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Full Length Research Paper

A system dynamics design for the structure of irrigated wheat mechanization in Fars province (Southwest Iran)

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The focus of this paper is on the mechanization of wheat, one of the oldest and most important and valuable plants on earth. Considering the fact that Fars province in recent years maintains the premier status in the production of this crop, in the country, a systemic view toward the mechanization of this product, may serve in the enhancement of efficacy of production. As far as the writer knows, such study on the mechanization of agricultural products is not carried out anywhere in the world. Here, in accordance to the methods of system dynamics, the authors utilized significant technological and economic factors, to design a System Dynamics (SD) structure for irrigated wheat (Triticum) mechanization in Fars province, Southwest Iran. The professional field known as SD has been developed for the last 55 years (1960) and it now has a world-wide and growing membership. SD combines the theory, methods, and philosophy needed to analyze the behaviour of the system, not only on its management, but also the environmental change, politics, economic behaviour, social science, medicine, engineering, agriculture and other fields. The System Dynamic model can be used to modify a few variables of the designed model which are important to future policy making, including optimum field capacity, wheat yield, and planting area, so that the proper efficacy is achieved. The overall results shows all measures leading to the reduction of the traction force, will result in the reduction of mechanical energy consumption of the plowing operations or mechanization capacity, and also increase the degree of mechanization, annual planting area and field capacity. The timeliness cost will also be reduced.

Key words: Agricultural mechanization, system dynamics, wheat yield, simulation model, fars province.

INTRODUCTION

Wheat is one of the oldest and most valuable plants on earth. It is quantitatively cultivated more than any other crop, and offers more calorie and protein in food portions for humans. The yield rate of this product has been increasing continuously throughout the world, such that, in 2000 the rate increased to 2710 kilogram per hectare.

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At the present, China, EU, India, USA, and Russia are respectively, the biggest producers of the crop. In Iran, the irrigated wheat planting area was between 2.35 – 2.8 million ha, with the average of 2.22 million, during the years 1982 to 2000. The yield has increased from 1840 kg per hectare in 1981, to about 3200, in 1999. However, in 2000 the irrigated wheat yield suffered a reduction, because of a severe drought.

Farts province has, every year, gained the premier status in the production of irrigated wheat, during the past years. The area of planting of this product in Fars, has recently been about 350000 ha in two years, almost all of which being mechanized planting. So the presence of a scientific view toward the mechanization issues may bring positive consequences for the production of irrigated wheat planting.

In one definition, mechanization is introduced as the utilization of modern technologies along with the observance of all the necessary aspects production for the enhancement of efficiency. Accordingly, taking the technological and economic factors into consideration as important aspects of the mechanization of wheat production in the province would be of special significance. So, it is important to study and analyze the mutual influence of the related factors, with the purpose of enhancement in yield and efficiency. These mutual influences and their outcomes can be expressed through a systemic viewpoint.

In many studies on agricultural machinery and mechanization, researches have been conducted about the mutual influence of technologic factors, and also their influence on yield production and the effects of other economic indexes. However, what is definite so far is the loss of any studies on finding the relationships between interactive factors, regarding the factor of time, and their total influence on the activity of mechanization. Systemic viewpoint claims the introduction of a method for a more fundamental treatment to the complexities of today's world, and, the relationship between related factors in agricultural mechanization is not an exception.

Regarding the subject of this paper "mechanization of irrigated wheat in Fars province", and the importance of this strategic crop, and also the fact that Fars has been the premier producer of this crop for several years, the relationship and the influence of different factors related to the issue of mechanization is of crucial importance. However, the loss of a systemic viewpoint to this kind of activity, has led to an incomprehensive manner in almost all of the research done in the province. Instead of pursuing the relationships existing among the many related factors, there is merely a look towards the influence of some limited factors on the matter of yield. The outcomes of such studies, although based on good statistical methods, suffer loss of a comprehensive viewpoint to irrigated wheat mechanization in Fars province. And the reason lies in the fact that these studies were simply based on comparisons between the influence of a very limited number of factors on the yield or on the elements of yield. The fact is that the rates of the majority of these factors undergo changes over time, so that the related outcomes lose their significance for future usages. Therefore, the general problem that we are facing here can be stated as:

Regarding the overall influence of the factors including climate, soil, technology, economic and social factors, etc, on irrigated wheat planting mechanization in Fars province, and considering changes that these factors undergo over time, what sort of systemic structure, indicating the status of the relations between all the above mentioned factors, can be utilized in order to evaluate the present situation, and how this structure can serve in decision making against present and foreseeable scenarios related to irrigated wheat mechanization in Fars province. The enhancement of efficiency is the ultimate goal.

