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CASE STUDY ON LIMITS AND CONSEQUENCES OF AGRICULTURAL TECHNOLOGIES IN THE NORTH-EAST REGION OF THE PEOPLE'S REPUBLIC OF BULGARIA.

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FOREWORD

The Food and Agriculture Program at IIASA focuses its research activities on understanding the nature and dimension of the world's food situation and problems, on exploring possible alternative policies which could improve the present situation in the short and long term, and on investigating the consequences of such policies at various levels -- global, national and regional -- and in various time horizons.

One part of the research activities focussed on investigations of alternative paths of technology transformation in agriculture with respect to resource limitations and environmental consequences in the long term. The general approach and methodology developed for this investigation is being applied in several case studies on the regional level. The reason for the studies is not only to validate the general methodology but also to develop an applicable tool for detailed investigations for a particular region which could then be applied on a number of similar regions.

Furthermore, some specific aspects are being addressed in all these case studies which has been initiated within the IIASA's Food and Agriculture Program. This will allow the behaviour of various systems to be compared, according to the selected aspects, and analyzed (in different social, economic and natural resource conditions) according to the selected aspects. One of the case studies is being carried out for the north-east region of Bulgaria. This paper describes the first phase of the study, the problem identification, the formulation of goals, and the basic methodological framework.

Kirit S. Parikh
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Introduction

Agriculture is largely dependent upon, and influenced by, the natural environment. Man's active influence on this environment in transferring natural resources into consumer goods, necessary for his existence, has governed human activities and trade over thousands of years.

All human activities in converting natural resources to the needs of society have, however, left lasting consequences--both positive and negative--on the environment and mainly on the most important element of agricultural production, the productive soil layer. As a result of the scientific and technical progress and the use of powerful mechanical and chemical production means, over the last decades these consequences for the environment are becoming increasingly pronounced.

Agriculture is one of the basic vital branches of national economy in the People's Republic of Bulgaria. It covers 16% of the basic production means, 12% of the total capital investments in national economy, 24% of the people, employed in the sphere of material production, 11% of the aggregate social product and 11% of the national income.

The basic tasks set before this branch of economy are the following:

- to satisfy the constantly growing miscellaneous requirements of the country as regards of its consumer goods and above all the rational, physiologically based, caloric and vitamin requirements of the population;
- to deliver the necessary inputs to the enterprises from the various branches of industry and coordinate the smooth running of the production process;
- to ensure the regular inflow of sufficient agricultural products; necessary to maintain the national strategic reserves (stockpiling);
- to ensure sufficient quantities and varieties of agricultural production for export purposes;

The rapidly expanding food processing industry, the increasing participation of the country in the international social division of labour, steadily improving living conditions of the population, and other factors, important for the development of society and social production have all put added demands on agricultural production too, for increased production.

Two successful methods of increasing agricultural production are through expansion or intensification of agriculture.

Similar to many other countries Bulgarian agriculture in earlier times developed through expansion of the areas of arable land, and increasing the number of animals, etc. Expansion of agricultural land has now reached its limits due to the restricted area of the land which can be used for agriculture and the absolute decrease of the other important production factor--the labour force. As a result of these factors, the all-round intensification of agriculture has become the alternative means for the further development of this branch of national economy. (The intensification of production in all branches of economy was declared as the general line of development in the People's Republic of Bulgaria for the 1980s until the end of the century.)

The investment of additional inputs of labour and production means to a unit area aimed at increasing production is the economic basis of intensification. The maximization of these investments is not however adequate to the maximization of the production (economic) and social results, especially if they are esteemed for a longer period of time and through the prism of the task to preserve this national wealth for the future generations.

In the conditions of contemporary socialist agriculture the production intensification is realized through considerable structural changes of the arable land, through increase and improvement of the irrigated areas and inclusion of new varieties of plants and breeds of animals with higher productivity and better qualities, through the utilization of an increased amount of more efficient technique, of new chemicals, etc. The additional investments are made not only for the increase of the production volume but also in order to diminish the social labour expenditure for a unit production.

There are complex bilateral ties between intensification and the scientific and technical progress. The separate trends of the scientific and technical progress in agriculture like the mechanization, use of chemicals, irrigation, etc. are characterized by strongly expressed all-round impact on intensification and the final results of production. The emergence of a new movement in the development of a certain trend determines the changes and new movement in the development of the remaining ones. The timely implementation of the rank experience and the achievements of scientific and technical progress in the field of agriculture is an important condition for its accelerated future intensification. On the other hand, the intensification, regarded as a process of continuous investments of production means on one and the same area is closely connected with significant changes in the system of growing and breeding of agricultural crops and animals, respectively, with an intensified use of fertilizers and herbicides, etc. with construction of new and the improvement of the existing machinery and technologies, etc. Thus intensification is becoming ever more contents and expression of the scientific and technical progress, while the supplementary investments, connected with it into a factor for the development of the scientific and technical progress.

The improvement of the various sides and trends of the agricultural scientific and technical progress is expressed in the elaboration of new and the improvement of the existing technologies for agricultural plant growing and animal husbandry. The whole range of consecutive operations, as well as the ways for their realization in the production of a certain product or the carrying out of a given work process.

The elaboration of different technological variants for the production of consumer goods of plant or animal origin is closely connected with the size, condition and utilization of the existing and additionally discovered resources.

These may be: natural (land, water, etc.); material (seeds, fertilizers, herbicides, machinery and equipment, etc.); labour and finance.

