FEATURES OF PLANNING TECHNOLOGIES IN COMPUTER-AIDED MANAGEMENT SYSTEMS OF AN AGRICULTURAL ENTERPRISE

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Abstract: The design principles of the functional subsystem of planning for automatizing management of a crop cultivating agricultural enterprise are shown. Main directions and tasks for the effective work planning of an agricultural enterprise are described.

Keywords: information technologies, planning, automatizing of management, agriculture enterprise.

ACM Classification Keywords: H.4 Information system applications, I.2.1 Applications and Expert Systems, G.1.6 Optimization

Introduction

The practice of use of information technologies by agricultural producers shows that the attention in the process of designing of a computer-aided management system is paid to implementing accounting functions, while the function of work process management is fulfilled by using traditional methods. This approach to functionality of the system has resulted in following: designing of long-term plans has almost fallen out of the planning system, both current and operational planning problems are mainly implemented in the sole variant, the implementation is carried out in the context of low reliability of the original information [Улезько, 2008].

However, a computer-aided management system of an agricultural enterprise is first of all a management system. It is designed to manage and control any technological processes. When the system was being designed, its specific features affecting automatizing of management were identified. Taking these features into account, a list of functional subsystems was selected. The subsystem of planning plays a special role among these subsystems. The general approach to its construction is described below.

Description of the subsystem of planning of an agricultural enterprise

The purpose of the subsystem of planning:

- Fixing the use of fields under crops;
- Calculating plans of agricultural work and operations;
- Planning the supply of resources necessary to perform agricultural work.

The classification of types of plans

It is supposed to use the following types of plans in the system:

1) Plans of seasonal work, which could potentially be divided into:
   - Plans of work (tillage, sowing, cultivating, harvesting);
   - Plans of operations. They are detailed plans of work, supported by typical technological maps.
2) Executive plans of operations. They are schedules of work for a short period (up to five days). Schedules are supported by technological maps, tied to the state of the fields and forecasted weather conditions.
3) Plans of supply of resources. They determine purchasing and involving the following resources: fuel and lubricants, fertilizers and plant protection products, seeds, tractor operated machinery, staff.

General technology of planning

General technology of planning is:

1) Fixing the fields use for a season based on market needs and crop rotation.
2) Estimating preliminary sequence of agricultural work in accordance with the life cycle of crops.
3) Detailing of operational representation of work and supporting their technological maps (on the basis of regulatory information).
4) Specifying the operations included in the work. A proper adjusting of the plan fragment is made on a five-day period. The adjusting is carried out depending on the state of the field, crops, weather, and provision of the work with resources.

The use of average predictive information concerning the factors that influence cultivating and harvesting is assumed.

Another approach to solving the problem is to consider as much as possible high quality prognostic information and bind the technological maps to field conditions and conditions of acceptable use of machinery (e.g. maintenance and repair). Here the planning process is oriented to the use of advanced machine technology, for example, the use of aggregates, mechanizing performance of groups of agricultural operations in a complex way.

The demand for machine resources, maintenance staff, fuel and lubricants, fertilizers, plant protection products and seeds is easily calculated from the plans of operations supported by refined technological maps with specified types of resources required to perform the operations.

Planning should take into account the specifics of the seasonal work, including time-frames, duration and parallelism of operations within the season. This planning should take into consideration the above aspects especially in its criteria basis. For example, the optimization criteria for cultivating will differ significantly from the criteria for harvesting. This is explained by the fact that the latter requires reducing the duration as much as possible because of the possible loss of yield.

As a central object of planning and management it is advisable to allocate a field with a single crop rotation. The whole subsystem of planning is carried out for it (Figure 1).

The complexity of planning problems provides several types of processes:

- Season;
- Campaign;
- Work;
- Operation.

The automating of planning problems is fulfilled taking them into consideration. The season means the whole cycle of agricultural work from tillage to harvesting.

Each agricultural campaign contains several types of work. The work is understood as a complex of interrelated operations. Work from the basic plan may be included into the executive plan, taking into account the state of the field. The executive plan is a set of operations that must be performed in the nearest future.

The operation – is a single continuous process with common technological features. For example, "early spring tillage" can be executed by means of different operations using different tillage technologies.

On the basis of the executive plan suitable daily schedules of staff, use of equipment, and supply with necessary materials are formed.