To treat the problem, the authors' have the idea of drawing a systemic model for irrigated wheat mechanization in Fars province. The systems theory was introduced by Bertalanffy in 1940. It is based on the assumption that deep down in all the problems, there exist a chain of principles and criteria, which horizontally cross all the scientific systems. That is, some major principles and criteria can be achieved, which, irrespective of their kind, define the overall behavior of systems. It is true that each one of the scientific trends of agricultural engineering have their own viewpoint about a certain dimension of planting this crop, so no single one of these trends can individually view the whole relationships that exist between the influential factors, which in their turn are related to certain different fields of study in wheat production. So the treatments offered for improvements in wheat production processes by different experts, reveal to be inefficient, mainly because of the limitations in their viewpoints. The authors' wishes to introduce a systematic design for irrigated wheat mechanization in Fars province.

An underlying assumption for all systems is that they are *dynamic* entities. Moreover, a *cause-effect* relationship exists between the components of a system, so that in almost all of the cases the passage of time leads to the development of a phenomenon, and eventually, that phenomenon will become the cause of a new factor. For example, if "poverty" is looked upon as a social phenomenon developing over time, and it leads to the reduction of income, and this reduction, in its turn prevents the farmer from conducting mechanized practices, that again leads to the reduction of the farmer's income, which accelerates the initial poverty. These effects emerge in the form of sequences in time, so this is the reason why it is said that systems undergo changes over time and also they are dynamic.

The methodology used for designing the systemic structure of irrigated wheat mechanization in Fars province is called System Dynamics (SD), used for studying and managing complex systems such as mechanization of agricultural production. The methodology was first introduced by Forrester and its first realm of application was in strategic management of industrial problems.

Literature review

Scientific magazines and different internet platforms were reviewed and several cases of the applications of SD were found, but none was involved directly in the mechanization of agricultural production. Nonetheless, some researches involving other topics are stated for illustration.

The idea of utilizing an SD approach in urban problems was introduced by Forrester (1969) in his book "Urban Dynamics". He discusses the settlement phases of different urban areas in cities of the U.S. His discussion is highly similar with the discussion of city dynamics. The SD by Forrester includes three sub-systems of population, dwelling, and industry, interacting with each other. Forrester, based on the model, proposes that for enhancement of the cities' conditions, the financial aids should be allocated to training programs, rather than to building low cost houses.

In some other researches, the factors influential in agricultural products, were simulated in a framework of a dynamic system. Bisht et al. (1994) simulated soybean production in India to a model of systems dynamics. Soybean is considered a relatively cash product in that country. In this model, factors like variations in planting area of different products, economic efficiency of soybean compared to rival products, annual rates of production, prices and cost proportions, were analyzed.

In this research, the fixed values considered for the factors of simulated system were determined according to farmers' evaluations and experts' hypotheses, and finally all the decisions concerning soybean production were made on the basis of long-term higher benefits.

In some other studies related to SD, investigations have been carried out about efficient policy making to challenge current land problems. For example, Naeem and McLucas (2006), utilizing SD, designed a model for the problem of salinity of dry lands. They realized this dry land salinity as a problem which increasingly, reduces the planting ability of the lands, and leads the agricultural production to a situation in which the long-term crop potentiality of the land diminishes.

In Australia, along with the destruction of millions of trees for creating more crop production areas, the situation is worsening. In this investigation, the major indexes influential in the behavior of land salinity, were used as factors for designing a system dynamics model. The model was then used in creating the chances for strategic management of land salinity in the Mary Darling region. The designed SD model was based on the indexes already determined for soil salinity. The behavior of the system was analyzed after modeling and its validity in expressing the causes of dry land salinity and, also in offering possible procedures for compensating the problem, widespread in the lands in critical conditions, was tested.