The arable land, used in agriculture in Bulgaria is naturally restricted. The development of science and technology open certain opportunities for its expansion by transforming one type of land into another but this is also insufficient. Consequently, one of the main characteristics of agricultural intensification is the increase of fertility (natural and artificial) of the surface land layer--the soil. The basic ways for the achievement of high soil fertility are: irrigation, suitable soil cultivation, appropriate succession of crops, fertilization, development of a uniform complete system of activities for struggle with the erosion processes, etc.

The implementation of the achievement of scientific and technical progress in agriculture is connected with the utilization of more diverse fertilizers and pesticides for pest control, with the creation of new and better techniques in view of the further complete mechanization and automation of the labour production processes, etc.

As in the other branches of national economy, however, the utilization of the scientific and technical achievements is connected with (or limited by) a whole range of economic, technical, environmental, social, etc., conditions, factors and consequences. This, in its turn, requires elaboration and estimation of different variants for solving the separate problems and achieving the final results.

From the point of view of inputs, for instance, the technological variants may be elaborated in two aspects--for limited and non-limited quantities. In the first case the problem consists in the elaboration of a technological production method, providing a maximum quantity or agricultural production per unit area or per animal, without limiting the quantity of the resources used. In the second case the task consists in the elaboration of a number of technological variants for the production of consumer goods and in the appropriate choice of the ones providing the best and most efficient utilization of the already limited in size resources (land, water, energy, chemicals, labour, etc.). Thus the connection between the inputs and the consumer goods production technologies results in a maximum quantity, high-quality production, intended to satisfy the needs of the society keeping a strict account of the rational utilization of the available resources.

It is however known that in recent years the final economic results of agricultural production are achieved through destroying the natural environmental balance and its pollution. The industrialization and wide utilization of chemicals in agriculture intensify these processes. That is why it is of essential importance to study and evaluate not only the agricultural products sufficiency level but also the level of rational and economic inputs utilization, i.e. to create production system ensuring favourable results at the lowest possible unfavourable environmental damages.

It is a well-known and accepted fact, that in the contemporary stage of development the processes of the expedient utilization of the environment are not yet fully regulated. This leads to a loss of natural resources and their irrational utilization as well as to soil, water and air pollution. The soil pollution has increased and biocide pollution in particular. This leads to deterioration of the soil microflora, to breaking of the structure and contamination of the crops grown in such soils, etc. Many and various are the contaminators of the atmosphere and the surface and underground waters. This destroys the natural ecological processes and reduces their natural resources.

The expansion of man's economic activities in industry and the intensified utilization of chemicals in agricultural production increase the society's influence on the environment--reduce natural resources and increase the direct and indirect negative influence on the environment. It is possible to observe the destruction of the natural environment systems on a local, regional and global level. The health conditions of the present and future generations are deteriorating too, and a number of other unfavourable phenomena are expected to appear.

Statistic data as well as data from a number of other sources convincingly indicate the interrelation between the unfavourable influence on the environment and the increasing health troubles of the population. In the future development of the scientific and technical progress the problem of preserving the environment from pollution is to gain further significance. This brings the necessity to create an agricultural management system, ensuring its optimal development at rational utilization of the natural resources and preservation of the environment.

A wide range of socio-economic, technological, medico-biological and ecological researches are carried out for the scientific determination of a similar system. It is however important to carry out full, extensive and scientifically grounded research work concerning the comprehensive interrelations between the three basic components of resources, consumer-goods and production technologies, and the environment, and regarding them as a whole. In the process of discovering and studying the character of the interrelations and interdependence between them, the greatest attention should be paid to the opportunities for increasing the volume of agricultural production and the realization of the most favourable and rational combination of these three components. The aim of the present study is to cooperate for the realization of this task and achieve maximum efficiency of the production system without destroying the available natural resources.

OBJECT OF THE STUDY

1. Soil-climatic and economic characteristics of the North-East Bulgaria as an important agricultural region of the country.

The North-East region of Bulgaria includes seven districts and covers 21% of the country's territory. In 1980 its population amounted to 1,801,684 people or 20% of the country's population.

The North-East region covers the East Danube hilly plain, the Fore-Balkan and the Northern part of the Black Sea and the Danube coast. The relief of the region is flat and hilly, which makes it suitable for the development of a number of branches in agriculture.

The climate of the region is moderately continental and favourable for growing grain crops, vines, vegetables and some industrial crops, etc.

The hydraulic power resources of the region are restricted by its own internal water resources, consisting mainly of the rivers Kamchyia, the Provadiya's and Rousse's Lom, etc. The importance of the Danube as a major water resource is constantly increasing.

Black and grey forest soils prevail in the North-East region, the first having greater importance and being more widespread. They are suitable for growing of grain crops, sunflower, sugar beet, etc. The grey forest soil is favourable for growing of vines and fruits.

The North-East region is characterized by a high degree of intensification of agricultural production and is of great importance for the better autarky of the population's needs of agricultural inputs and products.

The region includes 29% of the arable land and 33% of the corn-fields of the country. Its territory embraces 35% of the area under grain crops. Basic grain crops of the region are: wheat, maize and barley. That is the reason for its development as a major grain - bread basis of our country with particular importance of the nutrition of the population.

North-East Bulgaria has always been popular for its production of beans, covering 83% of the respective areas of the country and giving 78% of its production.

The industrial crops of the region are well developed too, 48% of the sunflower-planted areas, 54% of the soya-beans and 30% of the sugar beet-planted ones being situated here.

From the industrial cultures, sunflower is the most widely distributed crop. The region is the country's front ranker concerning not only the size of the area but also as regards the production and average yields of this crop. Sunflower is grown mainly in the Tolbouhin, Silistra and Razgrad districts. The new varieties created in the Institute of Wheat and Sunflower Cultivation near General Toshevo play an important role for increasing the yields of this crop and the amount of oil in its contents.