On the one hand, such a construction of the plan makes it possible to monitor effectively the implementation of each elementary operation. On the other hand it allows you to "see the whole picture," that is, to ensure control over implementation of the entire plan.

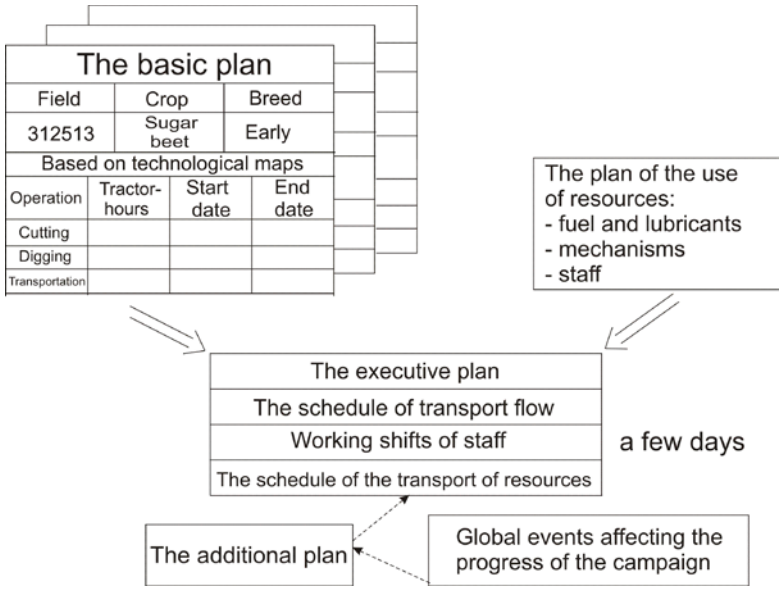

Figure 1. Functional subsystem of planning

Brief characteristics of tasks

To discuss technological features of the subsystem of planning more substantively, its tasks will be briefly reviewed:

1) Planning of annual cultivating states the breeds and amount of crops planned to be cultivated within a season.
2) Planning of fields use fixes the use of each field of the agricultural enterprise within a season for cultivating this or that agricultural crops, taking into account crop rotation.
3) Planning of annual agricultural work in the context of each field and all stages of agrocampaign (sowing, cultivating, harvesting). The structure of the life cycle of a crop determines the list of agricultural work, their optimal terms for each field and each work of agrocampaign.
4) Planning of operations to perform agricultural work for each field and all stages of agrocampaign. It determines further detailing of the plan of agricultural work to the level of agricultural operations. It takes into account weather conditions, soil conditions, weediness, presence of disease clusters and outbreaks of pests.
5) Planning of machine resources required to carry out agricultural works by type of machinery and terms of their use.
6) Planning of use of machine resources, taking into account the process of maintenance and repair, relocation to the place of use, transportation etc.
7) Planning of fertilizers, plant protection products, fuel and materials needed, terms of their purchase and transportation to storage places.
8) Evaluating of required volumes of use of own machine resources, lease and purchase of external resources within an agrocampaign.
9) Preparing of the operation plan of work in relation with the fields.
10) Maintaining standard technological maps of operations (including transport operations supporting basic operations), linking them to the passport information of a field, crops, soil and weather conditions.
11) Creating orders on the use of equipment and invoices to obtain the necessary resources.
12) Correcting of the executive plan of work (considering the information about the soil and crops condition, the volume of work performed) for a field under conditions of each campaign.

13) Taking care of meteorological information, both short-term and long-term weather forecasting.
14) The complex of tasks to plan transporting of harvest. It specifies the use of vehicles during the harvesting.

The order of the tasks in this sequence partially takes into account the sequence of their solving in the process of planning. However, their functionality is different: the tasks of resource supply depend significantly on the task 4. The accuracy and utility of resource planning will be determined depending on the consideration of external influencing factors. Therefore, first of all, an approach to its solving will be described. This approach takes into account external influencing factors on the planning processes deeper. Also some other tasks will be described.

Planning of annual agricultural work in the context of each field and all stages of agrocampaign

To design a plan of annual agricultural work the following data should be considered:

1) Life cycle of the crop on the phases of development (pre-emergence, vegetative, reproductive, etc.), which are characterized by:
   - Typical starting date, duration, ending of the phase under the annual conditions;
   - Qualitative characteristics (number of leaves, etc.);
   - Moisture reserves in the first meter of soil at the beginning of the phase;
   - Number of daylight hours at the beginning of the phase;
   - Average air temperature and precipitation per phase (based on figures for the previous seasons);
   - Quantitative characteristics (mass).
2) Fields, which are characterized by:
   - Area (size);
   - Type of soil (sand, mold, etc.);
   - Mechanical composition and structure of the soil;
   - Types and quantity of fertilizers;
   - Extent of infestation and weed species;
   - Previous crop in the rotation;
   - Crops and their breeds planned to be cultivated.
3) Standard technological maps of crop cultivation.
4) Standard technological maps of operations.