Still, other researchers utilizing SD have dealt with studying the level of environmental capabilities in projects of agricultural development. Saysel et al. (2002), stating potential influences of regional agriculture based on the development of water resources on the social and natural environments, related long-term, potential environmental problems in south regions of Anatoly (GAP), to factors such as water resources, land special usages, land reduction, agricultural pollution, and the rates of population. Furthermore, the interaction of these factors from a systemic point of view was taken into account. The focus of the analyses of this study was the general environmental, social, and economic issues. So, an SD model was developed as a tentative experimental base for the analysis of different decisions. Initially, using a range of registered experiments, the structure of the system was tested, and the behavior evaluated in the face of available information.

The behavior of the SD designed showed that: simultaneous to the expansion of irrigated fields, the southeast areas of Anatoly was faced with a significant reduction in water supplies. The reason was an increase in the accumulation of cotton crop, which is a product with high water demand. The results gained from the model also showed that the application of two environmentally important factors, that is, pesticides and fertilizers, may reach to an undesirable level. In the model, policies such as alternate liberation of irrigation water, the expansion of irrigated fields and rotation of crop production, was introduced as measures for sustainable protection of the environment. The SD designed by these researchers, granted the hope that it not only is a helpful decision-making instrument for the administrators of southeastern regions of Anatoly, but it is also a total structure utilizable as an efficient measure for the regional development projects.

The instrument of SD has also been helpful on the issues connected to rural and agricultural development. The most noticeable research on the issue being the studies done by Thomas et al. (2008), conducted in eleven countries. The purpose of the research was to elaborate a model of rural and agricultural development, in order to gain a better understanding of the crop, and ecological, economic, and social dimensions in the rural regions.

The resulted model which was called "The agricultural, rural model for policy-making on multi-purpose development" was the outcome of a research team from eleven countries in the world. The model includes seven sub-categories of land, agriculture, tourism, region, human resources, cash investment, and the level of life.

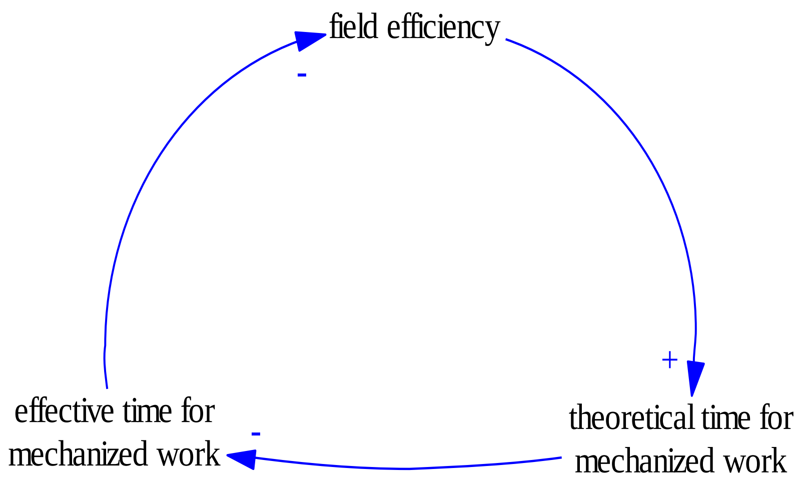

Figure 1. An example of a causal loop including three factors.

A series of input indexes and demand are also included. The special usage of the land is the key input index to the system. The index of land special usage connected to the production opportunities, the determiner of the cash investment, are the output of the system. The index of the level of life is somehow originated from the regressive analysis coefficient of immigration index, and the index of demand is found to be affected by the individuals' job enhancement.

All the above-mentioned studies, have utilized the methodology of system dynamics in the analysis of the interactions between the elements existing in the sub-categories, and according to the current scenarios, specified and evaluated the system's behavior, and used the results for solving the current problems.

MATERIALS AND METHODS

System dynamics model

The models built on the basis of SD provide the opportunity for introducing the quantitative and qualitative variables simultaneously into the system. This is a very important advantage, because the same is very difficult to conduct through the mathematical models. The models are based on empirical approach, and are formulated according to a computerized simulation. This approach makes it possible to form non-accurate equations for qualitative variables, then providing numerical simulation for them, to understand and realize their influence on the whole system.

