A MODEL FOR LEARNING ABOUT THE AGRICULTURAL BUSINESS SYSTEM.

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ABSTRACT

The aim of our paper is to present a simulation model for training which enables the behaviour of the agricultural business system to be studied in the light of different scenarios and policies. We will show the potential applications of the model developed .

1. THE SYSTEM UNDER STUDY

Although the structure we are about to present may be valid for different agricultural businesses, the varying typology that can be found in this area as regards the number and type of products, type of soil, climate, etc., has forced us to delimit the object of our study.

The model developed (Melero and Machuca, 1994) corresponds to a business in Córdoba (Spain) with 30 hectares of irrigated land, with the soil 30% clay and the normal levels of fertilizing elements. It is devoted exclusively to agricultural activities, growing just one product: hard wheat.

2. OBJECTIVES OF THE MODEL.

Our aim in the present study has been to construct a simulation model for training which will make it possible:

* to study the behaviour of the agricultural business system in the light of different scenarios and policies, seeking the causes that have brought them about,
* to analyse and evaluate the possibilities offered by System Dynamics as a tool: for planning in the agricultural business, for understanding the causes behind the phenomena observed, and for analysing the consequences of the decisions made,
* to use it later as a means of learning and evaluation in decision-making, both for managers and university students.

3. STATE OF THE QUESTION.

Traditionally, the modelling of an agricultural business has been carried out using optimization models[1]. In agriculture, the application of traditional simulation models is recent. At the global business level we have found simple models which show the transformations of inputs into outputs, but without explaining the mechanism which exerts an influence on the process under simulation[2]. As regards System Dynamics, we have found some references concerning applications in the stockbreeding sector[3]. In the agricultural sector, Street and Dent (1968) limit themselves to presenting the peculiarities of an agricultural business, and the methodology to be followed in order to use this approach; Bala et al. (1988) use System Dynamics only to model irrigation policies. As far as more global models are concerned, their potential for application has previously been unexploited.

4. CONCEPTUALIZATION OF THE SYSTEM

To develop the causal-diagrams we have spent months of work with a great number of experts on the agricultural sector. We have grouped the selected elements together in three subsystems: production, commercial and financial.

4.1. The production subsystem.

In developing this we have considered the technical and economic aspects of the process and, when possible, we have modelled the biological aspects.

The land is the basic resource on which the other factors of production are applied. Specifically, as factors affecting performance we have taken into account the following: *genetic, nutritional, sanitary, climatic, and production capacity.*

The variable representing the **genetic factor** is *seed* (fig.1), a basic factor if the expected production is to be achieved. The quantity to be used is determined by the type of crop chosen by the farmer on the basis of the potential production he hopes to achieve. It is impossible to achieve greater quantity than that permitted by the variety used.

In the category of **nutritional factors** we have considered the availability of water in the soil and the fertilizers available.

To explain the causal-loop diagram for *availability of water in the soil* (fig. 2) we have distinguished between demand and supply. Demand is determined by the potential evapotranspiration of the plant[4]. This depends on the temperatures and the needs of the crop at each of its stages of vegetative growth, the beginning of which will depend on the date of sowing, and the climatic conditions of the zone, especially temperature. This demand must be satisfied by the total water available in the soil (TWA). In this respect the ground has been regarded as a tank whose capacity will vary with the type of soil and the depth of the roots. To obtain maximum yield, the actual evapotranspiration, which is the real absorption by the plant depending on the water available, must be equal to the potential. Otherwise, the discrepancy will give rise to a reduction in yield because of inadequate moisture, if it occurs at times of great sensitivity to lack of water.

The increase in the level of total water available is achieved by rainfall and, if this is insufficient to meet the needs of the crop, with irrigation water. In addition, not all the moisture is available to the plant, since that which is at a greater depth than the roots is lost by percolation[5].

The irrigation water supplied depends on needs and availability. It is required if the humidity of the soil falls below a minimum recommended level at times of great sensitivity to lack of moisture.

Nutrients and fertilizers are another important factor (fig. 3). We have only modelled the influence of the macronutrients: Nitrogen, Phosphorus and Potassium. The amount of fertilizers to be applied is determined by the richness of the soil, the unitary needs of the crop, the potential production and the degree of fertility desired. Their application, when possible, will increase the richness of the soil, which in turn will be reduced by the absorption of the plant. Modification in yield occurs if this absorption is not suitable and affects the projected production and its quality.

In addition, we have considered **sanitary factors,** as every plant is exposed to a series of phytopathologies: *weeds, pests* and *diseases* which restrict development (fig. 4). Their presence raises the possibility of applying treatment to combat them. If this is not done, there will be alterations in the production, both quantitatively and qualitatively.

All the factors described so far can be controlled by the farmer at the planning stage. **Climatic factors**, though not controllable, have to be taken into account. There is no point in having the *temperature* favouring the progress of the productive cycle if an excess or lack of heat in just one day, at a critical moment, destroys the crop. The influence of the temperature affects both the quantity and the quality of the projected production (fig. 5).