The region offers favourable conditions for the development of market gardening, mainly in the Danube valley. Its vegetable-planted areas constitute 23% of the country's total vegetable-planted areas and turn out 20% of its production in this field.

Viticulture is a specific branch in the region constituting 27% of the country's wine and dessert wine.

Animal husbandry is well developed in the North-East economic region. Its most important branch is cattle-breeding. The region breeds 26% of the cattle and 24% of the cows in the country. In 1980 397 578 thousand litres of cow milk representing 28% of the country's total produce were produced here.

Sheep-breeding is the second important branch in the region's animal-breeding, raising 28% of the country's sheep and producing 22% of its sheep milk and 35% of its wool.

The well developed grain production of the North-East region created favourable conditions for pig-breeding the significance of which is also increasing. According to the number of pigs bred here, the region ranks first in the country--34% of its total production. The region is an important supplier of pork for the home needs and for export purposes.

Poultry-raising is a typical and promising branch in the region's animal-breeding industry. Thirty-one percent of the country's poultry and forty-one percent of its eggs are produced here.

2. Characteristics of the agricultural production in the Tolbouhin district.

The object of research in the case study with which Bulgaria participates in the Food and Agriculture Program of the International Institute for Applied Systems Analysis (IIASA), Vienna, is the Tolbouhin district, situated in the North-East economic region of our country.

According to the general methodology of the IIASA for the production of case studies aiming to ensure the necessary comparison between them in the choice of the object of research, the following have been taken into consideration:

- The Tolbouhin district is characterized by a marked agriculture- directed production, based on the favourable physico-geographical conditions, climatic and meteorological parameters, soil potential, substantial production experience and comparatively great relative share in the national agricultural production total volume.
- The district is fully autonomous as far as policy and administration are concerned. It is included as an independent unit in the plan system for management of national economy. This makes it easier to develop and investigate the economic and administrative plan and organizational activities which are carried out, relative to the conditions of inputs, technologies and environment.
- There are intensive direct and inverse connections of the region in the system of national economy determined by its great importance as a supplier of production, ensuring the country's food balance and as a consumer of the final economical results of the remaining districts.
- In its nature and geographical and socio-economic parameters as well as in its role in the work of the whole national complex, the North-East region of Bulgaria and the Tolbouhin district in particular, may be compared to the Stavropol region of the USSR and similar regions in Hungary where case studies are also to be carried out in cooperation with IIASA.
- The carrying out of a case study in the Tolbouhin district provides opportunities to use the substantial experience and scientific potential of the branch Institute of Wheat and Sunflower Cultivation in General Toshevo.

These considerations are important for the successful carrying out of the case study.

The Tolbouhin district is situated in the farthest North-East part of Bulgaria covering 21% of its territory and 14% of its population. Although it has the greatest territory in the region, compared to the remaining districts, it is most sparsely populated--53.5 people per square kilometer.

The district has an industrial-agrarian structure, the proportion between industry and agriculture being 63:37. The district's industrialization was carried out in the last 10-15 years. The most developed branch here is the food, beverage and tobacco industry represented by flour, meat and canning enterprises, milk-extraction plants, poultry slaughter-houses, milk processing and wine production. Machine-building and metal-working are of secondary significance.

The Tolbouhin district has highly developed agriculture and is the country's major agricultural region. It disposes of 26% of the arable land and 27% of the corn fields of the whole North-East region. The basic crop areas are 36% for wheat, 32% for maize, 34% for sunflower and 50% for the region's beans are concentrated here. The district is a major producer of these crops. In 1980, it has turned out 37% of the wheat, 21% of the maize, 37% of the sunflower and 63% of the beans in the region. The great production volume is on the one hand due to the large massives of land, covered by these crops, and on the other hand it is the result of the high average yields per area unit. Thus in 1980 the region has obtained the highest average yields of wheat, sunflower and beans from the Tolbouhin district--500.1 kg/dca (wheat), 199.6 kg/dca (sunflower), and 92.5 kg/dca (beans), or by 102.8 kg (wheat), 46.6 kg (sunflower), and 23.4 kg (beans) more compared to the average yields of the country.

Compared to the other districts of the region, the greatest amount of agricultural machinery had been concentrated in the Tolbouhin district: in 1980 it consisted of 3803 tractors and 1899 combines, 992 of which were grain threshers.

Simultaneously with plant growing, animal husbandry is well developed in the Tolbouhin district too. The district breeds the greatest number of animals in the region. In 1980 there were 102,286 cattle including 38,120 cows; 327,256 pigs, 663,305 sheep and 3,114,548 poultry all well known for their high productivity which is considerably above the average level. These favourable conditions provide opportunities for the production of a large volume of animal products. In 1980 the district has turned out 25% of the cow's milk, 21% of the sheep's milk, 39% of the eggs and 24% of the wool, produced in the North-East region.

In 1980 there were 9 Agro-Industrial Complexes in the Tolbouhin district with 3,157 dca arable land and 45,645 people employed.

The high degree of land concentration, the basic production funds and labour are typical for the region. In 1980 an Agro-Industrial Complex had 351 thousand dca arable land and 37,218 thousand leva basic production funds and 5,072 people employed. As a result of this the 1980 total production turn-out from all production activities at current prices, average for an Agro-Industrial Complex amounted to 41,854 leva. These indices are much higher than the average ones for the region and the country.