The components of the system dynamics

Causal loop diagrams

These diagrams are instruments for drawing the causal relationships among a set of variables (factors) involved in a system. The fundamental elements of the causal loops are variables (factors) and arrows (relationships). A variable is a situation, an attempt, or a decision which may have influence on other variables or be under their influence. Variables may be qualities or quantities. For example, wheat planting area is a quantitative variable, while the rate of market acceptability of produced wheat is a qualitative variable. The second element of causal diagrams is the relationship among these variables. An arrow (relation) shows the causal correlations between two variables or the rate of change in the variables. For example, increasing the ratio of used width for the implements reduces the effective time for mechanized work in the field. This can be shown as the following example:

After realizing the causal relationship between the two variables, it is also necessary to determine the type of the relationship. If an increase in variable X, increases variable Y, and vice versa, the variables' movement is in one direction. Conversely, when an increase in variable X, reduces variable Y, and vice versa, the movement is in opposite directions. In the arrows relations, the former type is shown by plus mark +, and the latter by minus mark _.

The causal Loops

When a set of variables relate to each other in a closed connected path, a causal loop is formed. So, in a causal loop, when we begin from one variable, we should return to that variable again. This closed loop creates an important element in the system's structure, called feedback. Feedback also involves the concept that changes in the variable, which ultimately influences the future amount of the variable itself. In the issue of wheat mechanization, an example of causal loop can be drawn like Figure 1.

Stock flow diagrams

Causal diagrams offer a visual understanding of the system's structure, but they are not enough for studying the system's behavior through time. Stock flow diagrams explain relations among the variables considering the factor of time, and so simulate the