The above factors determine the projected production per hectare. Total production depends on the surface-area devoted to the crop in question. In our model, since we adopt a single-crop hypothesis, the whole of the available surface-area is cultivated, the possible salvo being that, in order to qualify for certain subsidies, a decision may be made to withdraw a certain quantity (fig. 6).

In order to culminate the production process and apply the controllable factors, it is essential to carry out certain operations mobilizing labour and certain elements of the fixed production equipment, *factors* we have termed *production capacity*.

For the management of *machinery* it is necessary to determine the total capacity available, measured in hectares per time-unit (fig. 7). In principle, this coincides with the capacity of the machinery owned; the latter depends on the number of machines in the business' ownership, on their productivity and on the hours available with each of them (it is assumed, with a driver). This capacity will allow the different operations to be carried out over the whole of the cultivated area. In addition, we consider that we have a certain number of days when it is possible to carry out each of the tasks envisaged. We call these days the maximum length of the operation; if the work cannot be finished in this time with the farm's own capacity, then capacity will be increased, assuming this is possible, by means of hired machinery. Otherwise, the duration of the job will be longer, with the risk of loss of yield.

In modelling *labour* (fig. 8) we have distinguished between non-qualified (farm labourers) and qualified (drivers of tractors and other self-propelled machinery).

The number of driver-hours available depends on the length of the working day and the number of drivers, which we have assumed to be consistent with the number of machines to be used. The difference between the availability and the use of drivers, which is dependent on the productivity of the machinery and the surface-area to be cultivated, may lead to a discrepancy which will increase the availability of drivers with overtime.

The seasonal nature of the operations deprives the labour force of opportunities to practise their speciality in a continuous manner, and encourages them to become involved in other work. Thus, manpower not used in driving increases, together with the labourers, the number of hours of qualified labour available to carry out unqualified jobs. Again, a comparison with the existing needs will lead to a discrepancy which will have to be corrected with overtime.

4.2. The commercial subsystem.

Once the crop has been harvested, the process of marketing begins (fig. 9). The harvested production is a function of the projected production per hectare, which is determined by the factors of the subsystem of production and the number of hectares harvested. We have assumed that if machinery capacity is inadequate to complete the operation in the expected time, the unharvested product will be lost in the field.

Having been harvested, the crop can be stored, waiting for more favourable market prices, or be sold immediately. The quantity stored depends on the total harvested and storage capacity. We will assume that any production exceeding this capacity will be sold at once, although there would be no difficulty in introducing any other hypothesis.

Production stored may be reserved for the official Intervention Organizations (like the "Servicio Nacional de Productos Agrarios" [SENPA]) or else private commercial circuits. The quantity of sales to each destination will depend on the quantity stored and changes in prices. If the product does not satisfy minimum quality standards to qualify for intervention it must necessarily be sold on the market, although logically at the price of a product regarded as fodder-wheat.

4.3. The financial subsystem.

Finally, in modelling this subsystem we have aimed to quantify the economic results, as well as the liquidity generated by the agricultural activity.

In quantifying the **economic results** (fig. 10), we apply the term "explotation profits" to that directly attributable to the production activity of the business. It is calculated from the *contribution to fixed costs and to profits* and the *fixed costs*. If alongside this we consider the *subsidies* given by the European Union for surface-area available, we will have the *profits from ordinary activity*. The latter allows us to analyse the effects the Common Agricultural Policy may have on the behaviour of the system. If in addition we consider the financial results from *receivable or debit interests,* we will obtain the *pre-tax profit*, and if we deduct taxes, the profit for the whole financial period.

The value of the **sales** (fig. 11) is determined by the sale of products to intervention organizations or the market, and by the sales price in each market. The sales price has been considered external data and therefore beyond the control of the farmer.

Let us now consider **costs** (fig. 12). Their value depends on the prices of the different factors, which constitute an exogenous variable which can scarcely be controlled, if at all. They are explained on the basis of the input leading to them, distinguishing between fixed costs and variable costs. We have considered the following:

- *Raw materials and products*. For the whole of the surface-area cultivated, this category includes the value of seeds, fertilizers and treatment required by the crop. It forms part of the total variable cost. Here there is only reference to the cost of the factor in question; that corresponding to its application is considered globally under the heading of labour and machinery.
- *Irrigation water*. This gives rise to different cost categories. Fixed irrigation costs are formed by: amortization and maintenance of equipment and facilities, the cost of installed capacity and the irrigation rate payable to the corresponding Water Authority. They depend on the surface-area available and represent fixed costs (costs arising from the use of energy necessary to carry out the irrigation have been regarded as other fixed costs. The labour cost involved in irrigation is considered an integral part of the total labour costs).
- In *manpower cost* we have distinguished between labour connected with permanent exploitation (drivers and labourers) which come under fixed costs, and labour used sporadically, to complement the permanent labour force, at peak working periods and to carry out unqualified jobs. This comes under variable costs.
- *Use of own machinery* gives rise to various cost categories: amortization; repairs (which we have considered as variable); consumption of fuel and lubricants (a variable cost) and machinery insurance (which has been included with insurance in general, forming part of the fixed costs).
- The cost involved in the *use of hired machinery* has been regarded as variable.
- *General insurance*, that is, accident insurance and public liability insurance, is part of fixed costs, as is *crop insurance.*
- *Tributes* (property tax and social security payments for the theoretical number of working days) form part of the fixed costs.
- *Amortization of other assets* covers the amortization of the other assets not considered in previous categories and is regarded as a fixed cost.
- In *other fixed costs* we have included items like repair and maintenance of buildings, roads and fences, supply of water for domestic use, supply of electricity for domestic use and irrigation, administrative and commercial costs, because of their relative unimportance in this type of business.