2.1. Aims and purposes of the case study.

The idea for considering the interrelations: resources, technologies, environment, which we adopted from the IIASA laid the beginning of a new scientific trend in the research work of the Bulgarian scientific organizations. A group of research workers has been formed for the purpose in Bulgaria to the Problems of the Food Complex Research Laboratory, the Organization, Management and Modelling of Agro-Industrial Production Department at the Karl Marx Higher Institute of Economics, Sofia, and the Institute of Wheat and Sunflower Cultivation, General Toshevo, Tolbouhin district. For several years now, research workers from the group have been developing and applying economic-mathematical models for planning and developing the Tolbouhin and Varna district agriculture but these models did not take into account the interrelations: resources-technologies-environment. Now, regarding the IIASA general methodology, an improved mathematical model has been worked out used for studying the limits and consequences of agricultural technologies.

The new elements of the model are:

- each year of the planned period the agricultural crops and animals may be grown and bred at different technological variants;
- The pollution of the environment/soil, water and agricultural production, with nitrogen fertilizers, pesticides and animal farms is reported and limited for each soil region, for irrigated and certain non-irrigated conditions, respectively;
- the total quantity of power resources/liquid fuels and electric power is specified and limited;
- the water balance necessary for crop growing in the irrigated areas is ensured in certain periods of irrigation;

The economic and mathematical model thus elaborated makes it possible to answer the following concrete scientific tasks of the research work by changes in the optimum criterion and by varying the limiting conditions:

- what rate and level of agricultural production could be reached by maximum utilization (application) of the achievement of scientific and technical progress, with no restriction concerning the preservation of the environment, what kinds of inputs will be necessary and what will be the unfavourable influence on the environment;
- is it possible to reach a definite rate of increase of agricultural production/better sufficiency of the growing requirements of the population, determined as an obligatory condition for pollution-preservation of the environment;
- what rate and level of agricultural production could be reached by determining the limiting conditions for the unfavourable influence of fertilizers and pesticides on the environment with no specific requirements as to the preliminarily set rate of agricultural production increase;
- what will be the influence of agricultural production on the national programmes (forecasts) restrictions concerning the amount of the future agricultural resources.

Our country's production and export of fertilizers, production and export of pesticides, production and export of agricultural machinery, energy (liquid fuels, electric power) available for agriculture have to be considered.

- what will be the influence on the agricultural production of the obligatory implementation of technologies, ensuring minimum wind erosion.

Our research work has adopted the methodological approach offered by Task 2 of IIASA's Food and Agriculture Program. The basic instrument in the case study will be the simulation linear-programming model. It consists of two components: a static linear-programming component and a dynamic simulation component.

The static linear component expresses the production system in a one-year period, during which the production structure aims at realizing a definite task function at determining production conditions--resources, various production technologies, state tasks for the promotion of production, constant tasks, capital investments, pollution of the environment, etc.

The simulation component expresses the changes in each of the following periods of time in terms of natural resources, technology choice for crop growing and basic production funds. This component also reflects the long-term tasks for agricultural development.

2.2. Economic and Mathematical Model.

Formulation of the task. To develop variants for the agricultural development in the Tolbouhin district, with the rational utilization of the production resources and the necessary level of environment preservation. The solution of the real task will determine the cropped area, the number of animals, the size of the other activities, the agricultural production quantity, the basic production funds necessary and the capital investments, the best technologies and methods for crop growing and animal breeding, etc. The variant-solutions will be obtained by changing the limiting conditions for meeting the country's needs of a certain production, a change in the standards for preservation of the environment, a change in the size of the production resources and capital investments through change of the index accepted as an aim function of the model.

The arable land of the region has been divided into four regions, the irrigated areas being in the fourth region only.

Activities/unknown quantities. The main unknown quantities in the economic and mathematical model represent the cropped area, the number of animals, the production quantity, the quantity of the resources which are to be purchased--fertilizer, agricultural machinery, etc., the capital investments in directions, the amount of the environmental pollutants, the labour resources distributed according to qualification, etc.

When a certain task can be realized in different ways and it is necessary to estimate which is the most efficient of them in terms of the tasks of the case study, the number of the unknown quantities for this activity may be equal to the number of the possible variants for this realization. Thus it is possible to reflect the differences between the individual technologies for growing identical crops in a given region, the differences in the agricultural production utilization, etc.

Different types of technologies are used for the purposes of the case study: agricultural production technologies which have been elaborated and experimented in scientific and research institutes but have not been yet commonly used, and scientifically describe technologies which could be used in the future.

The most general characteristics of the technological variants, by which a certain crop could be grown are the following:

- technology for obtaining maximum production quantity per area unit without reflecting the limits of the necessary resources and the environment pollution quantity;
- technologies aiming at the preservation and the increase of the natural soil fertility;
- technologies ensuring minimum wind and water erosion;
- technologies with minimum water consumption;
- technology with furrow-irrigation
- technology, for irrigation conditions, aimed at the maximum restriction of lifting the underground water and the avoidance of soil swagging and salinization;
- technology with a least possible expenditure of liquid fuel and electric power;
- technology aiming to minimize the use of artificial fertilizers (nitrogen);
- technology aiming at minimizing the use of pesticides;
- technology with the smallest possible metal volume per unit area;

  technology with a minimum utilization of human labour;
- technology with minimum direct production expenditures.

