at and for all the farm types, are shown in Table III.6.3. Some particular features of these results are illustrated separately further on.

It is possible do derive some general conclusions, referring to the hypoteses formulated previously, directly from the Table III.6.3. Here they are:

* adoption share of intensive "new", crop raising technologies, increases with capital availability, reaching definite saturation (for given conditions) at various levels and for various capital availabilities farm types (see Fig. III.6.1);

* adoption share of intensive livestock breeding technologies increases with capital availability, reaches a maximum, and may even slightly decline beyond the maximum (for given other conditions), the decline occurring for the total and for the farm types 4 and 5, with farm type 2 displaying oscillations (see Figs. III.6.2 and III.6.3);

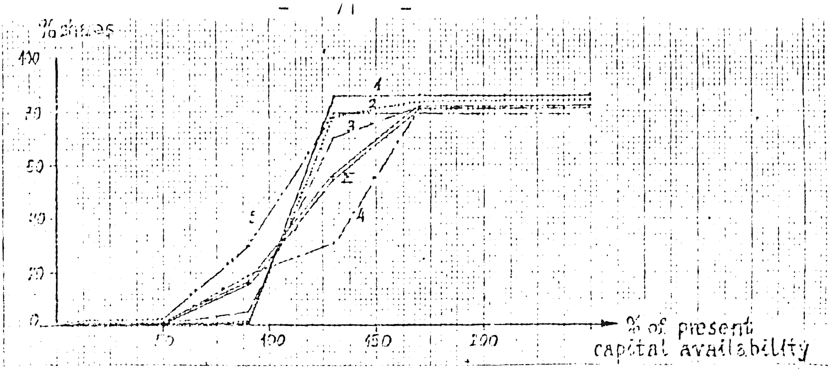



Fig . III.6.1 Shares of intensive crop technologies vs. capital availability, total and for individual farm types: ═══ total, ____ farm type 1, ····· farm type 2, ----- farm type 3, -·-·- farm type 4, -·.-·.·- farm type 5.

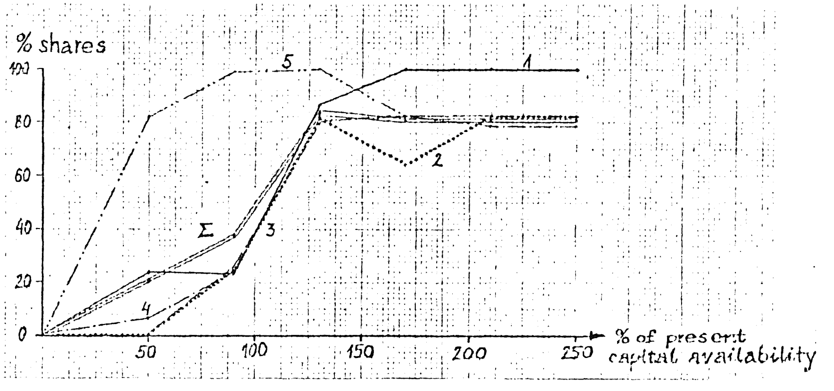



Fig. III.6.2 Shares of intensive livestock technologies vs. capital availability total and for individual farm types

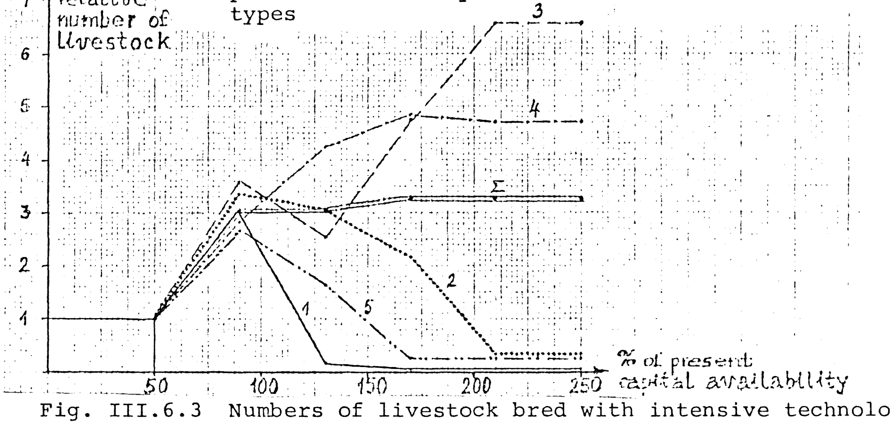



Fig. III.6.3 Numbers of livestock bred with intensive technologies, total and for individual farm types (poultry counted in hundreds), with numbers for 50% capital availability taken as 1.