Finally, all the operations carried out by the business are translated into a **monetary flow** (fig. 13). Increased liquidity is achieved by *exploitation revenues, aids from the European Union* and *receivable interests* generated by liquidity. A reduction in liquidity comes about when effecting the *payments* occasioned by the purchase of raw materials, salaries, insurance premiums, hiring of capacity, tributes, fuels, repairs, part of the fixed irrigation costs and other fixed costs, as well as taxes. The non-synchronization between incoming and outgoing payments can lead to *financial requirements* which will prompt a search for additional resources. Resources of this type increase liquidity but also give rise to outgoing payments in the form of interest and capital.

5. FORMALIZATION AND TESTING OF THE MODEL.

The **formalization** was based on the conceptualization presented above, resulting in a model with 430 variables and equations: 244 correspond to the production subsystem, 25 to the

commercial and 161 to the financial. The production subsystem has turned out to be the most complex, given the difficulty involved in establishing the nature of the interaction between the different factors of production. Production has been calculated bearing in mind the following considerations:
- Potential production would be achieved assuming no shortage of water and the application of suitable fertilization.
- Once the potential production is known, the first thing to be calculated is the production resulting from the moisture levels, since the actual evapotranspiration will be the same, independently of the amount of fertilizers available for the plant. After this, it is the production resulting from the moisture that will determine the need for nutrients. Thus, if a shortage of water leads to a reduction in the potential production, fewer fertilizing elements will be needed. Excessive water levels have not been considered, since this is not a common phenomenon in the zone studied.
- Irrigation imposes a greater need for nutrients since, water not being a limiting factor, greater production is possible along with greater extraction of nutritive elements. When the needs per production-unit are known, this is reflected in the variable *moisture production.*
- Fertilizers increase the efficiency of the water. For the same amount of water, fertilizing will permit greater production. Although the total quantity of potential evapotranspiration is the same, there is an increase in the percentage of water used in effective transpiration work and a reduction in the amount of water evaporated to no advantage in the soil. Thus, if on top of a lack of water we have inadequate fertilization, this will be another limiting factor affecting production. Actual evapotranspiration will be the same but the proportion between evaporation and transpiration will vary in favour of the former, with the subsequent reduction in yield.
- The length of the harvesting period affects, not production per hectare, but total production since, we regard as lost in the field any product that is not harvested by a certain date.

As regards the **validation,** since we had no access to data for the construction of reference modes, we have opted for a qualitative study, based fundamentally on the opinion of experts, concerning the behaviour of the model within the hypotheses under consideration. Our reasons for considering the model valid in relation to the data used and the relationships proposed are based on the fact that it offers feasible results which are completely supported by opinions regarding the behaviour of the real system. The study consisted in the sensitivity analysis and simulations of the model produced.

The **sensitivity analysis** was carried out by modifying different parameters and observing their effect on the evolution of the system. For example, we have analysed the influence of changes in the starting time of sowing on the development of the vegetative period, on irrigation needs and on the projected production; other parameters analysed are the availability of water for irrigation, the time and quantity chosen for irrigation, the availability of fertilizers, the application of phytosanitary treatment, temperatures, the productivity rates of different types of machinery, the number of tractors and labourers, the surface-area available, etc.

In connection with the **simulations** carried out, they have enabled us to establish behaviour in different climatic conditions (rain fall and temperatures), the behaviour of sales prices, the seasonal nature of production operations, the seasonal nature of incoming and outgoing payments, the type of aid from the European Union and the evolution of profits.

6. SOME RESULTS OF THE EXPERIMENT.

Different policies have been tested to help improve our understanding of the system under study, to increase the number of validation tests for the model developed and to demonstrate its potential. By means of these policies we have shown the influence exerted on the behaviour of the system by different possible surface-areas and by the possible inexistence of the Common Agricultural Policy (CAP).

For reasons of space, we shall only comment on one of them here, that is, the results of one of the policies which might be followed by farmers to counteract the effects of a reform of the CAP: a *renunciation of the withdrawal of land from cultivation*, as proposed by the Community.