The unknown quantities included in the first version of the economic and mathematical tasks have been divided into several groups:

The first group includes the unknown about the area of agricultural crops grown after different technological variants for each individual region, referring to the first region:

Region I

I.1 Wheat

- 1 basic variant - dca
- minimum fertilizers and pesticides - dca

- minimum cultivation - dca
- no cultivation - dca
- intensive technology - dca

I.2 Maize

I.2.1 Maize gathered on the cobs

1 basic variant - dca

- minimum fertilizers and pesticides - dca
- minimum cultivation - dca
- without presowing - dca

I.2.2 Maize gathered as grain

- 1 basic variant
- minimum fertilizers and pesticides
- minimum cultivation
- without presowing

I.2.3 Maize gathered on the cobs

- basic
- minimum fertilizers and pesticides
- minimum cultivation
- without presowing

I.3 Sunflower

1 basic variant

- minimum fertilizers and pesticides
- intensive technology

I.3.1 Sunflower gathered by an auger

- 1 basic
- minimum fertilizers and pesticides

intensive technology

I.4 Soya beans

I.5 Beans

- manually gathered beans
- mechanically gathered beans

I.6 Onion

- onion, intensive technology
- onion--minimum fertilizers and pesticides

I.7 Potatoes

- intensive technologies
- minimum fertilizers and pesticides

I.8 Fodder Maize

- fodder maize, intensive technology - dca
- fodder maize, minimum fertilizer and pesticides - dca

I.9 Alfalfa - old

- alfalfa - old, intensive technology - dca
- alfalfa - old, minimum fertilizers, and pesticides - dca

I.10 Alfalfa - new

- alfalfa - new - dca

Region II.

II.1 Wheat

- wheat 1 variant, basic for the region
- minimum fertilizers and pesticides
- minimum cultivation

  wheat without cultivation

  wheat, intensive technology

II.2 Maize

II.2.1Maize gathered on the cobs

- 1 basic variant
- minimum fertilizers and pesticides
- minimum cultivation
- without presowing

II.2.2Maize gathered as grain

- 1 variant
- minimum fertilizers and pesticides
- minimum cultivation
- without presowing preparation of the soil

II.2.3Maize gathered in ditches

- 1 variant
- minimum fertilizers and pesticides
- minimum cultivation
- without presowing preparation of the soil

II.3 Sunflower

- 1 basic variant
- minimum fertilizers and pesticides
- intensive technologies

II.3.1Sunflower gathered by auger

- 1 basic variant
- minimum fertilizers and pesticides
- intensive technology

II.4 Soya beans

- soya beans

II.5 Beans

- manually gathered beans

- mechanically gathered beans

II.6 Onion
- onion, intensive technology
- onion, minimum fertilizers and pesticides

II.7 Potatoes
- intensive technology
- minimum fertilizers and pesticides

II.8 Fodder maize
- intensive technology
- minimum fertilizers and pesticides

II.9 Alfalfa, old
- intensive technology
- minimum fertilizers and pesticides

II.10 Alfalfa, new
- alfalfa, new

Region III.

III.1 Wheat
- 1 basic variant
- minimum fertilizers and pesticides
- minimum cultivation
- no cultivation

III.2 Maize

III.2.1 Maize gathered on the cobs
- 1 variant
- minimum cultivation

III.2.2 Maize gathered as grain
- 1 variant
- minimum processing

III.2.3 Maize gathered in ditches
- 1 variant
- minimum cultivation

III.3 Sunflower
- 1 basic variant
- gathering by auger

III.4 Soya beans
- soya beans

III.5 Beans
- beans, manual gathering
- beans, mechanical gathering

III.6 Onion

- onion, intensive technology
- onion - minimum fertilizers and pesticides

III.7 Potatoes
- potatoes, intensive technology
- potatoes, minimum fertilizers and pesticides

III.8 Fodder maize
- fodder maize, intensive technology
- fodder maize, minimum fertilizers and pesticides

III.9 Alfalfa, old
- intensive technology
- minimum fertilizers and pesticides

III.10Alfalfa, new
- alfalfa, new

Region IV.

IV.1 Maize

IV.1.1Maize gathered on the cobs
- furrow-irrigation - dca
- spray irrigation - dca

IV.1.2Maize gathered as grain
- furrow-irrigation
- spray-irrigation - dca

IV.1.3Maize gathered in ditches
- furrow-irrigation - dca
- spray-irrigation - dca

IV.2 Soya beans
- soya beans

IV.3 Tomatoes
- intensive technology
- minimum fertilizers and pesticides

IV.4 Pepper (Capsicum)
- intensive technologies
- minimum fertilizers and pesticides

IV.5 Eggplant
- intensive technology
- minimum fertilizers and pesticides

IV.6 Spinach
- intensive technology
- minimum fertilizers and pesticides

IV.7 Fodder maize
- fodder maize

IV.8 Alfalfa, old

- alfalfa, old

IV.9 Alfalfa, new

- alfalfa, new

The second group contains unknown quantities about the quantity of the final plant production for various purposes/commodity production for food of the population--bread, seeds, etc.--or the production for similar purposes stored in different ways--dry maize grain for fodder; maize grain kept in ditches, for fodder.

Production V.

V.1 Wheat

- seeds - tons
- fodder - tons
- bread - tons
- commodity - tons

V.2 Maize

- grain, commodity - tons
- grain, dry, for fodder - tons
- grain from ditches

V.3 Straw

- fodder - tons
- commodity - tons

V.4 Cornstalks

- dry - tons
- for fodder - tons

V.5 Straw from beans

- straw from beans - tons

V.6 Sunflower heads

- sunflower heads - tons

V.7 Fodder maize

- green biomass - tons
- for fodder - tons
- for flour - tons

V.8 Alfalfa

V.8.1Alfalfa (1st mowing)

- green - tons
- hay - tons
- flour - tons

V.8.2Alfalfa (2nd mowing)

- green - tons
- hay - tons
- flour - tons

V.8.3Alfalfa (3rd mowing)

- green - tons
- hay - tons
- flour - tons

V.9 Concentrated mixes for:

- for cows - tons
- for calf fattening - tons
- for mother-sheep - tons
- for fattening - tons
- for pigs - tons
- for poultry - tons

Variables about the number of agricultural animals:

- structural cows
- calves for fattening
- structural sheep
- lambs for fattening
- structural pigs
- pigs for fattening
- layers
- broilers