Table III.6.3 Capital availability influence on new technology adoption

| Farm types, p= | Items* | Parametrization indicators, in % of present capital availability | | | | |
|---|---|---|---|---|---|---|
| | | 50% | 90% | 130% | 170% | 210% |
| 1 | a | 10.4/6.3 | 18.7/2.4 | 16.3/0 | 15.8/0 | 15.8/0 |
| | b | $90/\frac{106}{0}$ | $100/\frac{115}{5}$ | $100/\frac{157}{16}$ | $100/\frac{157}{16}$ | $100/\frac{157}{16}$ |
| | c | 39/0 | 57/0 | 32/0 | 31/0 | 31/0 |
| | d | 0 | 0 | 85.7 | 85.7 | 85.6 |
| | e | 24 | 23.3 | 86.0 | 100 | 100 |
| 2 | a | 11.2/10.0 | 20.2/3.4 | 29.2/0.6 | 29.5/0 | 15.6/0 |
| | b | $87.2/\frac{89}{0}$ | $100/\frac{111}{6}$ | $100/\frac{134}{16}$ | $100/\frac{138}{19}$ | $100/\frac{151}{19}$ |
| | c | 51/0 | 65/0 | 54/0 | 56/0 | 35/0 |
| | d | 0 | 1.2 | 77.3 | 83.0 | 84.1 |
| | e | 0 | 23.8 | 81.7 | 64 | 82 |
| 3 | a | 6.7/8.7 | 12.1/3.8 | 17.5/0.7 | 22.9/0.2 | 26.5/0 |
| | b | $82/\frac{87}{0}$ | $100/\frac{106}{1}$ | $100/\frac{128}{15}$ | $100/\frac{134}{17}$ | $100/\frac{137}{18}$ |
| | c | 38/0 | 47/0 | 37/0 | 42/0 | 47/0 |
| | d | 0 | 5.3 | 70.0 | 82.0 | 82.0 |
| | e | 0 | 24.1 | 81.1 | 82.1 | 82.1 |
| 4 | a | 7.2/8.7 | 13.0/3.8 | 18.8/0.7 | 24.5/0.2 | 24.9/0 |
| | b | $81.4/\frac{87}{0}$ | $100/\frac{106}{1}$ | $100/\frac{107}{15}$ | $100/\frac{134}{17}$ | $100/\frac{137}{18}$ |
| | c | 72/0 | 84/0 | 83/0 | 83/0 | 84/0 |
| | d | 0 | 18.4 | 31.0 | 81.4 | 81.4 |
| | e | 6.3 | 24.2 | 80.9 | 81.9 | 78.7 |
| 5 | a | 8.2/5.5 | 14.8/1.8 | 18.4/0 | 13.9/0 | 13.9/0 |
| | b | $79.5/\frac{69}{0}$ | $79.5/\frac{108}{0}$ | $100/\frac{107}{8}$ | $100/\frac{132}{13}$ | $100/\frac{136}{17}$ |
| | c | 100/38.5 | 100/30.5 | 100/13.0 | 100/2.99 | 100/0.2 |
| | d | 1.8 | 30.0 | 79.5 | 79.5 | 79.5 |
| | e | 82 | 98.8 | 100.0 | 82.1 | 82.1 |
| Totals | f | 13724/20.4 | 41491/37.8 | 41806/83.2 | 45354/80.1 | 45342/80.1 |
| | g | 0.4 | 16.6 | 55.2 | 81.3 | 81.4 |
| | h | 3.410 | 4.330 | 4.584 | 4.641 | 4.644 |

* a: capital use per hectare of the overall land within a given farm type ownership per year, in $10^3$ zlotys / dual values of capital available in zl/zl,

Notes continued on next page

Notes to Table III.6.3. continued:

b: % of owned land used by the given farm type / max (best soils) and min (worst soils) dual values of land used, in $10^3$ zl per year,

c: % use of the initial labour force (1982) / dual values of labour force available, in $10^3$ zl per fte (full time equivalent) per month,

d: share, in % of the land used under crops raised with advanced technologies, i.e. s=2 and 3,

e: share, in % of the total number of livestock bred by a given farm type, of livestock bred with advanced technology, i.e. s´= 2,

f: total number of animals bred / share of s´= 2 in the total,

g: share of advanced crop raising technologies in total of land used,

h: value of the objective function, in $10^9$ zl per year.