To be elegible for the system of subsidies, farmers must obligatorily withdraw from cultivation 15% of the surface-area devoted to the cultivation of cereals in previous years. On the one hand, renunciation of withdrawal of land from agricultural use would mean that no type of compensation would be received (simulation 1, fig. 14). On the other, it would make it possible to receive greater subsidies for the production of hard wheat (fig. 15)[6] since the surface-area given over to it would be greater (fig. 6).

The total amount of aid received, as well as the timing of it, can be seen in fig. 16, which shows that the more firmly established the reform, the more it is in the farmer's interest, at least from the point of view of receiving aid, to follow Community guidelines on withdrawal of agricultural land. However, this is not the only factor that determines profits (fig. 10). It can be expected that such a withdrawal will have effects on income from sales and variable costs, which will reduce (except in the first year simulated, when withdrawal is not yet obligatory) (figures 17 and 18).

The reason is that the smaller surface-area cultivated will make it possible to produce and sell less (see fig. 9), with the consequent repercussion on revenue (see fig. 11) and on costs (see fig. 12), as the consumption of the variable factors is reduced. The quantitative differences from one year to another can be explained by the productions projected and also, in the case of revenues, by the variation in prices. The final result of the behaviour, unfavourable as regards revenues and favourable as regards costs, together with the behaviour of the E.U. aids is reflected in figures 19 and 20, which show the effects the policy of land-withdrawal would have on the results of the yearly profit and liquidity respectively.

To eliminate the possible effect on the results of variability in production, we have also analysed the situation in which there are no limiting factors, as a result of which, in all the years simulated, actual production coincides with the potential, unless climatic conditions are unfavourable. Figures 21 to 23 show the behaviour of revenues, variable costs and the result of the yearly profit in the hypothesis under consideration. We can deduce that the agricultural policy measure involving the withdrawal of land would only in part manage to improve farmers' financial-economic results in a business of the characteristics of the one simulated.

7. BY WAY OF CONCLUSION.

To finish, we would like to stress the usefulness of the approach we have employed: 1. The model produced provides a tool to study the response of the system to modifications in the environment or structural changes, considering the business as a whole; 2. In the area of training, the model developed serves as a tool with which to communicate the general principles, making it easier for those not familiar with the system to understand the causal structure and the behaviour it brings about; 3. The potential of simulation goes beyond the university environment and, although further research is needed, it may be of use in dealing with problems of agricultural management, in that it makes it easier to understand systemically the causal structure of agricultural businesses. Greater knowledge should be reflected in better management; 4. Our research provides sufficient ideas on how to go about modelling systems of these characteristics, as we consider that much of our work could be applicable to other studies.

In spite of the limitations of our research, we hope we have made some contribution to a field -agricultural businesses and their management- which has been seriously neglected by developments such as the one presented here. We would also like to think we have contributed to the dissemination of System Dynamics as a precious tool with which to achieve a better knowledge of the agricultural business system, and that we have shown the possibility of this method being used by those interested in managing such businesses, providing a base to design, understand and improve the systems under study.

Notes

[1] As an example we might mention the works of Judez Asensio (1975), Hazell and Norton (1986), Cabanes Fuentes (1987), Romero and Rehman (1989), Dent (1990), etc.

[2] In this respect, see Zusman and Amiad (1965), Hutton (1966), Eisgruber (1965) Hesselbach and Eisgruber (1966), Patrick and Eisgruber (1968), Donaldson (1968) Johansson (1969), Dalton (1969), Hinman and Hutton (1970), Beck, Harrison and Johnston (1982), Elderen (1987), Klein, Kulsreshtha and Klein (1989), Walker and Stuth (1989), Sorensen (1989), etc.

[3] Halter and Dean (1965) , Crabtree (1969), Charlton (1972), Blackie and Dent (1974), Girault (1974), González de Chaves (1981), Bowman, Wysel, Fowler and White (1989), White (1983), Uys (1989), etc.

[4] Evapotranspiration is the loss of water through evaporation and plant transpiration. Potential evapotranspiration represents the amount of water required for optimum yield, without limitations.

[5] Percolation is the loss of water, in excess of the capacity of the ground, to deeper layers. It is lost in that it ends up beyond the reach of the roots

[6] It should be stressed that receipt of aid is not linked to land-withdrawal

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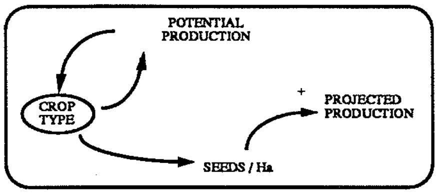

