

**РОЗВИТОК РЕГІОНІВ, ГАЛУЗЕЙ ТА ВИДІВ ЕКОНОМІЧНОЇ
ДІЯЛЬНОСТІ**

**DEVELOPMENT OF REGIONS, INDUSTRIES AND TYPES OF ECONOMIC
ACTIVITY**

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**INTEGRATED TECHNOLOGICAL MANAGEMENT SYSTEMS IN AGRICULTURAL
PRODUCTION DEPENDING ON THE TIME OF OPERATIONS**

The integrated systems of control of technological processes implementation in agricultural production, which depend on the initial and final moments of their operation time, are substantiated. In order to optimize the management processes of these systems, a generalization of the results of researches of the influence of various factors on the efficiency of crop production has been carried out. The most important technological, technical and organizational criteria of the quality work of agricultural machines are determined along with their level of influence on the final result - the magnitude of the harvested yield, as well as the possible level of efficiency of the application of the corresponding technical means of mechanization with a controlled effect on the quality of the actual performance of the technological operations itself.

Key words: *integrated control systems, technological processes, agricultural production, dependence, initial and final moments of functioning/operation.*

Introduction. It is known that integrated systems of automatic control of the technological processes implementation in agricultural production are the most promising. They should ensure the creation of qualitatively new technologies (innovative technologies), which have the latest economic, social and environmental indicators.

It is clear that in order to generalize the results of previous studies concerning the level of influence of various factors on the efficiency of crop production, it is necessary to identify the main technological (application rate, depth of cultivation, etc.), technical (speed, engine load, etc.) and organizational (terms of execution, machine-tractor unit (MTU) loading) criteria for the quality work of agricultural machines, the importance of the influence of these factors on the size of the harvested yield (the final result), as

well as the probability (possible) level of efficiency of the applied relevant technical mechanical means with controlled impact on the quality of technological operations.

According to the authors' of this study opinion, it is necessary to consider a specific class of managed systems that depend on the initial and final state and which adequately simulate integrated systems of automatic control of the technological processes implementation in agricultural production, including crop production. The tasks of managing such systems are somewhat different from the traditional tasks of management (including optimal) and are primarily related to the planning of the work of each of these systems.

It is clear that the simulation of such systems, methods of optimal management of them are relevant studies of the present and require further in-depth study.

Literature review. The authors of the works [1-7] consider and comprehensively explore various aspects of the management of finite-dimensional linear objects, various problems of the theory of motion control, automatic control of linear (nonlinear) systems. However, the management of the system, which depends on the start and finish, in the opinion of the authors of this study, require further thorough study.

It should be noted that the results of the above quoted works will be used in this study.

The purpose of this work is to substantiate the approach to the solution of the main problems of the theory of system management, depending on the start and finish, as well as the problem of complete control of such systems in optimizing management.

Results and discussion. Let's consider that it is a question of growing some crops, such as corn. On the starting date, let us take January 1. The state of plants at any given time t , $t > 0$ can be characterized by a set of parameters $x_1(t), \dots, x_n(t)$. The rate of growth and maturation of plants depends on many factors. We will indicate only some of them: the quality of seeds at the time $t = t_0$ when grains enter the soil, the quality of soil, the quality of vegetation care, the time when harvesting is taking place, and so on. Considering the quality of seeds and soil predetermined and constant, one can study the dependence of the development of the plant on other factors. If we take into account that the rate of development of a plant at an arbitrary time t depends on the initial moment of time, when the grain enters the soil, the quality of the plant care at a given time t , from the state of the plant at the current time, then the process can be described by a system of equations:

$$\dot{x}_i = f_i(t, t_0, x, u), \quad i = 1, \dots, n, \quad (1)$$

where the vector $x = \{x_1, \dots, x_n\}$ characterizes the state of the plant, and $u = \{u_1, \dots, u_n\}$ - the care of the plant. The initial state of the system can be considered as given:

$$x(t_0) = x^0 \quad (2)$$

If this process is considered to be controlled, then the in the right part of the system (1) the function $u_k = u_k(t, t_0, T)$, $k = 1, \dots, r$, should be introduced, where T - the end of the plant care process (i.e. harvesting), the choice of which depends not only on the optimality of the system, but also on the t_0 and T . Substituting such a control into equation (1), we have a level system that depends on t_0 and T .

The following should be noted:

1. Managed movements of the system, depending on the start and finish, in some cases can be considered as multi-step processes, described by the equations of the form:

$$x_i(n+1) = f_i(t_0, T, t, n, x(n), u), \quad i = 1, \dots, m, \quad n = 1, \dots, N, \quad (3)$$

where n - segment number when dividing $(T - t_0)$ into N parts.