* with regard to objective function increments saturations occurred for levels of capital availability lower than for those corresponding to technological adoption shares (see Fig. III.6.4 and Fig. III.6.5).

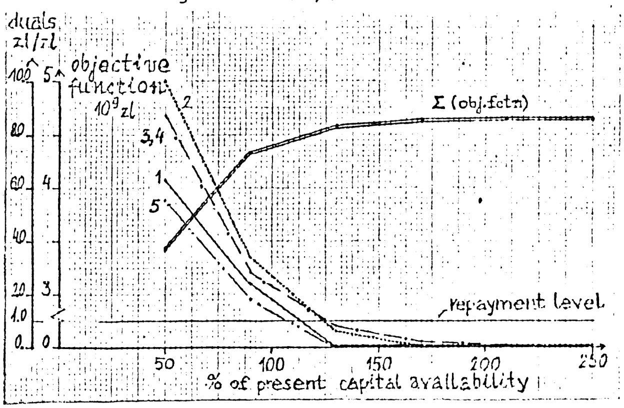



Fig. III.6.4 Total objective function value and dual values of capital availability for individual farm types vs. capital availability for all farm types.

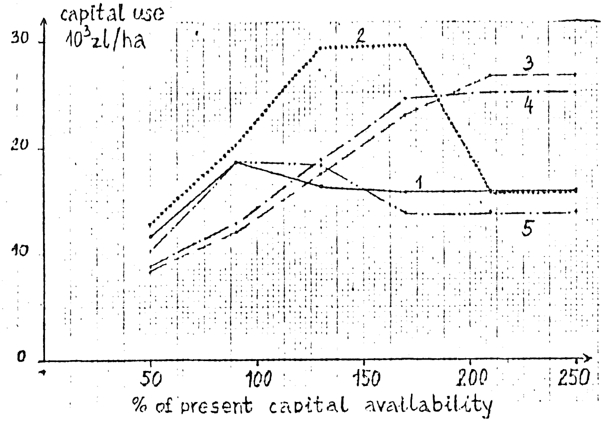



Fig. III.6.5 Actual capital use per hectare of the land used for individual farm types vs. capital availability for all farm types.

With regard to income generating role of capital two conclusions, besides the one already forwarded, are due in the light of Figs. III.6.4 and III.6.5. First, it is obvious that sectors 3 and 4 could use additional captial, beyond a certain limit, more efficiently, than the other ones. Secondly, as to farm type 5 picture is blurred by shortage of labour there. Thus, the optimum allocation of additional capital would depend upon the amount of capital actually available and the amount's of other resources. In initial conditions priority should go to farm types 2,3 and 4.

Note the displaced increase of share of intensive crop technologies and the displaced capital use saturation within the farm type 4, the most important one in the area, indicating clearly that the level of capital there is now far from satisfactory.
It can easily be seen from Fig. III.6.3 that increased capital availability switches importantly the inter-farm specialization: farm types 3 and 4 specialize strongly in livestock, while all the others retract to almost exclusive crop raising.

In spite of what could be anticipated, capital and labour do appear as substitutes only on one particular segment of the parametrization trajectory depicted here. This phenomenon is worth a bit more of analysis. Figure III.6.6 presents the capital / labour "substitution" rates calculated according to the following simple formula:

$$S_{M-1}(C/L) = \frac{CU\ (CA_M) - CU\ (CA_{M-1})}{LU\ (CA_{M-1}) - LU\ (CA_M)}$$

where M indicates the sequential number of the parametrization step, $S_{M-1}$ (C/L) is "substitution" rate for capital change, CU is capital used, CA is capital available, and LU is labour actually used. Values of $S_M$ (C/L) in Fig. III.6.6 are expressed in $10^3$ zl per fte. Of course, these values are positive when actual substitution takes place, and negative when, instead, a synergistic action occurs.