Fig.1. Influence of seeds on production

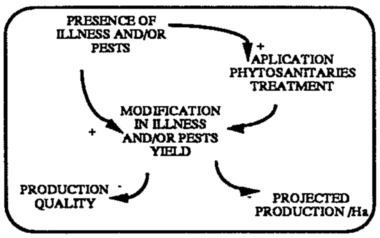

Fig.4.Modification of yield and phytosanitary treatment

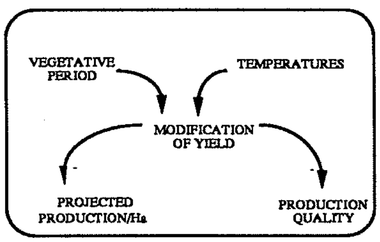

Fig.5. Modification of yield and temperature

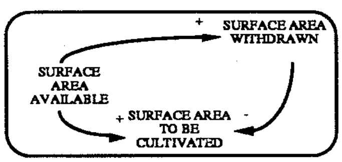

Fig.6. Surface area to be cultivated

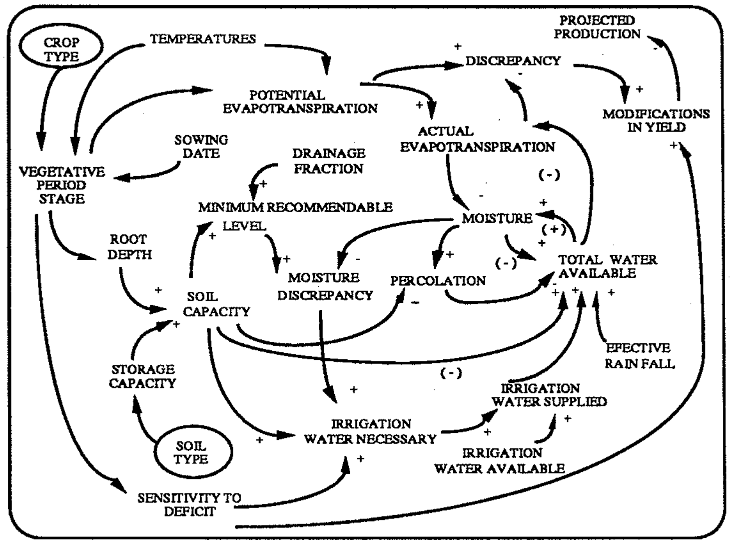

Fig. 2. Problems of soil moisture

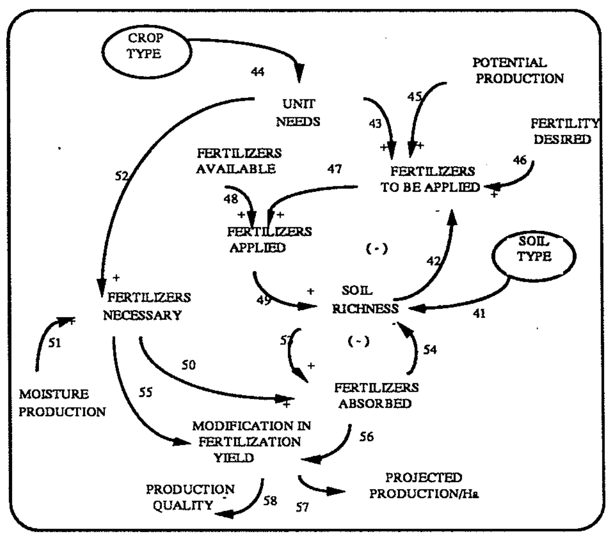

Fig. 3. Modifications in yield and fertilization

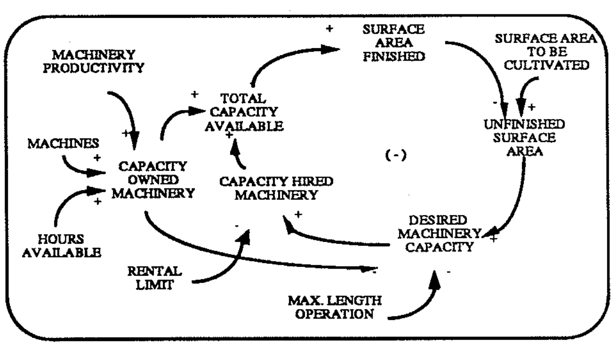