Variables about the amount of labour resources:

- machine-operators
- servicing personnel
- unqualified workers
- stock-breeders
- temporary aid (seasonal workers) VIII
- temporary aid (seasonal workers) IX
- temporary aid (seasonal workers) X

Variables about the amount of animal production:

- cow milk
- beef

- veal
- sheep milk
- sheep meat
- lamb
- wool
- eggs
- poultry meat
- pork

Variables about the necessary agricultural machinery:
- heavy tractors
- light tractors
- grain combines
- ensilage combines
- trucks
- hay presses
- equipment for grain (grain platforms)

Variables about the quantity of artificial fertilizers:
- nitrogen fertilizer
- phosphorus fertilizer
- potassium fertilizer

- herbicides

- insecticides

- liquid fuel
- electric power
- water

- capital investments in machinery for crop growing
- capital investments in machinery for animal-husbandry
- capital investments for warehouses
- capital investments for drying rooms
- capital investments for ensilage and hay stores
- capital investments for buildings for animal husbandry
- capital investments for animals (basic herds)
- capital investments for new irrigated areas

- capital investments for qualification of workers

Variables about the environmental pollution:
- nitrogen in the surface water
- nitrogen in the subterranean water
- waste materials of the animal husbandry in the surface water
- soil sediment: nitrates, nitrites
- crop pollution

A number of subsidiary variables are included in the economic and mathematical problem, facilitating the mathematical formulation of some of the constraints or allowing the automatic calculation of the amount of the respective technological and economic indices:

- transforming the non-irrigated into irrigated area
- amount of fodder units intended for ruminants
- amount of dry matter of fodder, intended for ruminants
- nitrate quantity above the admissible limit in surface water
- nitrate quantity above the admissible limit in subterranean water
- nitrate quantity within the admissible limits
- total agricultural output - leva
- material expenditures - total
- wage fund - total

The economic problem is characterized by a great value and expansive interrelations between the vectors and the determining conditions. That is why all factors and conditions having an important influence on the production development are expressed in the mathematical model.

2.3. Constraints.

The basic constraints express the various economic, organizational, technical, agro-technical, zoo-technical and other conditions to which the plan for agricultural production development should comply. An essential group in this economic and mathematical task are the constraints connected with the environmental polluting in the process of agricultural development.

(a) Constraints about the balance of cultivated land.

The number of constraints in this group depends on the degree of soil homogeneity and the possibility to transform one soil type into another during the perspective time horizon.

The correct expression of the different conditions of the individual regions of cultivated land is achieved by formulating the constraints concerning each region. In the economic and mathematical task the differentiated regions of arable land with equal quality, natural soil fertility, relief, situation, when a certain agricultural crop, whenever it is situated in the region gives equal yields at equal technologies and equal production expenditures, have constraints concerning the size of the area. The respective variables allow to determine the amount of the agricultural crops for the particular region of cultivated land.

(1) Balance of the cultivated area in the first region

(2) Balance of the cultivated area in the second region

(3) Balance of the cultivated area in the third region

(4) Balance of the cultivated area in the fourth region

Nonirrigated land transformed into an irrigated one

$$\sum_{j \in K_i} X_j - X_t \leq B_i$$

where:

K_i set of indices of the values which may use area B_i;

X_t transformed t-land proportion;

B_i the initial i-land proportion.

(b) Constraints for crops ration in crop rotation.

The admissible variables of the production structure for each land category should ensure the suitable rotation of agricultural crops, in order to use better the soil fertility and have a more successful disease and pest control. The concrete diagrams of crop rotation will be prepared after determining the size of the crops and the branches, due to which the economic and mathematical task reflects the most general agro-technical requirements, which will ensure, after fulfilling the task, the creation of an agro-technically grounded crop-rotation.

One of these most general characteristics is the ratio between the area of integrated crops and the one of earthed up crops. The size of the integrated crops should not be bigger than the one of the earthed up crops. The ratio is not fixed but the limits for its fluctuation are determined, as for instance the area of autumn-wheat crops should be at least 45% and no more than 50% from the whole crop rotation area:

- autumn-wheat crops in the I region - minimum
- autumn-wheat crops in the I region - maximum
- autumn-wheat crops in the II region - minimum
- autumn-wheat crops in the II region - maximum
- autumn-wheat crops in the III region - minimum
- autumn-wheat crops in the III region - maximum

The other general characteristics refer to the requirements for a periodicity in sowing sunflower and alfalfa on one and the same area.

- Sunflower I region - maximum
- Sunflower II region - maximum

- Sunflower III region - maximum
- Alfalfa I region - minimum
- Alfalfa I region - maximum
- Alfalfa II region - minimum
- Alfalfa II region maximum
- Alfalfa III region - minimum
- Alfalfa III region - maximum
- Alfalfa IV region - minimum
- Alfalfa IV region - maximum

$$\sum_{j \in E_{qf}} P_{qf} X_j - \sum_{j \in E'_{qf}} P_{qf} X_j \leq 0$$

where:

E_{qf} set of indices of those variables which enter in relation with the variables of the aggregate E'_{qf}; such relations may be formulated for the respective crop group - q, and for each land category - f;

P_{qf} coefficient defining the variables proportion ratio in the two aggregates.

(c) Forage balance constraints.

The formulation of the conditions ensuring adequate nutrition of ruminants and forage balance is characterized with the following characteristic features: the contents of the most important nutritive components, absolutely necessary for providing an acceptable type of nutrition is controlled. The abovementioned components include: minimum contents of energy (in food units) in the rations, digestible protein, potassium and phosphorus and a maximum content of dry substance. As the control of the contents of the indicated components only, cannot guarantee a biologically adequate nutrition for the ruminants as regards the contents of the necessary nutritive substances and the volume, taste qualities, etc., minimum and maximum share control of the individual types and groups of forage in the ration is envisaged too. This warrants that the type of the nutrition of ruminants will be within the scientifically-grounded limits.