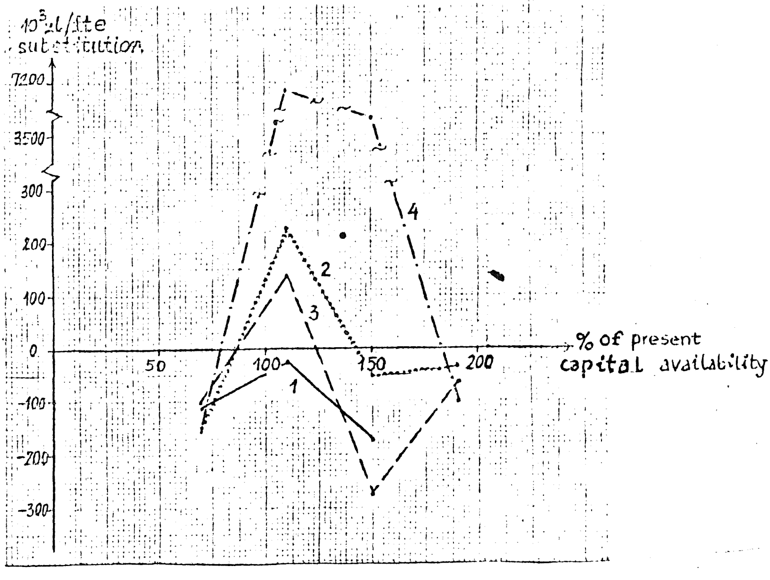



Fig. III.6.6 Model - defined substitution rates of capital vs. labour, for capital availability changes, farm types 1 to 4.

It should be noted that, first, Fig. III.6.6 does not represent the substitution rates for the farm type 5, since its labour was in the run analysed totally used. Thus, it was only possible to calculate surrogate values of substitution, putting into the formula used for substitution DL ($CA_M$), i.e. dual values of labour instead of LU ($CA_M$). Fig. III.6.7 presents these surrogate values for farm type 5, in zl of capital per zl of dual value of labour force. Of course, rational reading of this figure is the relative one.

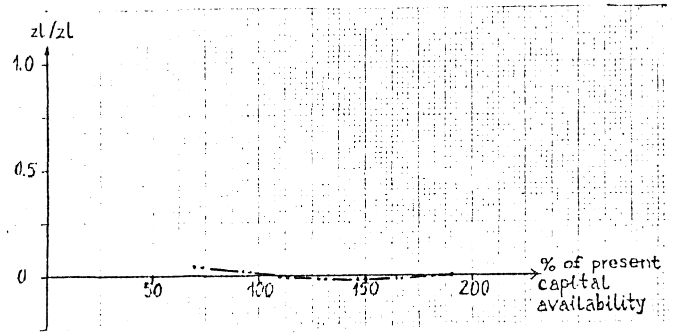



Fig. III.6.7 Model-defined substitution rates of capital use vs. dual value of labour for capital availability changes, farm type 5.

The capital vs. labour results presented, read together with the technological shift indicators, point out to one very important conclusion. Namely, substitution tends to be positive only for the 90-130% segment of the present capital availability and even this with quite important reservations (substitution for farm type 4 is prohibitively expensive, while for farm type 5 it actually stops at about 100%). Notwithstanding that, such a result is in partial agreement with Hypothesis 1, unless one looks beyond 130%, where, however, some farm types may not use additional capital efficiently (especially farm types 1 and 5) in given conditions. In order, however, to get really plausible policy results one would have to consider both the capital allocation schemes and the role of labour force of farm types 5.

Before returning yet to the capital allocation subject let us then look at the results obtained for higher labour force of farm type 5. These results are given in Figures III.6.8÷10. It can be seen that although no dramatic changes occur, several clear consequences of allotting 1020 fte instead of 685 fte(increase by 50%) to p=5 should be emphasized:

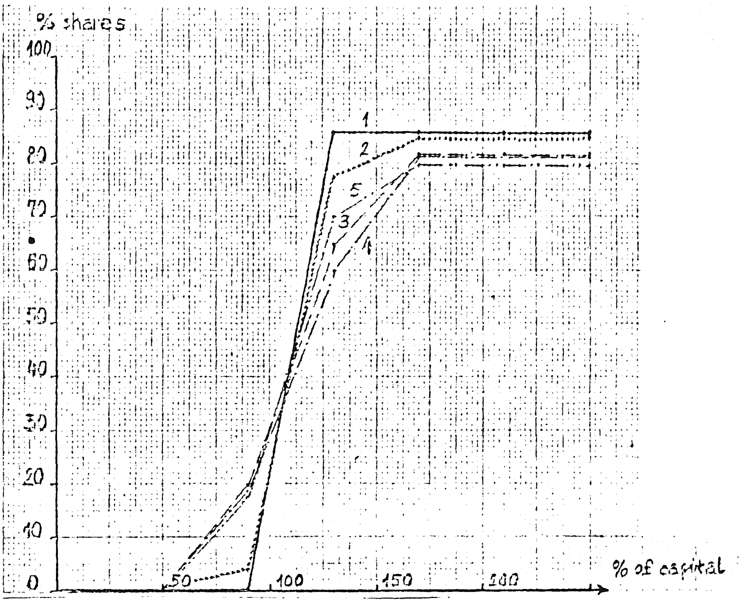



Fig. III.6.8 Shares of intensive crop technologies vs. capital availability, total and for individual farm types, labour force for p=5 increased by 50%.

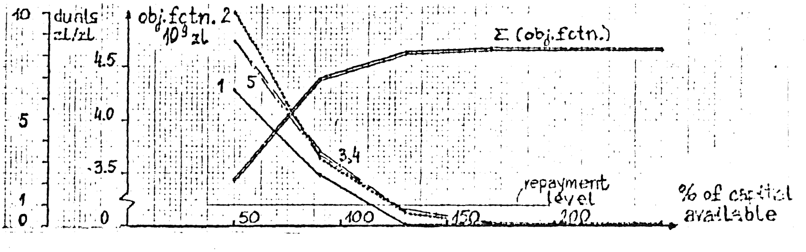



Fig. III.6.9 Total objective function value and dual values of capital availability for individual farm types vs. capital availability for all farm types, labour force for p=5 increased by 50%.

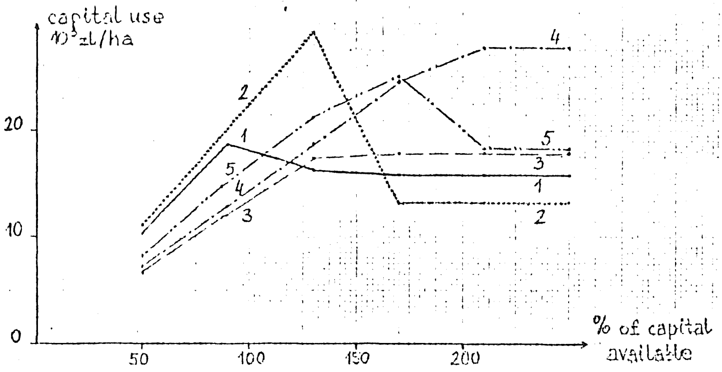



Fig. III.6.10 Actual capital use per hectare of the land used for individual farm types vs. capital availability for all farm types, labour force for p=5 increased by 50%.

* technological shift takes place over a much smaller range of additional capital (Fig.III.6.8), although the share plateau is on practically the same level (even p=4 does not "drag" behind), i.e. other constraints act,

* objective function reaches, of course, higher values and farm type 5 joins farm types 2,3 and 4 in that it pays off to give it additional 25% of investment capital, as compared to 12% for farm type 1 (Figs. III.6.9 and III.6.4),

* there is an additional increase in actual per hectare capital use in farm type p=4 (the mainstream of private farming), and a decrease farm type p=3, but other farm types "consume" only a little bit more of capital per hectare than in the previous case (Figs. III.6.5 and III.6.10); as mentioned, the shape of these curves is largely influenced by the crops-livestock alternative.

Having thus, in fact, started the analysis of the influence of labour force availability on technological shift conditions, let us look into this aspect with some more precision.