2. In tasks that should take into account continuously variable time, processes in systems that are dependent on start and finish can be described by differential levels of the form:

$$\dot{x}_i = f_i(t, t_0, T, x, u), \quad t_0 \leq t \leq T, \quad i = 1, \dots, n \quad (4)$$

Similarly, we can consider systems with distributed parameters, depending on the start and finish.

3. For this type of systems, the main problems of the theory of management remain the natural ones (controllability, observation, optimality, etc.). However, now they acquire some new shades because the right-hand sides of the equations of motion can be continuous coordinates t , x and u , but to

be discontinued at t_0 and T . This last fact can significantly affect the content, respectively, in each particular task of the theory of management.

As it is shown below, in these cases, the method used to solve a problem may be considerably complicated.

Controllability. First, let us consider the system

$$\dot{x} = A(t) \cdot x + B(t) \cdot u, \quad t_0 \leq t \leq T, \quad (5)$$

In which $A(t)$ is a continuous matrix of order n , and $B(t)$ a continuous matrix of dimension $[n \times m]$, $x \in E^n$, $u \in E^m$. Admissible control is considered to be piecewise-continuous functions $u = u(t)$ with values in the whole space E^m .

It is known that the system of equations (5) is called controlled, as for a given t_0 and any one $x^0 \in E^n$, $x^1 \in E^n$, it is possible to specify $T(t_0)$, $T > t_0$, and the permissible control $u = u(t, t_0, T, x^0, x^1)$ such, that there $x = x(t)$ is a solution of the equation:

$$\dot{x} = A(t) \cdot x + B(t) \cdot u(t, t_0, T, x^0, x^1), \quad x(T) = x^1, \quad (6)$$

with the initial condition (2).

If t_0 and T are given, then the system is called controlled by a segment $[t_0, T]$. We know the conditions for controllability, for example [1-3]. Here we present them in a convenient formula for further analysis [4]. To do this, we write a Cauchy matrix $W(t, s)$ of a homogeneous equation:

$$\dot{y} = A(t) \cdot y \quad (7)$$

If now indicate $h_i(t, T)$ the i -th column of the matrix $B^*(t)W^*(t)$, then the condition of control is that, for a given t_0 vector-function $h_1(t, T), \dots, h_n(t, T)$ are linearly independent on a certain segment $[t_0, T]$. This condition remains fair in the case when the matrices $A(t)$ and $B(t)$ are piecewise and continuous.

In the case when the linear control system is considered, depending on the start and the finish, the process is described by the equation:

$$\dot{X} = A(t, t_0, T) \cdot x + B(t, t_0, T) \cdot u, \quad t_0 < t < T. \quad (8)$$

We will assume that $A(t, t_0, T)$ and $B(t, t_0, T)$ are continuous on t in any segment $[t_0, T]$ and piecewise-continuous in t_0 and T .

It is clear that in the problem of controllability of the system (8) on a given segment no new features arise in comparison with the same problem for the system (7). In the case when t_0 and T the columns of the matrix $B^*(t, t_0, T) \cdot W(T, t; t_0, T)$ and T , then the linear dependence or independence of the vector of the function:

$$h_1(t, t_0, T), \dots, h_n(t, t_0, T) \quad (9)$$

is determined not only by the variable t , but by the parameters t_0 and T . As it is shown in the following example, in this case there may not be quite normal situations.

Example 1. Consider the managed system:

$$\dot{x}_1 = x_2 + \alpha(t, T)u_2, \quad \dot{x}_2 = u_1, \quad \dot{x}_3 = x_4 + (t-1)u_2, \quad \dot{x}_4 = u_1 + \beta(t, t_0)u_2, \quad (10)$$

in which

$$\alpha(t, T) = (t-1) \cdot \Theta(T-2) = \begin{cases} 0 & \text{npu } t_0 \leq t \leq T \leq 2, \\ t-1 & \text{npu } t_0 \leq t \leq T, T > 2 \end{cases} \quad (11)$$

$$\beta(t, t_0) = \Theta(t_0 - 1) = \begin{cases} 0 & \text{npu } t_0 \leq t \leq T, t_0 \leq 1, \\ 1 & \text{npu } t_0 \leq t \leq T, t > 2 \end{cases} \quad (12)$$

If the system (10) is rewritten in the form (8), then we will have:

$$A(t, t_0, T) = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \quad B(t, t_0, T) = \begin{bmatrix} 0 & \alpha(t, T) \\ 1 & 0 \\ 0 & t-1 \\ 1 & \beta(t, t_0) \end{bmatrix}, \quad (13)$$

$$W(t, s) = \begin{bmatrix} 1 & t-s & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & t-s \\ 0 & 1 & 0 & 1 \end{bmatrix}. \quad (14)$$

