Computer Science Journal of Moldova, vol.6, no.3(18), 1998

Mathematical Modeling of the Agriculture Crop Technology

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Abstract

The organized structure of computer system for economic and ecological estimation of agriculture crop technologies is described. The system is composed of six interconnected blocks. The linear, non-linear and stochastic mathematical models for machinery sizing and selection in farm-level cropping system is presented in the mathematical model block of computer system.

1 Introduction

The agricultural multiply cropping systems are characterized to be complex, dynamic, ecological and stochastic. The cultivation activities of agricultural crops are performed according to the season, so it is necessary to examine their fulfillment every day. Another important characteristic of this system is the necessity to take into consideration the weather forecasting. The agricultural system is stochastical because it strongly depends on the weather conditions.

The method of simulation is very often applied during the estimation and analyzing of agricultural systems. A simulation run is an experiment designed with the assistance of mathematical model and computer software to evaluate system parameters, described through a set of constraints.

There was found a method to solve using simulation difficult kind of problems as the field optimization, usage of necessary and available equipment, need and calculation of power consumption, of fuel consumption, of fertilizers, making up agricultural operations schedule, etc.

2 Computer System

This paper describes a simulation model of agricultural technologies for the multiply cropping systems. Diverse alternatives and performances of agricultural technologies could be examined on the basis of this very model.

The simulation system is composed of six blocks (Figure 1): the data input block, the agricultural technology analysis block, the simulator, the agricultural technology data base, the mathematical model block, the algorithm block. The simulation system models the agricultural system over a sezon. The user introduces the production plan of agricultural system, the area and yield of agricultural crops. The simulator imitates the crops cultivation process chosen trough data base, mathematical models and optimization algorithm.

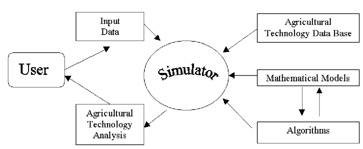

Figure 1:The simulation system arhitecture

The organizational structure of the simulation system allows the adequate calculation of used energy. The system includes the calculation of non-renewable energy and energy of biomass. The energy estimation algorithm is composed of several steps. A way to increase the perfomance of agricultural operations can be found using the mathematical model of energy consumption minimization. Then the components of non-renewable energy, i.e. fertilizer energy, fuel energy, tillage energy, labor energy and electric energy, are found through energy estimation block.

3 Multi-Crops System

The agricultural system is composed of the following interacting objects (Figure 2): the agricultural crop, the agricultural operation, the agricultural technique, the agricultural technology and the agricultural unit. The agricultural technique is distributed in two subsets: tractors and agricultural equipment. There are two formalized objects: the algorithms of the operation volume calculation and the energy equivalents. These subjects are described using tens of parameters. A part of these parameters describes energy and stochastic properties[1,2]. Besides that, the system contains a set of equivalencies of energy measures.

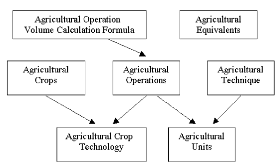

Figure 2:The agriculture crop production system objects

Let's denote the set of agricultural crops by S, the set of agricultural operations by I, the set of agricultural machines and tractors by J, and the set of agricultural equipments by L.

The agricultural unit is an aggregate of the agricultural machines and agricultural techniques with the goal to perfom certain agricultural operation. For each agricultural operation we will examine several kinds of agricultural units. Let's denote the set of agricultural units for the i-th agricultural operation by N_i, the subset of agricultural units for the i-th operation with contains the j-th agricultural machine by N_{ij}, the subset of agricultural units for the i-th operation with contains the l-th agricultural equipment by N_{il}.

Let K be the sets of days in the agricultural year.

The agricultural technology is the set of all agricultural operations performed during a certain period of time for crop cultivation. Each agricultural operation which belongs to the agricultural technology has its starting day and its period. Let's denote the set of the agricultural operations in agricultural technology by R, the subset of of agricultural operations which will be executed in the k-th day by R_k, the subset of day for the r-th agricultural operation by K_r.