The constraints concerning the formulations of the nutrition conditions of ruminants in the winter period are divided into two groups. The first group includes the constraints, formulating the mathematical requirements to ruminants to the basic nutritive substances. This group includes six constraints. Four of them ensure that the required food units, digestive protein, calcium and phosphorus, supplied during nutrition, would not be less than those needed for the respective category of animals. The fifth and sixth constraints determine the amount of the dry substance and of carbamide in the animals rations.

- necessary food units for the ruminants
- necessary digestive protein
- necessary calcium

- necessary phosphorus
- dry substance maximum
- carbamide maximum

$$\sum_{j \in M'_l} A'_{hlj} X_j - \sum_{j \in M_l} A_{hj} X_j \lesseqgtr 0$$

where:

M_l set of indices of the variables signifying forages purposed for the l-group of animals;

A_{hj} contents of h-nutrient substance in a forage unit;

M'_l aggregated indices of the variables signifying livestock (l-group)

A'_{hlj} necessary h-nutrient substance for the l-group of animals.

Due to the fact that the first group of constraints are not sufficient to ensure a rational type of feeding, a second group of constraints has been included in the block, controlling the minimum and maximum relative share of forage types in the animals rations. These are the constraints for the minimum and maximum limits of:

- Sum of the feed units
- Concentrated forage minimum
- Concentrated forage maximum
- Silage and hay minimum
- Silage and hay maximum
- Hay minimum
- Hay maximum
- Coarse forage minimum
- Coarse forage maximum
- Green forage minimum
- Green forage maximum

$$\sum_{j \in M_v} A_{hj} X_j - K_v \bar{X} \lesseqgtr 0$$

where:

$\bar{X}$ sum of the feed units;

M_v set of indices of those variables signifying V-type forage whose minimum or maximum share in the aggregate quantity of forage is restricted;

K_v coefficient determining the minimum or maximum relative share of V-type forages.

Non-ruminants will be fed with nourishing concentrated mixes, due to which only one constraint is placed in the economic and mathematical task for each particular type or production group of non-ruminants. This constraint ensures the aggregate quantity of concentrated mix, needed for the respective group of non-ruminants.

(d) Constraints concerning the balance of labour resources.

There are constraints concerning the balance of the available and necessary labour resources aiming the timely carrying out of agricultural activities in each planned period of the economic and mathematical task: the necessity of labour resources for the production program realization should not exceed their availability. Due to the seasonal character of agricultural production this requirement refers to seven sub-periods of the production period--from April to October, including. Three constraints have been formulated for each of the sub-periods to control individually the labour of operators, servicing personnel and unqualified workers.

A constraint has been placed for the year as a whole, effecting the distribution of the available workers according to qualification (operators, servicing personnel, unqualified workers, stock-breeders).

Balance of the labour force - according to qualification
Balance of the operators' labour 4th month
Balance of the servicing personnel labour 4th month
Balance of the unqualified workers' labour 4th month
Balance of the operators' labour 5th month
Balance of the servicing personnel labour 5th month
Balance of the unqualified workers' labour 5th month
Balance of the operators' labour 6th month
Balance of the servicing personnel labour 6th month
Balance of the unqualified workers' labour 6th month
Balance of the operators' labour 7th month
Balance of the servicing personnel labour 7th month
Balance of the unqualified workers' labour 7th month
Balance of the operators' labour 8th month
Balance of the servicing personnel labour 8th month
Balance of the unqualified workers' labour 8th months
Balance of the operators' labour 9th month
Balance of the servicing personnel labour 9th month
Balance of the unqualified workers' labour 9th month
Balance of the operators' labour 10th month
Balance of the servicing personnel labour 10th month
Balance of the unqualified workers labour 10th month
Balance of the stock-breeders

$$\sum_{N_t M_t} W_{stj} X_j \leq \sum_{j \in S} K_{stj} X_j + X'_{st}$$

where:

N_t set of the indices of the variables, requiring labour in the period t;

W_{stj} coefficient expressing the necessity of s-th labour in the period t for the j-th variable;

S set of the indices of the variables, standing for the s-th category of workers;

K_{stj} coefficient, expressing the working days of the s-th category of workers in period t;

X'_{st} temporary aid (men/days).

These constraints place the requirement that the number of man-days needed for carrying out the technological operations in a given period of time should not exceed the sum of man-days which the permanent and temporarily participating in production workers could input.

In stock-breeding labour balance is not controlled in periods, but for the year as a whole, as labour tension in this branch cannot be considered as being evenly distributed.

(e) Constraints concerning the water resources, fertilizers, pesticides and power inputs.

$$\sum_{j \in H_r} m_{rj} X_j \leq L_r \qquad (1)$$

where:

H_r set of the variables' indices utilizing r resources;

m_{rj} rate of the utilization of the r-th resources from a unit j-th variable;

L_r r-th resource;

As regards the water resources, fertilizers, pesticides and power inputs the task has two formulations:

(1) Resource L_r is accepted with preliminarily determined volume, according to the state plans and forecasts;

(2) Resource L_r is regarded as a variable and the volume needed for realization of the optimum plan is searched in the solution process.

$$\sum_{j \in H_r} m_{rj} X_j = L_r \qquad (2)$$

Nitrogen fertilizer

Phosphorus fertilizer

Potassium fertilizer

Herbicides

Insecticides

Fuel

Electric power

Water

(f) Constraints concerning the balance of basic production funds and capital investments.