Expression (14) is a Cauchy matrix, and the vector functions (9) have the form:

$$\begin{cases} h_1(t, t_0, T) = \begin{bmatrix} T-t \\ \alpha(t, T) \end{bmatrix}, h_2(t, t_0, T) = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \\ h_3(t, t_0, T) = \begin{bmatrix} T-t \\ t-1 + \beta(t, t_0) \cdot (T-t) \end{bmatrix}, h_4(t, t_0, T) = \begin{bmatrix} 1 \\ \beta(t, t_0) \end{bmatrix}. \end{cases} \quad (15)$$

From the definition of the function $\alpha(t, T)$ and $\beta(t, t_0)$ (see (11) and (12)), it follows that these vectors are linearly independent only under the condition of $t_0 > 1, T > 2$ or $t_0 > 1, T \leq 2$.

In these cases, the system under consideration is controlled. In other cases ($t_0 \leq 1, T > 2; t_0 \leq 1, T \leq 2$), the function vectors h_1, h_2, h_3 and h_4 are linearly dependent, and system (10) is not controlled in a segment $[t_0, T]$.

It is appropriate to pay attention to the following interesting facts. The system (10) is controlled on a small segment $[t_0, T]$ at $t_0 > 1, T \leq 2$ and uncontrolled on a large segment $[t_0, T]$, at $t_0 < 1, T > 2$

Identity and visibility. We will consider the system of equations of management:

$$\begin{cases} x = A(t, t_0, T) \cdot x + B(t, t_0, T) \cdot u \\ y = C(t, t_0, T) \cdot x \end{cases}, \quad (16)$$

in which the matrices A and B are the same as in the system (8), and $C(t, t_0, T)$ is continuous at t and piecewise continuous at t_0 and T matrix with dimensionality $[n \times m]$.

When fixed t_0 and T this system can be presented as:

$$\begin{cases} x = A(t) \cdot x + B(t) \cdot u \\ y = C(t) \cdot x \end{cases} \quad (17)$$

As it is known, the task of observation is the task of a definite state of the x^r system at the time r of the input and output signals, which will be measured in the future, that is, according to the data of the control $u(t)$ and the signal $y(t)$ at $t \geq r$. The task of identity of a system is to evaluate the state of the system x^r at a time r with data about $u(t)$ and $y(t)$ at $t \leq r$.

A point (r, x^r) is called an event for the characteristic of which we introduce the following two concepts. An event (r, x^r) is called unidentified, if $y(t, r, x^r, u)|_{u=0} = 0$ for every $t \geq r$. In accordance with these concepts, the following characteristic of the system is given (17).

This system is called the observed (identified) at the time $t = r$, unless any event (r, x^r) is not observable (unidentified), with the exception of an event $(0, r)$. The known criterion for unidentified of a system (for example, [1]) can be formulated as follows.

In order for the event (r, x^r) of the system (17) to be unidentified, it is necessary and sufficient that the vector x^r belongs to the matrix kernel:

$$M(t_0, r) = \int_{t_0}^r W^*(t, t_0) \cdot C^*(t) \cdot C(t) \cdot W(t, t_0) dt, \quad t_0 < t < q \cdot T, \quad (18)$$

In the same way, the criterion of unobservability is formed.

In order for the event (t_0, x^0) system (17) to be unobservable for a time interval $t_0 < t < T$, it is necessary and sufficient that the vector x^0 belongs to the matrix kernel:

$$N(t_0, r) = \int_{t_0}^T W^*(t, t_0) \cdot C^*(t) \cdot C(t) \cdot W(t, t_0) dt \quad (19)$$

In the case of the system (16), which depends on the start and the finish, the quantities t_0 and T are variable, therefore, the matrices $M(t_0, r)$ $N(t_0, r)$ are not constant and their rank can vary depending on the variables t_0 and T . As a result, the structure of unobservable and unidentified systems will vary depending on t_0 and T .

