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OPTIMALITY IN AGRICULTURE: GENERATING OPTIMAL STRUCTURE OF CULTURES WITHIN A FARM USING GENETIC ALGORITHMS

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Abstract

Optimization in agriculture can have various forms, depending on its various processes or the market evolution. It can be financial or product-based and can lead to minimization, if related to costs, or maximization, related to profit. In this paper we will present a method of determining an optimal repartition of an agricultural surface for a number of cultures based on a genetic algorithm in order for the profit to be maxim. The model takes into consideration several requirements related to cultures selling price, obtained production, direct costs and costs related to human workforce. The genetic algorithm uses basic structures (chromosomes, genes) and operations (mutation, crossover) to generate a repartition. In this case, the chromosomes are defined as the surface itself, a gene within a chromosome being the surface for a specific culture. The length of the chromosome is equal to the number of cultures desired to be cultivated. The operations are basic and will be described in the paper. The fitness function is defined as the difference between the incomes and the costs, thus the profit. The results will be then compared to the results obtained by the traditional method that uses linear programming.

Key words: *genetic algorithms, culture, rotation, optimality, surface*

INTRODUCTION

In the process of production, there are many parameters that influence the final result. A great deal of them is found beyond the limit of controllability, such as weather, geolocation, topology or market dynamics. Thus, the control over some key parameters (irrigation, cost control, quality raw material etc.) offers the possibility of maximizing the output, either physical or financial. Another implication of the agriculture is the impact on the environment [2], which is extremely important for a sustainable agriculture.
One of the easiest ways to maximize the output and protect the environment is the determination of the optimal repartition of cultures, taking into consideration key requirements, such as the cropping-system [5], the direct and indirect costs and the cultures prices on the market. Deciding the repartition of culture, in the sense of determining the order and the surface within the total arable land, has the great advantage of quasi-inexistent costs for the implementation, while the effects are more than satisfactory.
In the literature, there exists a very efficient method for finding the optimal surfaces for every culture. This method is based on linear programming, as described in paper [1] and can be suited to a model that fits the pattern of a linear programming model that maximizes an objective function with requirements owed to surfaces, workers and labour quantity.
Based on the same idea that maximizes the same objective function and takes into consideration the same requirements, we have built a method that has the same finality, but obtained in a different way. We used a genetic-based algorithm, in order to obtain the optimal structure of cultures.
Added to this method, we have previously built a method that generates a cropping-

system order, based on the restriction given by the species of the culture, is known as cropping-system [6]. This method has as result an order of crops that suits these restrictions.

The two combined methods create a powerful tool that can be used successfully to maximize the profit of an agricultural enterprise.

Of course, other types of optimizations exist, such as cost control [7] for consumables (diesel, insecticide etc.) or sustainable operations (e.g., soil tillage [3]) and agricultural education [8].

MATERIALS AND METHODS

We have used for applying the genetic algorithm classical structures and operations.

The structures that were used are genes and chromosomes. An example of a chromosome is presented in Figure 1. A chromosome actually codifies the entire surface, while a gene represents the codification of the surface of a single crop within the cropping-system. The data contained by a gene is the number of hectares that the crop can be cultivated.

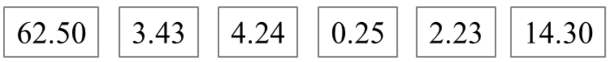

Fig. 1. Representation of a chromosome with 6 genes

The operations that we have used in the model were the mutation and the crossover in one point. Mutation consists in replacing a gene within a chromosome with a randomly-generated gene. Crossover consists in choosing randomly a common position within two chromosomes and replacing the second part of the first chromosome with the second part of the second chromosome and the first part of the second chromosome with the first part of the first chromosome. The scheme of the two operations is shown in figure 2.

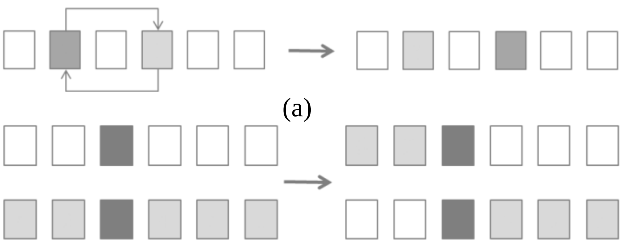

Fig. 2. Mutation (a) and crossover (b)

At each appliance of an operation, the requirements are checked to be accomplished. Firstly, an initial population of chromosomes is generated randomly, and then mutation and crossover are applied. After each operation, the chromosomes are sorted descending based on the objective function. These operations are repeated for a fixed number called the number of generations.

The fitness function (the correspondent of objective function for genetic lexicon) is calculated as the difference between the total income for the data in the genes and the costs according to the same data (i.e., the profit of the whole cropping-system).

The results of the method depend greatly on the parameters of the genetic algorithm: the size of the initial population, the mutation rate and the crossover rate.

The order of the crops is a separate subject studied in previous papers ([4]) and is based on a matrix (practically, a database) that contains data related to an extended series of crops that can be fully updatable with new crops. The matrix let the user know whether a crop can follow another crop (if crops can be neighbours).

RESULTS AND DISCUSSIONS

The implementation was made in Java programming language. A print-screen of the resulting implementation is shown in Figure 3. The database contains now data for only 9 crops, but it can be extended. The interface contains also a possibility for a demonstrative test.