The problem can be formulated as follows: to determine the scope of work for all basic campaigns of cultivating and harvesting of the crop on each field.

Let us single out a common designing technology of an annual plan of agricultural work:

1) If there is a standard technological map of crop cultivating, the scope of work is determined basing on it.
2) If there is no standard technological map of crop cultivating, the scope of work can be determined by taking into account the life-cycle phases of the crop (for the phases of development of crops, coinciding with periods of mechanized field work).

According to the list of phases of crop development and their conformity to the periods of work, the work itself can be determined. Thus, the compiled list of work can serve as a standard technological map of the crop.

With the aid of standard technological maps of specific work and the results of projected phases of crop development the terms of work can be clarified.

The technique of phenological predictions of terms of individual phases of development can be used. The use of the described technique allows specifying terms of the beginning, end and duration of phenological phases of the life cycle of the crop. This technique is based on empirical equations [Арютов, 2010].

The problem solving enables to obtain the stages of work for each field, characterized by:

- Optimal terms;
- A set of standard (including alternative) operations;
- Conditions.

Designing of the executive plan and its providing with technological maps of operations

An executive plan is based on the following factors:

- Short-term weather forecast;
- Current state of the soil;
- Current state of the crop at each phase of the life cycle of its cultivating;
- Supply of resources.

In the process of designing of an executive plan the following points should be determined:

- The possibility of shifting of a specific work from the basic plan to the executive one. This step is performed basing on the short-term weather forecast, prioritization of the work, the terms of the work and compliance of the current state of the crop to the phase of the life cycle of its cultivating;
- The possibility to include additional work into the executive plan. This step is performed in the case of out-of-management condition of the current state of the soil or crop;
- Operation specification of the work of the executive plan;
- A technological map for each operation. The technological map is clarified on the basis of data concerning the state of the soil, crop and resources supply.
- The resources necessary to fulfill the operation, and schedules of their use. This step is performed on the basis of the technological map of the operation and availability of resources for the operation.

While the work is carried out its quality is evaluated. Evaluation is performed in accordance with established standards. Work can be considered completed only when all the operations are over and the quality of the work is confirmed. After that, a corresponding note is entered into the basic plan. Then the work is removed from the executive plan. Otherwise, the operations may be re-added to the executive plan.

Supporting and binding the technological maps of operations to the passport information of fields, crops and weather conditions

Normative-reference information in the form of a technological map of cultivating can exist for the crop rotation. A technological map is the complete description of all operations, their sequence indicating transitions and technological conditions. Typical zonal technological maps of crop cultivating were designed and published for each crop. On the basis of the zonal technological maps planners can design a basic plan of crop cultivation. This plan takes into consideration any specific field conditions, working conditions and the technical equipment of the agricultural enterprise.

Thus, the technological map is transformed into a basic plan of crop cultivation. In this case the technological foundation of the operation remains unchanged. It should be represented by the technological map of the operation. If the technological map of the crop cultivation answers the question: "what should be done to get products?", the operating one answers the question: "how can agricultural work be performed with high quality?". The main purpose of the operating technology is to prevent the shortcomings in the work and to do it in the best

possible time with high quality and the lowest cost of labor and resources. The map must contain seven components [Маслов, 2011]:

1) Initial data or working conditions (the area of the field, its topography, soil and machine resistivity, expenditure norms of seeds, fertilizers and pesticides, crop-producing power of main and sideline products, the distance of transportation of materials).
2) Agrotechnical requirements.
3) The structure of tractor operated machinery, preparing it for use.
4) Work to prepare the field and the working area.
5) Work of the tractor operated machinery in the field.
6) Control and evaluation of work quality.
7) Safety instructions.

Binding of the technological map to different factors (conditions and state of the field, crops, resources, weather forecasts) is done by selecting the most efficient available alternative. Such choice can be made:

- On the basis of formal dependencies of technological norms of the operation on the complex of factors. The dependences can be obtained experimentally;
- When the formalizing of this kind of dependency is impossible – on the basis of expert decisions (of an agronomist, a planner, a controller).