Fig.7. Machinery diagram

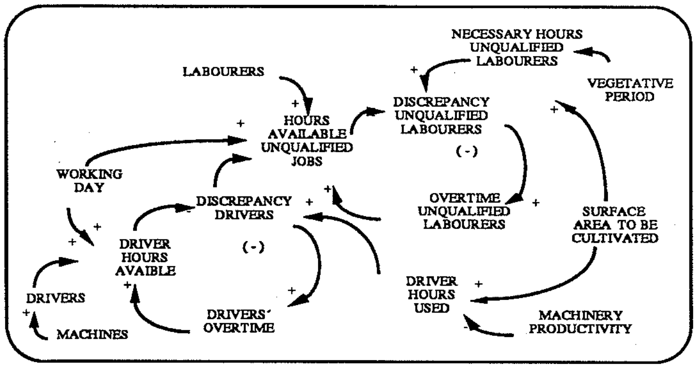

Fig.8. Problem of labour

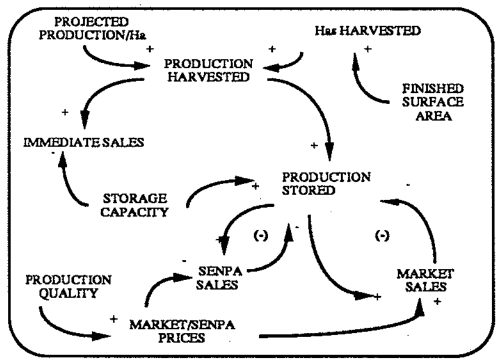

Fig.9. Production in store

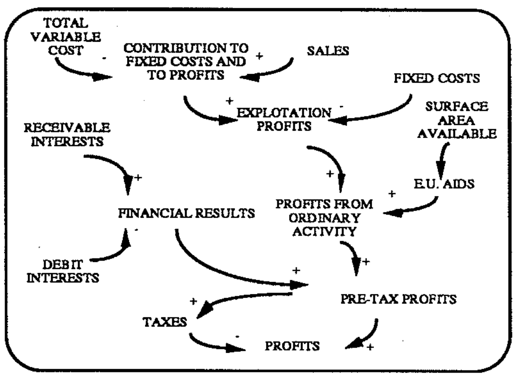

Fig.10. Results for the financial period

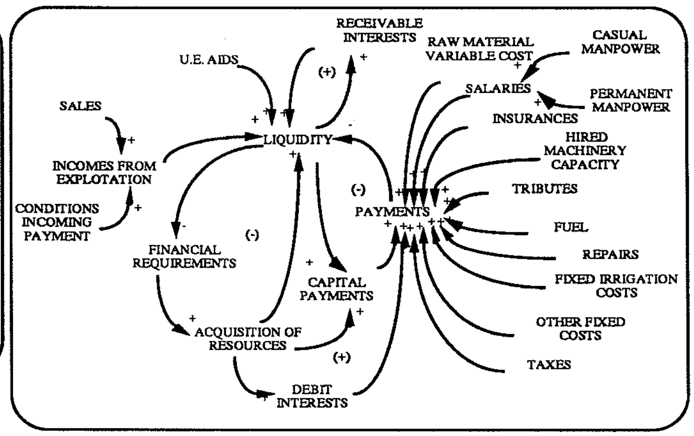

Fig. 13. Monetary flow

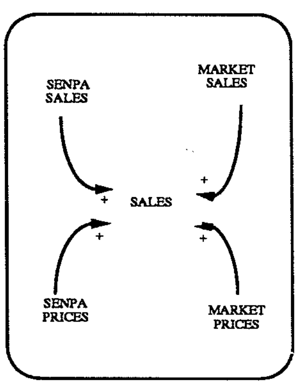

Fig.11. Revenues from sales of production

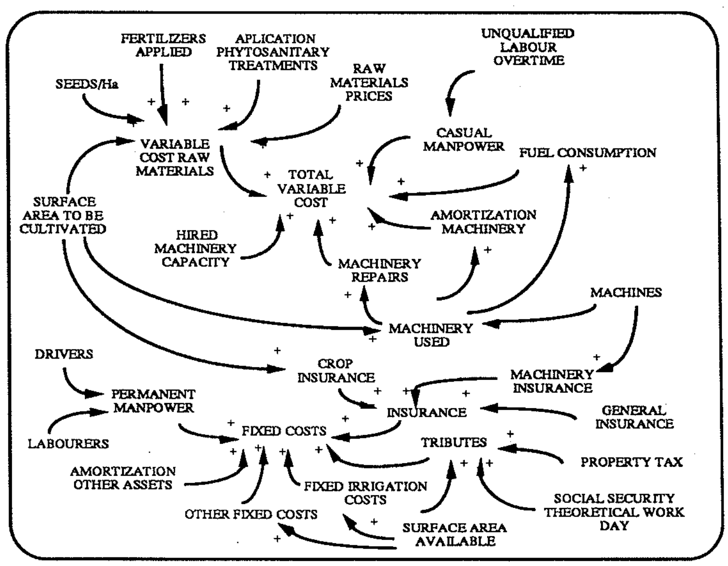

Fig. 12. Production costs