Example 2. Consider the system:

$$\begin{cases} \dot{x} = x_2, \dot{x}_2 = u_1, \dot{x}_3 = x_4, \dot{x}_4 = u_1 + u_2 \\ y = x_2 + x_4, y_2 = \alpha(t, T) \cdot x_1 + (1-t) \cdot x_3 + \beta \cdot (t, t_0) \cdot x_4 \end{cases} \quad (20)$$

In which $\alpha(t, T)$ and $\beta(t, t_0)$ are determined by formulas (11) and (12), then by means of direct calculations we find that the matrix $M(t_0, r)$ is a Gram matrix:

$$\Gamma = \begin{vmatrix} q_{11} & q_{12} & q_{13} & q_{14} \\ q_{21} & q_{22} & q_{23} & q_{24} \\ q_{31} & q_{32} & q_{33} & q_{34} \\ q_{41} & q_{42} & q_{43} & q_{44} \end{vmatrix}, \quad (21)$$

of vectors of functions

$$q_1(t, T) = \begin{vmatrix} 0 \\ \alpha(t, T) \end{vmatrix}, \quad q_2(t, t_0, T) = \begin{vmatrix} 1 \\ (t-t_0) \cdot \alpha(t, T) \end{vmatrix}, \quad q_3(t, T) = \begin{vmatrix} 0 \\ (t-1) \end{vmatrix}, \quad q_4(t, t_0) = \begin{vmatrix} 1 \\ (t-t_0) \cdot (t-1) + \beta \cdot (t, t_0) \end{vmatrix}, \quad (22)$$

where the scalar product is determined by the formula:

$$(q_i, q_k) = \int_{t_0}^r q_i^* \cdot q_k dt. \quad (23)$$

It is known that the rank Γ of such a matrix is equal to the number of linearly independent vectors-functions in the system $q_1, q_2, q_3,$ and q_4 .

We find that by direct computation at which values of the parameters t_0, r and T the rank of the matrix can not be equal to four. Only the following partial cases are possible:

$$\begin{aligned} \text{Rank } \Gamma = 3 & \text{ if } t_0 > 1, T \leq 2, \\ \text{Rank } \Gamma = 3 & \text{ if } t_0 \leq 1, T \leq 2, \\ \text{Rank } \Gamma = 3 & \text{ if } t_0 > 1, T > 2, \\ \text{Rank } \Gamma = 3 & \text{ if } t_0 \leq 1, T > 2. \end{aligned} \quad (24)$$

Thus, in the first three cases, the set of unidentified events (r, x^r) forms an one-dimensional space, that is, the general solution of the equation:

$$\Gamma_x = 0 \quad (25)$$

depends on one arbitrary constant. In the fourth case, the set of unidentified events forms a two-dimensional space.

Similarly, one can consider the dependence on t_0 and T of the matrix $N(t_0, T)$, which defines the unobserved initial states.

Optimal control. When considering the problem of optimal control of the system (5) depending on the start and finish, it is formally possible to proceed from the fact that these systems depend on two parameters t_0 and T . As it is known, systems dependent on the parameters began to be considered in the mathematical theory of optimal processes at the dawn of its development (for example, [5]). The necessary optimality conditions for them were formulated in the form of a maximum limit.

It seemed that these results could be used without any additional conditions and in the analysis of a system that depends on the start and the finish. However, this approach in the case under consideration does not provide an exhaustive answer, because here the value of the parameters t_0 and T affect the area of definition of functions f_i in the variable t . Such a dependence is not foreseen in the classical problems of optimal processes with parameters. Therefore, various features are possible here.

The results of the analysis of Example 1 show that the solution of the problem of the complete controllability of the system of the form (5) can essentially depend on t_0 and T . Therefore, when studying the problems of optimal management it is expedient to consider individual situations, when the system is completely guided in a segment $t_0 \leq t \leq T$, sometimes such control is not present. This analysis is necessary regardless of whether the length of the process $(T - t_0)$ is fixed or not (for example, as in problems with optimal performance).

Example 3. Consider the problem of optimal performance in the system (10) under initial conditions:

$$x_i(t_0) = x_i^0, \quad i = 1, \dots, 4, \quad (26)$$

where the vector $x^0 = (x_1^0, x_2^0, x_3^0, x_4^0)$ is assigned.

It is necessary to transfer the system to a state:

$$x_i(T) = x_i^1, \quad i = 1, \dots, 4, \quad (27)$$

for the shortest period of time $(T - t_0 = \min)$ with additional restrictions on permissible control:

$$J(u) = \int_{t_0}^T u^*(t) \cdot u(t) dt = \int_{t_0}^T [u_1^2(t) + u_2^2(t)] dt \leq \nu^2, \quad (28)$$

where ν - given constant. At the same time, the start time t_0 of the system is not specified.

Assuming that the vectors x^0 and x^1 do not undergo any additional condition, then the problem must be solved with the same values t_0 and T , under which the system is fully controlled. In this case, the function vectors h_1 , h_2 , h_3 and h_4 (see example 1) must be linearly independent of T .