### III.6.3 Influence of labour force availability

Previous results indicate that there may be superfluous labour force in farm types p=1,2 and 3, but not necessarily so in p=4, and certainly not in p=5. Table III.6.4 shows numbers of effectively used manpower, their duals and relation to present availability for various levels of labour force available, other conditions being as in the baseline solution, Table III.6.1.Table III.6.4 is

| Conditions | Farm type | | | | | Total |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| 40% of initial availability | 50/50/19.2 | 292/292/36.3 | 1032/1032/11.7 | 1008/1008/62.8 | 274/274/101.2 | 2656/2656/40 |
| 72% of initial availability | 76/90/0 | 488/526/0 | 1221/1858/0 | 1814/1814/5.9 | 494/494/81.1 | 4093/4782/62 |
| 104% of initial availability | 64/130/0 | 463/759/0 | 1090/2683/0 | 2103/2620/0 | 712/712/30.4 | 4432/6904/67 |
| 136% of initial availability | 57/170/0 | 445/993/0 | 1090/3509/0 | 2089/3427/0 | 932/932/3.3 | 4613/9031/69 |
| 168% of initial availability and beyond | 51/210/0 | 442/1226/0 | 1129/4334/0 | 2047/4233/0 | 1018/1151/0 | 4687/11154/71 |
| baseline solution for GPR | 100/125/0 | 599/730/0 | 1465/2580/0 | 2529/2529/28.4 | 685/685/31.7 | 5387/6649/81 |

Table III.6.4 Labour force uses, availabilities and dual values.
Entries for "farm types": use/availability/dual value in $10^3$ zl per fte per month.
Entries for "total": use/availability/ use as % of initial availability.

based upon the parametrization run in which the labour availabilities for all the farm types were parallelly changed from 40% to 200% of the 1982 level. Taking into account the fact that between 1982 and 1985 there has been continuing labour drain from agriculture it can be stated on the basis of Table III.6.4 that there may still be some surplus in labour force of this sector, but certainly not in farm types p=4 and 5. It is on the basis of this Table that Fig. III.3.1 was sketched. It is interesting to note, though, interrelations among optimal labour force employed in various farm types - with increase of labour force use in p=5 by 306 from 712 to 1018 the use by other farm types together fell by some 50 fte.

The influence of mentioned labour force changes on the technological shift shares in crop raising is shown in Figs. III.6.11 and III.6.12. The first of these figures, in which , as emphasized,

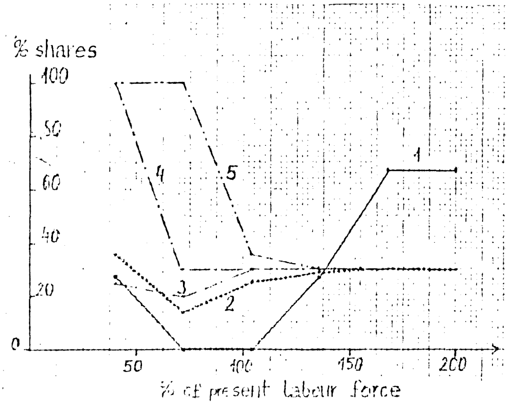



Fig. III.6.11 Shares of intensive crop raising technologies in land actually used vs. labour force available, in and for all farm types.

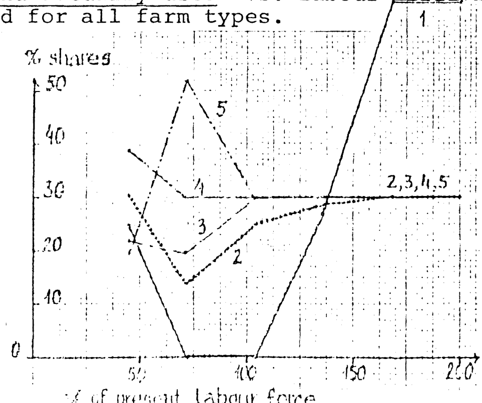



Fig.III.6.12 Shares of intensive crop raising technologies in overall land owned vs. labour force available, in and for all farm types.

shares of intensive technologies are calculated for land actually used, seems to imply that H.1 might hold at least for a range of labour availability. When looking at Fig. III.6.12, and also at Fig. III.6.13 and recalling the influence exerted on levels of new technology adoption by the capital availability one can, though, easily conclude that the phenomena displayed by the system at below 100% of 1982 labour force for p=5, and below 72% for other farm types are distortions connected with fairly lowered levels of activity. Thus, it is obvious that the fact of quick saturation of intensive technology shares with increase of available manpower is as much connected with relative excess of labour in some of the farm types as it is to lack of adequate investment capital availability.