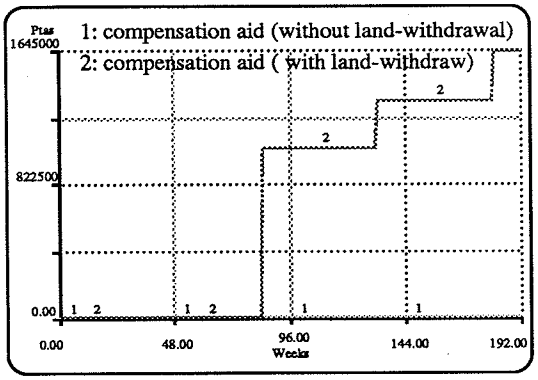

Fig.14. Impact of land-withdrawal on the amount compensatory aid

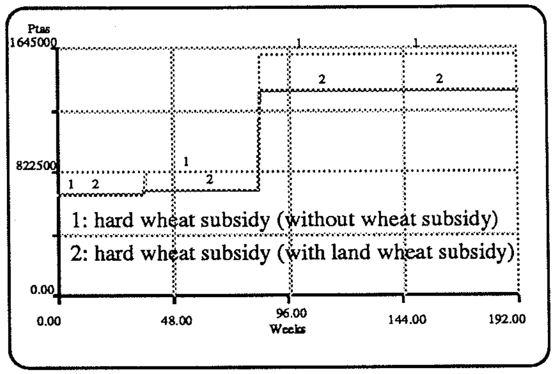

Fig.15. Impact of land-withdrawal on the amount of aid for hard wheat

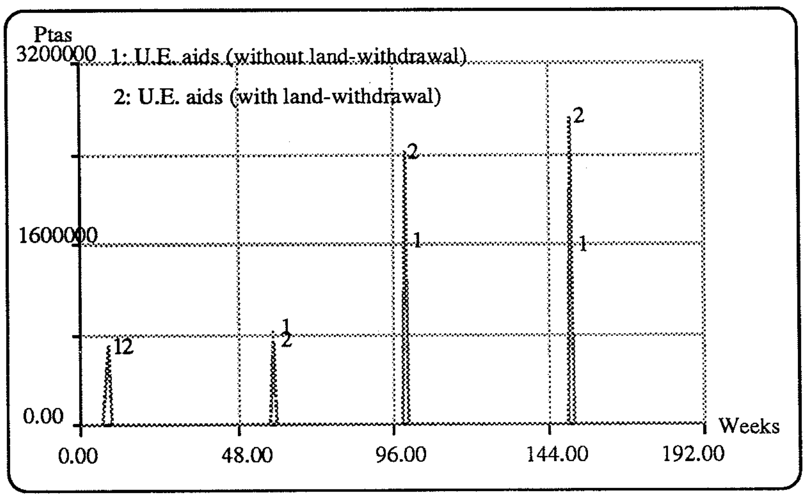

Fig.16.Impact of land-withdrawal on the total amount of aid

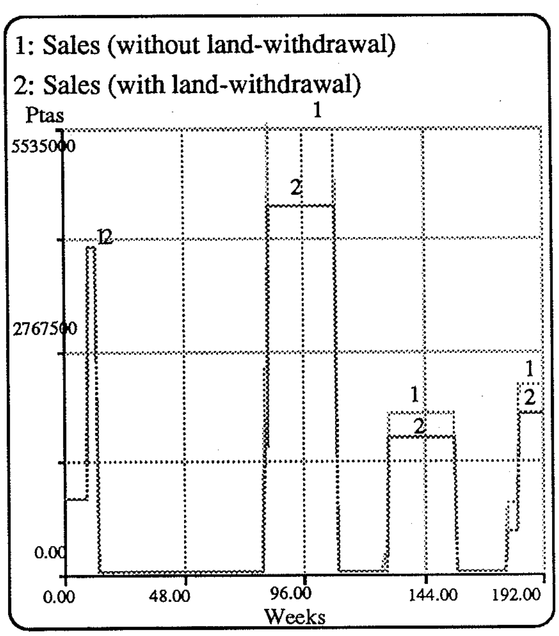

Fig.17. Impact of land-withdrawal on sales (A)

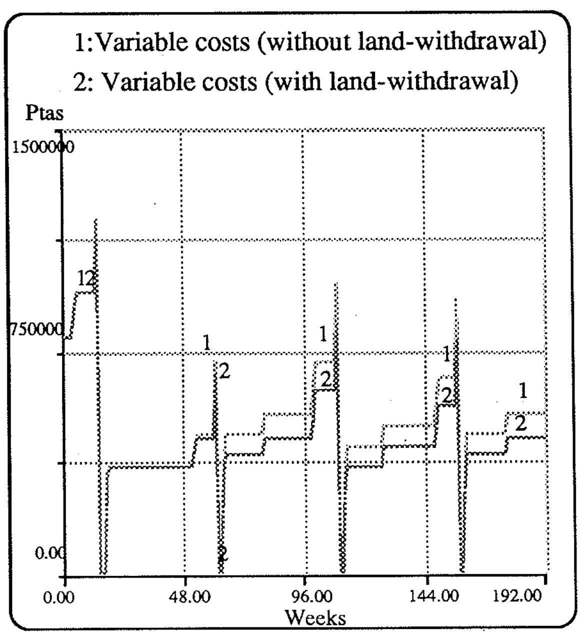

Fig.18.Impact of land-withdrawal on variable costs (A)