First, in accordance with the known method (for example, [2,4]) the solution of the problem of speedwork, we fix t_0 and T and solve the problem of control with minimal energy. First and foremost, we write out the condition that the solution $x = x(t)$ of the equations (10) to the initial conditions (26) must satisfy the condition (27). This requirement leads to moment proportions:

$$\int_{t_0}^T h_i^*(t, t_0, T) \cdot u(t) dt = C_i, \quad i = 1, \dots, 4, \quad (29)$$

where C_i , $i = 1, \dots, 4$ is the component of the vector $C = x^1 - W(T, t_0; t_0, T) \cdot x^0$.

With linear independence of vectors-functions h_i , $i = 1, \dots, 4$, (this case we are considering now) control with minimal energy can be presented as:

$$u^0 = \sum_{i=1}^4 \gamma_i \cdot h_i(t, t_0, T), \quad (30)$$

where $\gamma_i = \gamma_i(t_0, T)$ is uniquely determined by a system of equations

$$\sum_{k=1}^4 \gamma_k \int_{t_0}^T h_k^*(t, t_0, T) h_k(t, t_0, T) dt = C_i(t_0, T), \quad i = 1, \dots, 4. \quad (31)$$

If equation (30) is substituted on the left side of the relation (28) and the equation (31) is taken into account then we have:

$$\varphi(t_0, T) = \int_{t_0}^T u^*(t, t_0, T) dt = \sum_{i=1}^4 \gamma_i \cdot C_i, \quad (32)$$

here $\varphi(t_0, T)$ is the minimum value of the functional J of equation (28).

The solution of systems (31) can be presented as:

$$\gamma_k = \frac{1}{\Delta(t_0, T)} \cdot \sum_{i=1}^4 \Delta_{kj}(t_0, T) \cdot C_j, \quad k = 1, \dots, 4, \quad (33)$$

Where Δ is the determinant of the system, and Δ_{kj} is the algebraic complement of the element, which stands at the intersection of the k -th row and j -th column.

Therefore, we can write:

$$\varphi(t_0, T) = \sum_{k=1}^4 \sum_{i=1}^4 C_k \cdot C_i \frac{\Delta(t_0, T)}{\Delta(t_0, T)} \quad (34)$$

Consider now t_0 and T as variables (where $t_0 < T$), we have the problem of optimal speedwork, which can be formulated as follows.

You need to know t_0 and T such that:

$$t_0 < T, \quad \varphi(t_0, T) = \nu^2, \quad T - t_0 = \min.$$

Since we consider the case of complete controllability of the system (10), then, in addition, one more condition must be fulfilled (see example 1): $t_0 > 1$, $T > 2$, $t_0 > 1$, $T \leq 2$.

The optimal problem is the non-linear programming problem, in which the area of variables t_0 and T is not complete. It follows that it may not have solutions.

Let us now consider the problem of optimal speedwork in one of the cases when the system (10) is not controlled.

Let, for example, $t_0 \leq 1$, $T > 2$. In this case (see example 1):

$$h_1 = h_3 = \begin{pmatrix} T-t \\ t-1 \end{pmatrix}, \quad h_2 = h_4 = \begin{pmatrix} 0 \\ 1 \end{pmatrix}. \quad (35)$$

Accordingly, in system h_1 , h_2 , h_3 and h_4 it is possible to receive only two linearly independent vector-functions. Let it be h_1 and h_2 .

Since the relations (35) are executed, then the constant C_i , $i = 1, \dots, 4$, at the time of the correlations (29) must follow the condition:

$$C_1 = C_3, \quad C_2 = C_4. \quad (36)$$

According to the ratio vector $C = \{C_1, C_2, C_3, C_4\}$ is determined by the formula:

$$C_1 = X^1 - W(T, t_0) \cdot x^0.$$

Therefore equalities (36) can be presented as:

$$x_1^1 - x_1^0 - (T - t_0) \cdot x_2^0 = x_3^1 - x_3^0 - (T - t_0) \cdot x_4^0 \quad (37)$$

$$x_2^1 - x_2^0 = x_4^1 - x_4^0 \quad (38)$$

Condition (38) does not depend on t_0 and T . Therefore, it can be characterized as a "severe restriction" to the state of the system at the initial and final moment of time. The content of the restriction (37) is slightly different. It connects the points x^0 , x^1 and the duration $T - t_0$ of the process under consideration. Therefore, if the points are given, then this condition determines the length of the process, taking into account the limitation $t_0 \leq 1$, $T > 2$. It remains to build a control. To find it, we have moment

correlations (29) and restrictions (28). At the same time t_0 and T are not fixed, but only the difference is known $T - t_0$. Such a task is solved by the known methods.

The agro enterprise has mastered the production of several types of agricultural products, such as four assortments (rye B_1 , corn B_2 , rape B_3 , wheat B_4), which annually an agricultural enterprise can produce in limited quantities (because it is a resource!). Annual income of the necessary raw materials A_i , $i = (1,4)$, raw material costs per unit (per 1 metric center/quintal) of each type of product, the profit from the sale of 1 q is shown in the table 1.