4 Mathematical Modeling

There are two known methods for agricultural cropping technology analysis: economic (costing) and energetic. Obviously, now the second method is more appropriate. It is not dependent of many economic factors, as, for example, inflation. Using the energy analyzes method we can see the impact of the agricultural crop technologies on the environment, and it is easier to consider the agricultural cropping system as an ecological one.

The description of mathematical model follows. The goal is to execute all agricultural operations included in the agricultural technology at minimal of expenses or using minimal energy.

The formulation of the mathematical model will be:

$$\sum_{r\in R}\sum_{n\in N_i}\sum_{k\in K_r} C_{in}X_{rnk} + \sum_{j\in J} C_j(O_j+E_h)\max_{k\in K}(\sum_{r\in R_k}\sum_{n\in N_{ij}} X_{rnk}) +$$

$$+\sum_{l\in L} C_l(O_l+E_h)\max_{k\in K}(\sum_{r\in R_k}\sum_{n\in N_{il}} \lambda_{inl}X_{rnk}) \to \min$$

subject to restrictions

$$P\{\sum_{n\in N_i} W_{in}X_{rnk} = Q^d_{rk}(\omega)\} \geq \alpha, r\in R, k\in K_r$$

$$\max_{k\in K}(\sum_{r\in R}\sum_{n\in N_{j_\mu}} X_{rnk}) \leq M_{j_\mu}, j_\mu \in J$$

$$X_{rnk} \geq 0$$

where

X_{rnk}	an unknown daily number of agricultural units of the n-th type at the r-th operation in k-th day;
C_{in}	daily operating expenditures of the n-th agricultural unit at the i-th operation;
W_{in}	daily productivity of the n-th agricultural unit at the i-th operation;
$Q^{d}_{rk}(\omega)$	daily volume of r-th operation in k-th day;
E_h	standard ratio of efficiency of investments in new machinery;
O_j, O_l	ratios of deduction on renovation on the j-th agricultural machine or tractor and the l-th agricultural equipment;
C_j, C_l	costs of the j-th agricultural machine or tractor and the l-th agricultural equipment;
λ_{inl}	number of the l-th agricultural equipment in the n-th agricultural unut at the i-th operation;
M_{j_μ}	limitation on number of the j_μ-th agricultural machine or tractor;
P, α	probability operator and critical probability level.

Another formulation of the mathematical model follows:

$$\sum_{r\in R}\sum_{n\in N_i} D_i(\omega)C_{in}X_{rn} + \sum_{j\in J} C_j(O_j+E_h)\max_{k\in K}(\sum_{r\in R_k}\sum_{n\in N_{ij}} X_{rn})+$$

$$+\sum_{l\in L} C_l(O_l+E_h)\max_{k\in K}(\sum_{r\in R_k}\sum_{n\in N_{il}} \lambda_{inl}X_{rn}) \rightarrow \min$$

sabject to

$$P\{\sum_{n\in N_i} D_i(\omega)W_{in}X_{rn} = Q_r(\omega)\} \geq \alpha, r\in R$$

$$\max_{k\in K}(\sum_{r\in R}\sum_{n\in N_{j_\mu}} X_{rn}) \leq M_{j_\mu}, j_\mu \in J$$

$$X_{rn} \geq 0$$

where

X_{rn} an unknown number of the n-th agricultural units at the r-th operation;

$Q_r(\omega)$ volume of r-th operation;

$D_i(\omega)$ agricultural period of i-th operation

5 Results

Within a period of several years the agricultural technologies for 40 agricultural crops which are cultivated in the Republic of Moldova were elaborated in accordance with the above-mentioned computational methodology. As building the technologies we designed them taking into consideration that the very process consists of about 100 agricultural operations, the agricultural entity has at its disposal about 40 machines and tractors and 100 units of different agricultural equipment. The most of agricultural operations which are characteristic for Moldova have a period of 5–10 days. A maximum number of 6 of its performances was examined for each operation. In this situation the mathematical optimization model of agricultural techniques for an agricultural farm which produces only one kind of crop consists of 150 constraints and 800 variables, at the average rate. Certainly, when the farm cultivates 10 different crops, the number of constraints and variables are increased 10 times respectively.

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Received June 16, 1998