The change in the character, level and efficiency of production is determined to a great extent by the organization of new and the expansion, reconstruction, modernization, etc. of the existing branches and activities, by the construction of new production premises, the implementation of highly efficient technology, the increase of the number and the improvement of the animal breeds, crop irrigation, and better qualification of the workers, etc. All those require the respective amount of capital investments as a source for the increase of the basic production funds.

Compared to other production resources, which after undergoing a relatively stable distribution can be attached to individual economic organizations, capital investments could be transferred or redistributed between the organizations in the framework of the whole national economy. Land and labour force are considerably restricted in size and do not depend on the production resources, while the amount of capital investments is directly connected with production and its efficiency.

Regarding the necessity of the basic production funds the task may have two variants. In the first the need of capital investments is planned by accepting full provision with basic production funds on the basis of specific production technology and organization. In this case the norms of the planned funds volumes are determined by rendering an account of the full provision of production with basic funds. In the second variant the need of capital investments is planned by considering the existing potential level for provision of basic production funds in the planned period and rendering an account of the present conditions of the production funds. The possibilities for development in the planned period of the branches, ensuring agricultural production means, and the chance for import of machinery, materials, etc. are taken into consideration, too.

In planning the sum of capital investments necessary for a certain plan-period, the need of basic production funds at the end of that period is taken as a basis. The essence of this plan consists in the working out of the basic production funds balance, taking in mind their availability in the beginning of the planned period and their replacement on the account of new capital investments.

$$\sum_{j \in Z_g} V_{gj} X_j - X_g \leq U_g$$

where:

V_{gj} g-th type production funds, needed for a unit j-th variable;

X_g capital investments of the g-th type;

U_g known volume of the g-th type production funds;

Z_g set of indices of the unknown, using the production funds;

Necessary capital investments for machinery in plant growing;

Necessary capital investments for machinery in animal-breeding

Necessary capital investments for warehouses

Necessary capital investments for drying-houses

Necessary capital investments for premises in animal-breeding

Necessary capital investments for ensilage and hay storehouse

Necessary capital investments for animals (in herds)
Necessary capital investments for establishment of new irrigation areas
For qualification of labour hands.

(g) Pollution damages constraints caused by the technologies used in agriculture.

The realization of the task aiming to improve further the living conditions of our people requires the constant increase of industrial and agricultural production. In this respect the problem for the choice of optimal rates of production development, in compliance with the environment preservation is of essential importance. The expansion of the economic activities of man, the rapid development of industrial production and the intensive utilization of chemicals in agriculture increase man's impact on the environment, reduce natural resources and broaden the direct and indirect negative impact of man on nature and society itself. Destroying of the natural systems, exhausting of the natural resources, worsening the people's health conditions and a number of other phenomena, still poorly investigated, are being observed. As practice has shown, nitrogen fertilizing considerably increases the yields of agricultural crops, its inappropriate utilization, however, may bring forth nitrate pollution of the soil and subterranean waters, and it may have a negative effect on the quality content of plant nutritive products. The intensive nitrification of nitrogen fertilizers in soil and the transformation of nitrates in plants, man and animals may lead to negative consequences. The compounds of the nitrates with the secondary and tertiary amines, nitrosamines have strong cancerous effect.

Experts express a fear from the increasing nitrates in agricultural production, connected most of them with the utilization of great amounts of nitrogen fertilizers. One of the most important tasks today is to find a criterion for the nitrates content in soil which is on the one hand sufficient for obtaining high yields, but on the other admissible in terms of people's health.

Application of pesticides is one of the most widely distributed types of pollution of agricultural environment. Pesticides have great advantage in agricultural production contributing to a large-scale production and high mechanization of the processes but they have serious disadvantages too: whatever the poison is, earlier or later the pests get used to it. The immune specimens give posterity with increased resistance. Poisons have weak selective action. Wild animals and useful insects die alike. Most of them have cumulative effect on man's constitution.

As regards pollution the problem will be solved in two directions: with the first their total quantity D_e will be calculated; after which the respective experts will examine the nitrates in surface and subterranean water, the wastes in animal-breeding and surface waters, the soil sediment, agricultural production pollution, etc.; with the second some of them will be considered as known limit quantities, which should not be surpassed.

$$\sum_{j \in R_e} dej \cdot X_j = D_e \quad (1) \qquad \sum_{j \in R_e} dej \cdot X_j \leq D_e \quad (2)$$

where:

R_e set of indices of the activities polluting the environment;

dej coefficient expressing the quantity of the e-th polluter of the j-th unit activity;

D_e total quality of the e-th polluter.

The elaborated economic and mathematical model makes possible the change of optimum criterion and by varying the limiting conditions it answers the following concrete scientific tasks of the research work:

- what rate and level of agricultural production could be reached by maximum utilization (application) of the achievements of scientific and technical progress, with no restriction concerning the preservation of the environment, what kinds of inputs will be necessary and what will be the unfavourable influence on the environment; the gross production, net production, net income, etc. could be maximized in the objective function.
- Is it possible to reach a certain rate of increase of agricultural production (better sufficiency of society's growing requirements), placed as an obligatory condition for pollution preservation of the environment; the production costs or reduction costs could be minimized in the objective function.
- What rate and level of agricultural production could be reached by limiting the unfavourable influence of fertilizers and pesticides on the environment and the preliminarily set rates of production increase.
- What will be the influence on agricultural production of the national programs (forecasts) concerning the amount of agricultural inputs the production and import of fertilizers and pesticides; the production and import of technologies (energy/fuel) inputs in agriculture.
- What will be the influence on the production size of the obligatory implementation of technologies, ensuring minimum wind erosion.