Table 1

Annual income of the necessary raw materials, raw material costs per unit (per 1 metric center/quintal) of each type of product, the profit from the sale of 1 q

Type of raw material	Annual raw material flow, c	Consumption of raw materials per center			
		B_1	B_2	B_3	B_4
A_1	1260	2	4	6	8
A_2	900	2	2	0	6
A_3	530	0	1	1	2
A_4	210	1	0	1	0
Quantity of products received (yield), c / ha		X_1	X_2	X_3	X_4
Profit from sales, c.u./ha		8	10	12	18

$$\begin{cases} 2 \cdot X_1 + 4 \cdot X_2 + 6 \cdot X_3 + 8 \cdot X_4 \leq 1260; \\ 2 \cdot X_1 + 2 \cdot X_2 + 0 \cdot X_3 + 6 \cdot X_4 \leq 900; \\ 0 \cdot X_1 + 1 \cdot X_2 + 1 \cdot X_3 + 2 \cdot X_4 \leq 530; \\ 1 \cdot X_1 + 0 \cdot X_2 + 1 \cdot X_3 + 0 \cdot X_4 \leq 210. \end{cases} \quad (1)$$

$$X_1 \geq 0; X_2 \geq 0; X_3 \geq 0; X_4 \geq 0. \quad (2)$$

Profit from sales, c.u./ha:

$$Z = 8 \cdot X_1 + 10 \cdot X_2 + 12 \cdot X_3 + 18 \cdot X_4 \rightarrow \max \quad (3)$$

This is a classic linear programming problem:

$$\text{PROFIT} = \text{INCOME} - \text{EXPENDITURE} \quad (4)$$

$$\text{EXPENDITURE} \downarrow \rightarrow \text{PROFIT} \uparrow \quad (5)$$

Rewrite the problem of linear programming in our case. Let the cost of information (annual) about the possible yield is I_{Σ} . The coefficients k_1, k_2, \dots, k_n give the value Z of each type of product, at an

increment per 1 hectare $I_1 = k_1 \cdot I_{\Sigma}$; $I_2 = k_2 \cdot I_{\Sigma}$; \dots ; $I_8 = k_8 \cdot I_{\Sigma}$. Then the table 2 will be the same,

but the raw material needs to be transferred into Z :

$$\sum_{i=1}^8 k_i = 1. \quad (6)$$

Table 2

Mathematical model with data of annual income of the necessary raw materials, raw material costs per unit (per 1 metric center/quintal) of each type of product, the profit from the sale of 1 q

Type of raw material / information	Annual supply of raw materials in Z , c/ $A_i, i = \overline{(1,4)}, I_i, i = \overline{(1,8)}$	Consumption of raw materials per center			
		B_1	B_2	B_3	B_4
A_1	3000	12	14	16	18
A_2	1000	20	20	0	60
A_3	500	0	10	10	20
A_4	200	10	0	10	0
$I_1(k_1)$	400	11	15	16	17
$I_2(k_2)$	5000	17	18	19	20
$I_3(k_3)$	700	16	20	21	23
$I_4(k_4)$	1400	18	33	32	40
$I_5(k_5)$	800	19	45	44	15
$I_6(k_6)$	900	22	22	14	19
$I_7(k_7)$	1200	13	17	34	8
$I_8(k_8)$	1400	14	9	0	16
Quantity of products received (yield), c / ha		X_1	X_2	X_3	X_4
Profit from sales, c.u./ha		$X_1 \geq 8$ 15	$X_2 \geq 10$ 12	$X_3 \geq 12$ 14	$X_4 \geq 18$ 19

$$\left\{ \begin{array}{l} 12 \cdot X_1 + 14 \cdot X_2 + 16 \cdot X_3 + 18 \cdot X_4 \leq 3000; \\ 20 \cdot X_1 + 20 \cdot X_2 + 0 \cdot X_3 + 60 \cdot X_4 \leq 1000; \\ 0 \cdot X_1 + 10 \cdot X_2 + 10 \cdot X_3 + 20 \cdot X_4 \leq 500; \\ 10 \cdot X_1 + 0 \cdot X_2 + 10 \cdot X_3 + 0 \cdot X_4 \leq 200; \\ 11 \cdot X_1 + 15 \cdot X_2 + 16 \cdot X_3 + 17 \cdot X_4 \leq 400; \\ 17 \cdot X_1 + 18 \cdot X_2 + 19 \cdot X_3 + 20 \cdot X_4 \leq 5000; \\ 16 \cdot X_1 + 20 \cdot X_2 + 21 \cdot X_3 + 23 \cdot X_4 \leq 700; \\ 18 \cdot X_1 + 33 \cdot X_2 + 32 \cdot X_3 + 40 \cdot X_4 \leq 1400; \\ 19 \cdot X_1 + 45 \cdot X_2 + 44 \cdot X_3 + 15 \cdot X_4 \leq 800; \\ 22 \cdot X_1 + 22 \cdot X_2 + 14 \cdot X_3 + 19 \cdot X_4 \leq 900; \\ 13 \cdot X_1 + 17 \cdot X_2 + 34 \cdot X_3 + 8 \cdot X_4 \leq 1200; \\ 14 \cdot X_1 + 9 \cdot X_2 + 0 \cdot X_3 + 16 \cdot X_4 \leq 1400. \end{array} \right. \quad (7)$$