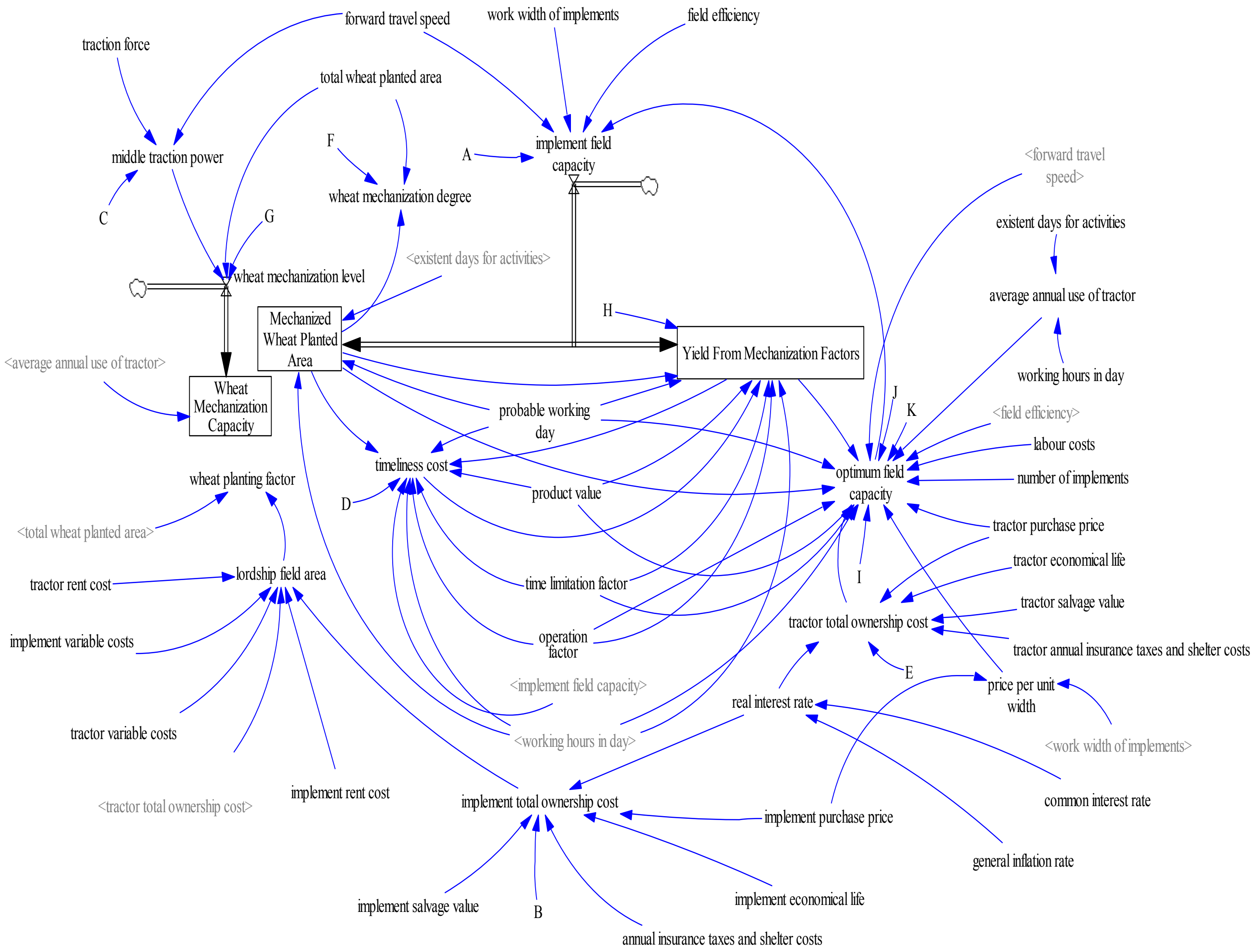

Figure 2. Stock flow diagram (model's structure) for wheat mechanization.

amount of the variables through time. The present article, in effect, is pursuing such diagrams for irrigated wheat mechanization system in Fars. There are three factors in stock flow diagrams, and they are:

(i) Level variable,
(ii) Rate variable, and
(iii) Auxiliary variable

Level variables relate to the elements whose amount is formed during a period of time, like mechanized wheat planted area. These kinds of variables are shown by a rectangle in graphic diagrams. Rate variables are indicators of the rate of change of a variable in the unit of time. For example, Implement field capacity is stated on the basis of hectare per hour, and its amount changes through time. Auxiliary variables are indicators of the coefficients which determine the relations among other variables.

The formation of the model's structure

The above topic, in this paper, means to draw a stock flow diagram for irrigated wheat mechanization in Fars province. To this end the most important technical and economic factors, related to the matter were recognized, then, considering the determined relationships among them, were used in order to drawing the stock flow diagram. All the related factors included the three types of level, rate, and auxiliary variables. The software Vensim PLE was utilized in the formulation of the structure.

RESULTS

The relationships among all the related factors in wheat mechanization are shown by a stock flow diagram in Figure 2. Level variables are expressed within a rectangle, and rate variables are indicated by the mark. As it is evident, a set of technical and economic variables influence the structure, and since the time factor is also considered in the model, it can be helpful in future decision making.

DISCUSSION

The details of the model in Figure 2, show that a number of very important factors in wheat mechanization are themselves are influenced by some other factors. These latter factors are capable of positive improvements through time, so that they can warrant future decision making. For example, Optimum field capacity is under the influence of so many factors and is known as a variable which minimizes the labor and timeliness costs. So it is considered as quite important, and its amounts gained in years to come through model simulations can serve as criteria for decision making for policy makers of Fars province. They can canalize the policy of purchasing agriculture implements to provide the optimum capacity.

Irrigated wheat yield in Fars province have appeared to be an important factor for economic policy makers. This variable is influenced by a number of factors like coefficient of time limitation, and other factors relating to mechanization. In occasions when obstacles like high prices of input or the loss of soil fertility, etc, are at work as inhibitions to the enhancement of yield efficiency, using the model and making appropriate policies, the effective factors are changed so that the best efficiency can be achieved.

Mechanized wheat planted area

Often, decision making on the rate of mechanized wheat planted area is not made according to proper technological and economic bases. As the structure of the model offers, this factor is influenced by implementing field capacity, probable working day, etc. and influencing factors like timeliness cost and wheat mechanization degree. So when the decisions are being made for the development of planting area, the degree of changes on the influenced factors, and also whether these changes are proper according to technological and economic interests, should be taken into account.

Other related and important factors are decidable according to the capabilities of the model. Thus, the effective role and importance of this model in determining policies of irrigated wheat mechanization in Fars province is noticeable.

Conflict of Interest

The authors have not declared any conflict of interest

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