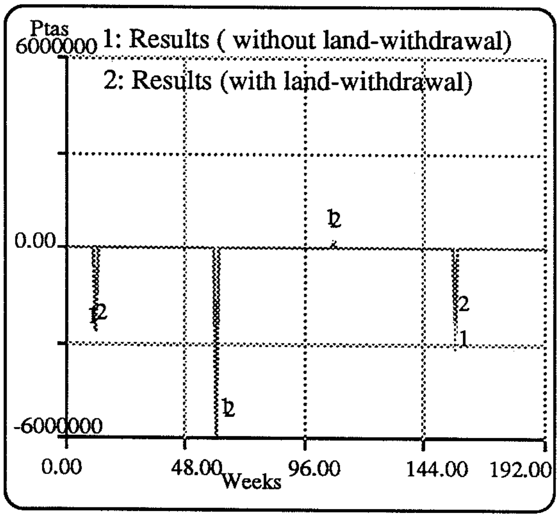

Fig.19.Impact of land-withdrawal on the results of the period (A)

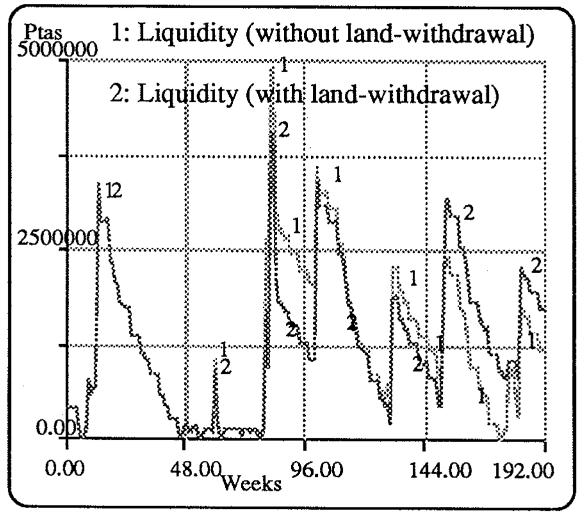

Fig.20.Impact of land-withdrawal on liquidity (A)

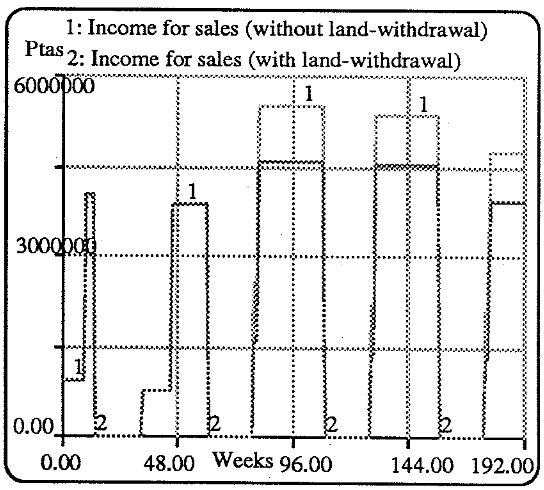

Fig.21.Impact of land-withdrawal on income from sales (B)

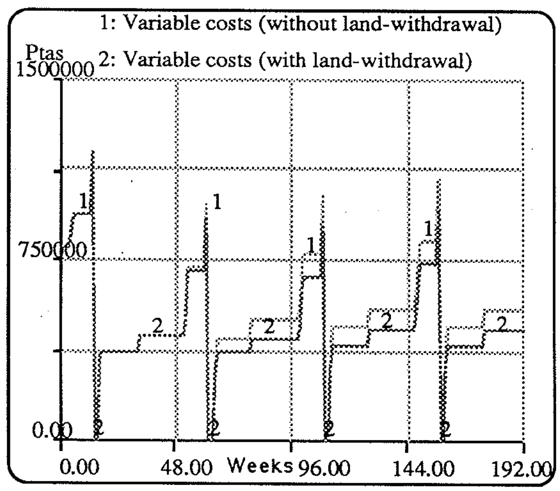

Fig.22.Impact of land-withdrawal on variable costs (B)

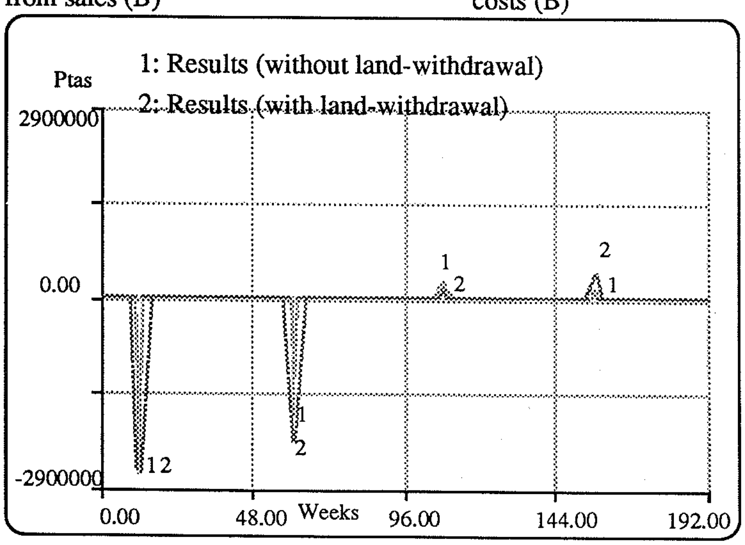

Fig.23.Impact of land-withdrawal on the results of the period (B)