$$X_1 \geq 0; X_2 \geq 0; X_3 \geq 0; X_4 \geq 0. \quad (8)$$

Profit from sales, c.u./ ha:

$$Z = 15 \cdot X_1 + 12 \cdot X_2 + 14 \cdot X_3 + 19 \cdot X_4 \rightarrow \max \quad (9)$$

Specify how much we will get a profit compared to a task when there is no information.

Table 4

Mathematical model of annual income of the necessary raw materials, raw material costs per unit (per 1 c) of each type of product, the profit from the sale of 1 c when the raw material needs to be transferred into Z

Type of raw material / information	Annual supply of raw materials in Z , $c/ A_i , i = \overline{(1,4)} , I_i , i = \overline{(1,8)}$	Consumption of raw materials per center					
		B_1	B_2	B_3	B_4	...	B_n
A_1	W_1^A	a_{11}	a_{12}	a_{13}	a_{14}	...	a_{1j}
A_2	W_2^A	a_{21}	a_{22}	a_{23}	a_{24}	...	a_{2j}
A_3	W_3^A	a_{31}	a_{32}	a_{33}	a_{34}	...	a_{3j}
A_4	W_4^A	a_{41}	a_{42}	a_{43}	a_{44}	...	a_{4j}
.....
A_n	W_n^A	a_{i1}	a_{i2}	a_{i3}	a_{i4}	...	a_{ij}
$I_1(k_1)$	W_1^I	b_{11}	b_{12}	b_{13}	b_{14}	...	b_{1j}
$I_2(k_2)$	W_2^I	b_{21}	b_{22}	b_{23}	b_{24}	...	b_{2j}
$I_3(k_3)$	W_3^I	b_{31}	b_{32}	b_{33}	b_{34}	...	b_{3j}
$I_4(k_4)$	W_4^I	b_{41}	b_{42}	b_{43}	b_{44}	...	b_{4j}
.....
$I_n(k_n)$	W_n^I	b_{i1}	b_{i2}	b_{i3}	b_{i4}	...	b_{ij}
Quantity of products received (yield), c / ha		X_1	X_2	X_3	X_4	...	X_n
Profit from sales, c.u./ha		Y_1	Y_2	Y_3	Y_4	...	Y_n

$$\left\{ \begin{array}{l}
 a_{11} \cdot X_1 + a_{12} \cdot X_2 + a_{13} \cdot X_3 + a_{14} \cdot X_4 + \dots + a_{1j} \cdot X_n \leq W_1^A; \\
 a_{21} \cdot X_1 + a_{22} \cdot X_2 + a_{23} \cdot X_3 + a_{24} \cdot X_4 + \dots + a_{2j} \cdot X_n \leq W_2^A; \\
 a_{31} \cdot X_1 + a_{32} \cdot X_2 + a_{33} \cdot X_3 + a_{34} \cdot X_4 + \dots + a_{3j} \cdot X_n \leq W_3^A; \\
 a_{41} \cdot X_1 + a_{42} \cdot X_2 + a_{43} \cdot X_3 + a_{44} \cdot X_4 + \dots + a_{4j} \cdot X_n \leq W_4^A; \\
 \dots \\
 a_{i1} \cdot X_1 + a_{i2} \cdot X_2 + a_{i3} \cdot X_3 + a_{i4} \cdot X_{i4} + \dots + a_{ij} \cdot X_n \leq W_n^A; \\
 b_{11} \cdot X_1 + b_{12} \cdot X_2 + b_{13} \cdot X_3 + b_{14} \cdot X_4 + \dots + b_{1j} \cdot X_n \leq W_1^I; \\
 b_{21} \cdot X_1 + b_{22} \cdot X_2 + b_{23} \cdot X_3 + b_{24} \cdot X_4 + \dots + b_{2j} \cdot X_n \leq W_2^I; \\
 b_{31} \cdot X_1 + b_{32} \cdot X_2 + b_{33} \cdot X_3 + b_{34} \cdot X_4 + \dots + b_{3j} \cdot X_n \leq W_3^I; \\
 b_{41} \cdot X_1 + b_{42} \cdot X_2 + b_{43} \cdot X_3 + b_{44} \cdot X_4 + \dots + b_{4j} \cdot X_n \leq W_4^I; \\
 \dots \\
 b_{i1} \cdot X_1 + b_{i2} \cdot X_2 + b_{i3} \cdot X_3 + b_{i4} \cdot X_{i4} + \dots + b_{ij} \cdot X_n \leq W_n^I.
 \end{array} \right. \quad (7)$$