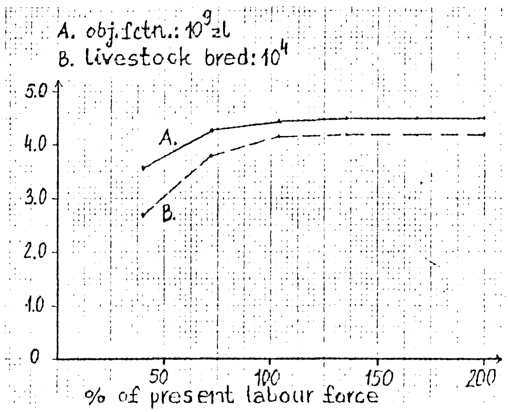



Fig. III.6.13 Objective function values and number of livestock bred as dependent upon the labour force availability for the whole of the subregional system.

Additional illustration for the value of labour force is provided by Fig. III.6.14, related directly to Table III.6.4. It shows that even back in 1982 farm type 5 necessitated and could potentially motivate to work there some 20% of additional work force. This conclusion, though, is based upon the country average wages, while local development related to mining and energy offered wages up to 2-2.5 times higher, thereby showing capacity of draining labour from all the farm types, money-wise. Losses therefrom, in terms of objective function value per annum for this particular subregion may go as high as $250 \cdot 10^6$ zl or even beyond. Resulting eventual technologica shift towards more intensive technologies is confined to shrinking areas which are actually used and to less and less diversified activities.

## III.7 Conclusions

Most of the statements contained in this short section refer to formulation of the three hypotheses, H.1, H.2 and H.3, given in III.1.

Hence, it turns out that H.1 is to some degree true, since by lowering the manpower availability one can in fact force an increase in shares of intensive technologies in some farm types and some groups of activites, as indicated by the results obtained with the SEMORA B model. Value of this verity is, however, quite low, since lowering of labour available in all the farm types, with given current capital availability, shall simultaneously lead to lowering of averall agricultural intensity, to decrease in agricultural land use and in the global value of objective function. It is certainly not this type of technological shift that was looked for.

Hypothesis no. 2, H.2, proved to be entirely correct in that it is only the additional investment capital, on top of the amounts which are already available, that can secure significant increase of shares of new, more intensive technologies. By adding 50% of investment capital these shares can in crop raising be increased from around 20% to around 80% of the overall arable land. This hypothesis is not correct, however, in that indiscriminate labour drain from agriculture might make completely impossible the capital-induced technological shift mentioned.

Thus, it is H.3 that highlights the best the situation. When additional investment capital is available and a limited labour drain, mainly concerning farm type 3, and to a much smaller degree - 1 and 2, is accompanied by labour force increase within the farm type p=5 and labour force maintenance within p=4, then it is possible to attain the 60% increase in the shares of new technology, as mentioned previously.

Because of time delay, present situation may not allow further labour diversion, in view of the fact that it has been going on since 1982, and a large portion of manpower in p=3 is already constituted by biprofessionals (workers-peasants), while all of the other surpluses might have been depleted, without adding any employee to p=5. Moreover, if investment capital available was not increased, there might have appeared a margin of abandonment. Thus, results cited here indicate the internal technology-change--oriented propensities of the system, which can either be used to introduce more robustness and diversity into regional development or overlooked and in fact, destroyed. There is some resilience in the system, but indiscriminate development-bound changes can even impinge on that. It is because of these potentials and trappings that the study of conditions for technological change in regional agriculture is important. Model SEMORA B turns out to be the proper tool for that purpose.

* * *

References to this chapter are given after Chapter V, Part 2.

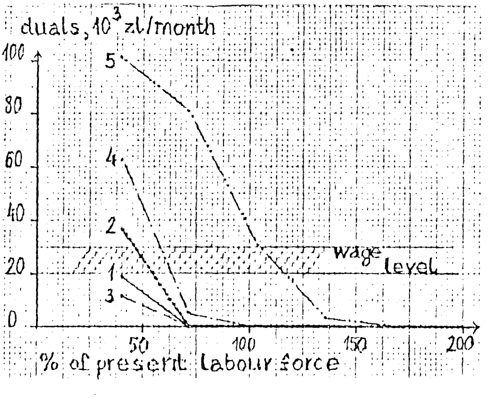



Fig. III.6.14. Dual values of labour force for farm types, as compared to current wage levels.

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STUDY REPORT

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