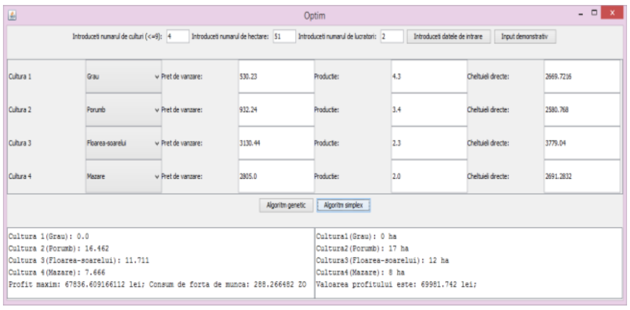

Fig. 3. Interface of the implementation

The results obtained for the demonstrative input (4 crops, 51 hectares and 2 permanent workers) given by the interface is presented in Table 1.

Table 1. Results for the input

Crop	Price	Production	Direct costs	No ha genetic	No ha LP
Wheat	480	4.3	2,669.72	0	0
Corn	500	3.4	2,580.77	0	0
Sunflower	1,100	2.3	3,779.04	0	0
Peas	2,805	2.0	2,691.28	8	7,995
Total				22,474.47	22,488.52

As we can observe, for the same input data, the maximum obtained profit is almost the same.

We will try to find the optimal parameters for the genetic algorithm. Figures 4, 5, 6 and 7 present data for different values of the size of the initial population (N), the mutation rate (m), the crossover ratio (c) and the number of generations (NG).

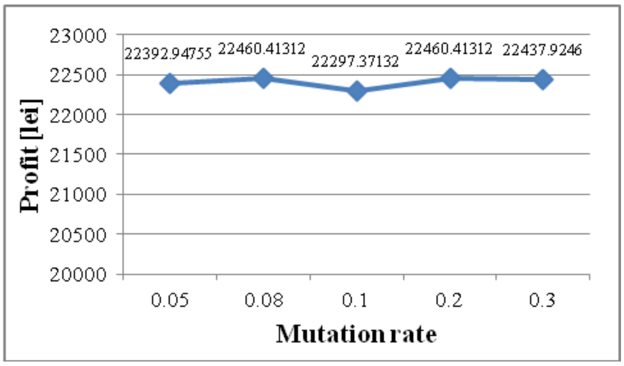

Fig. 4. Evolution of profit based on mutation rate (c=0.6, N=100, NG=3,000)

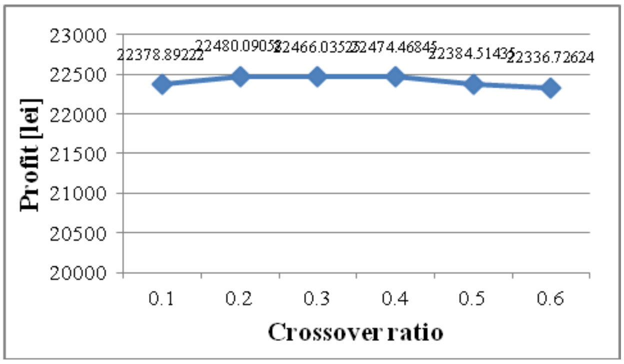

Fig. 5. Evolution of profit based on crossover ratio (m=0.1, N=100, NG=3,000)

We can observe that the optimal mutation rate states somewhere under 0.1, the crossover ratio between 0.2 and 0.4, the size of the initial population under 150 chromosomes and as higher number of generations as possible.

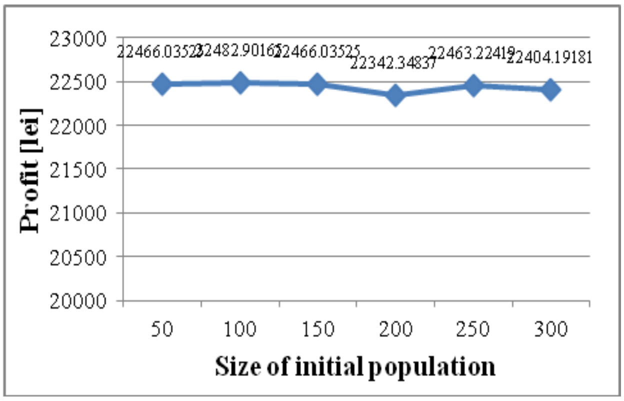

Fig. 6. Evolution of profit based on size of initial population (m=0.1, c=0.2, NG=3000)

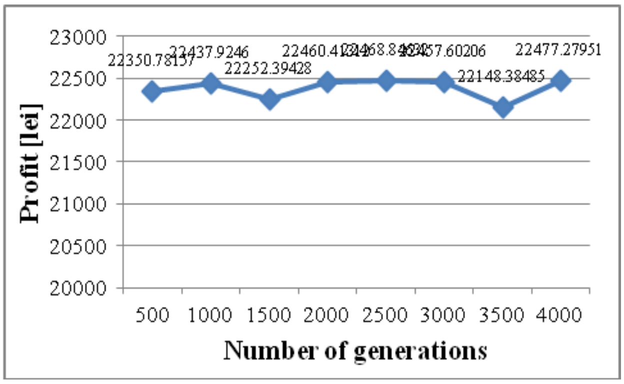

Fig. 7. Evolution of profit based on the number of generations (m=0.1, c=0.2, N=100)

CONCLUSIONS

Finding ways to optimize the activity in agriculture has strong implications in the agricultural domain and in the economy branches that are connected to agriculture. Lower costs for raw material in industry and services from agriculture mean lower prices for the final user. In addition, scale economies are made and the efficiency in agriculture increases.

Any method of optimization, either by reducing costs, increasing incomes or growing average productions, means larger profits, efficiency in consuming resources and a healthier environment.

Regarding the method presented, we intend to develop it by creating a global application which will provide valuable data for the user, helping him in the farming activities and economic tasks.

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