$$X_1 \geq 0; X_2 \geq 0; X_3 \geq 0; X_4 \geq 0. \quad (8)$$

Profit from sales, c.u./ha:

$$Z = Y_1 \cdot X_1 + Y_2 \cdot X_2 + Y_3 \cdot X_3 + Y_4 \cdot X_4 + \dots + Y_n \cdot X_n \rightarrow \max \quad (9)$$

Specify how much we will get a profit compared to a task when there is no information.

To compare the expedient standard of agricultural land cultivation it is necessary:

$$\Delta Z \geq Y_i$$

Data that satisfy this requirement should be used in terms of agricultural production.

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ІНТЕГРОВАНІ СИСТЕМИ УПРАВЛІННЯ ТЕХНОЛОГІЧНИМИ ПРОЦЕСАМИ У СІЛЬСЬКОГОСПОДАРСЬКОМУ ВИРОБНИЦТВІ ЗАЛЕЖНО ВІД ЧАСУ ЗДІЙСНЕННЯ ОПЕРАЦІЙ

Проблема. Найбільш перспективними у сільськогосподарському виробництві є інтегровані системи автоматичного управління технологічними процесами. Вони повинні забезпечити створення якісно нових технологій (інноваційних технологій), які мають найновіші економічні, соціальні та екологічні показники. Для узагальнення результатів попередніх досліджень щодо рівня впливу різних факторів на ефективність виробництва продукції рослинництва необхідно визначити основні технологічні (норма внесення, глибина вироцування тощо), технічні (швидкість, навантаження двигуна тощо) та організаційні (терміни виконання, завантаження машинно-тракторного агрегату) критерії якості роботи сільськогосподарських машин, значення впливу цих факторів на величину зібраного врожаю (кінцевий результат), а також імовірний (можливий) рівень ефективності застосовуваних відповідних технічних механічних засобів із контрольованим впливом на якість технологічних операцій.

Метою наукової статті є обґрунтування методологічних підходів до вирішення основних проблем теорії системного управління технологічними процесами у сільськогосподарському виробництві залежно від початку та закінчення операцій.

Результати. Обґрунтовано інтегровані системи контролю впровадження технологічних процесів у сільськогосподарському виробництві, які залежать від початкових та кінцевих моментів часу здійснення операцій. З метою оптимізації процесів управління цими системами проведено узагальнення результатів досліджень впливу різних факторів на ефективність рослинництва. Найважливіші технологічні, технічні та організаційні критерії якості роботи сільськогосподарських машин визначаються разом із рівнем їх впливу на кінцевий результат – величину зібраного врожаю, а також можливий рівень ефективності застосування відповідних технічних засобів механізації з контрольованим впливом на якість власне виконання самих технологічних операцій.

Наукова новизна. Розвинуто методологічні підходи до вирішення основних проблем теорії системного управління технологічними процесами у сільськогосподарському виробництві залежно від початку та закінчення операцій. На основі результатів досліджень сформульовано оптимальну математичну модель різниці швидкостей нанесення залежно від агробіологічного стану ґрунтового середовища.

Висновки. Впровадження запропонованих методологічних підходів до оптимізації управління технологічними процесами у рослинництві зумовлює мінімізацію витрат виробництва, підвищення продуктивності праці та зростання прибутку сільськогосподарських підприємств. На думку авторів цього дослідження, необхідно розглянути конкретний клас керованих систем, що залежать від початкового та кінцевого стану здійснення операцій та які адекватно моделюють інтегровані системи автоматичного управління технологічними процесами у сільськогосподарському виробництві, зокрема в рослинництві. Завдання управління такими системами децю відрізняються від традиційних завдань управління (включаючи оптимальні) та пов'язані, насамперед, із плануванням роботи кожної з цих систем.

Ключові слова: інтегровані системи управління, технологічні процеси, сільськогосподарське виробництво, залежність, початкові та кінцеві моменти функціонування / експлуатації.

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