Thus, each operation will be based on such a technological map that describes the individual characteristics of the field in the most effective way.

Planning of resource needs, terms of their purchase and transportation to storage

When designing the basic plan it is necessary to determine the total resource needs. Then a schedule of use of labor and material resources is to be prepared for different cases:

- When own resources are supplied;
- When the resources from outside organizations are supplied.

Following points are to be fulfilled:

- Identifying and distributing the resources required for the operations according to the time;
- Identifying the resource suppliers;
- Taking into account the factors affecting the availability of resources for operations;
- Identifying the terms and conditions of storage of resource stocks;
- Designing the schedules of supply of resources.

The total demand for some types of resources often depends on the intensity of work. First of all it relates to the engaged equipment and staff. Such multicriterial task should be solved by means of designing the schemes of involving and interacting of these resources. Other types of resources, such as seeds, fertilizers, fuel and lubricants, plant protection products can be calculated before the season basing on data about the crop, area and condition of the field, and consumption norms. Designing of schedules of delivery of these resources to the warehouse directly depends on the terms and conditions of their storage.

To optimize resource allocating and resolve resource conflicts alignment methods can be used. They take into account the limits of resource consumption. These methods allow using resources in the most efficient way. Resource leveling can eliminate peaks in the use of resources and set the level of their use below the maximum limit. This is done by shifting some work to later dates. Moreover, the natural shift of work is possible due to the impact of unforeseen external factors. The influence of these factors cannot be eliminated in a short time. Therefore, to establish the terms of the work the apparatus of fuzzy set theory is supposed to be used. The

apparatus implies some "blurring" of the terms of the work. Due to the possibility of emergencies resources may be needed in somewhat larger volumes. In this case, total resource requirements can be planned on somewhat larger scale. Or supply with resources should be planned when designing additional work.

Correcting of the executive plan of work

The perfect fulfilling of plans is known to be impossible to reach. Therefore, when designing a subsystem of planning the specific character of extraordinary situations must be taken into account. Global extraordinary situations are events associated with unsatisfactory condition of crops or soil, disruption of operations, or even a whole range of works. When planning the additional work it is necessary to correlate the current condition of the soil or crop with the terms, the cost of additional work and the extent of possible improvement of the soil or crop condition. Thus, an expert should participate in the decision making that concerns including the additional work into the executive plan.

The executive plan represents the current set of operations that must be performed taking into account the condition of crops, soil and external factors. Considering the foregoing, the executive plan can be viewed as an important component of the mechanism of adaptation of the system managing an agriculture enterprise.

The role of the cartographic system

Unfortunately, it is rather difficult to obtain measuring information concerning the conditions of agricultural objects. The complexity is determined by the length of large objects of work and other specific factors. Shortage of measurement data leads to considerable uncertainty of the results. Practically most of the data is formed only on the basis of agronomists' observations [Garam, Pashko, 2005]. However, it is better to estimate with the help of special equipment:

- By direct contact;
- Without contact by means of remote sensing.

The obtained data can be analyzed using GIS technologies. Spatial analysis provides real processes of dynamics of objects, events or processes. The real processes of dynamics of spatial analysis are obtained by processing and applying a wide range of well-known techniques and models [Balchenko, 2012]. So, geoinformation spatial data analysis can be represented in the form of thematic cartograms of spread of contamination of crops and soil by pests (Figure 2), weeds, diseases, as well as a variety of maps of the movement control of machinery and motor transport, weather forecast

Thus, in case of emergency of situations of global nature, it is necessary to provide the ability to create additional operations. The additional operations can be based on the basic operations regulating the order of actions in case when certain kinds of events take place. For example, in the case of pests, the action can be scheduled to eliminate them by appropriate means.

Conclusion

The concepts in designing the functional subsystem of planning provided by the authors will enable to rationalize the whole system of management of an agricultural enterprise. This is accomplished through the use of modern methods of information-analytical support along with mathematical methods of planning.

The important factors increasing the scientific validity of the designed plans are information technology and mathematical methods of planning of agricultural works. Using the methods of mathematical programming and multicriterial optimization is the most reasonable way of planning. The presented method allows obtaining plans balanced by various criteria of optimality.

Figure 2. Example of use of cartograms to demonstrate the spread of contamination by pests

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