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SUSTAINABLE AGRICULTURAL DEVELOPMENT: KNOWLEDGE-BASED DECISION SUPPORT

Algimantas Kurlavičius

Department of Informatics, Lithuanian University of Agriculture, Universiteto g. 10, LT-53361 Kauno raj., Lithuania, e-mail: info@kurlavicius.lt

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Abstract. The article introduces the knowledge-based agricultural decision support system. The system includes database and knowledge base as well as modules used for formation of models, optimization, simulation, decision analysis and inference. The linear programming model contains several hundreds of variables and restrictions. The farm model, using entered data, is formed according to "if-then" type rules that are stored in the knowledge base. Having solved the task of optimization, the particular values of variables indicate what kind of crops should be grown and in what area, as well as what animals and how many of them should be kept and what resources and how much of them have to be used for achieving the biggest benefit under the environmental and other conditions. The simulation was employed to test the sensitivity of the plan to weather and market variations. Having applied a set of production rules to the given facts and modelling results within the module of decision analysis and inference, conclusions and suggestions are made. Decision support system performs the analysis of production efficiency, resource reserves and shortage, and with the help of the Internet in real time provides a farmer with conclusions and suggestions necessary to increase the efficiency of production conforming to environmental constraints. The integration of optimization calculations and knowledge management into the agricultural decisions-support system expands its possibilities and improves the quality of solutions.

Keywords: sustainable agricultural development, decision support system, linear programming, optimization, simulation, knowledge-based.

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1. Introduction

Agrarian ecosystems are created due to human activities, which always have a purpose, i.e. to produce products, to protect nature, etc. Agrarian systems as well as natural systems are fed by the sun; however, in order to ensure high productivity of these systems, the removal

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of nutrients together with production has to be compensated and the system has to be supplemented with large amounts of energy and materials. Optimal functioning of an agrarian ecosystem, as a complex biological-social-technical system, can be ensured only by systematic solution of the analyzed problems. The methods of systematic analysis and modelling are intensively applied not only in urban and industrial sectors, but also in the research of agricultural development. Systematic approach requires a complex and comprehensive investigation of the analyzed object. The agrarian ecosystem should be analyzed as the one consisting of the components that interact among themselves and with external environment; all important internal and external relations of the components have to be evaluated. As agrarian ecosystems combine biological and physical components, the social and agricultural production aspects have to be analyzed in them. The analysis of agro ecosystems unites the efforts of economists, agronomists, zootechnicians, ecology specialists, sociologists, engineers and other specialists.

Agricultural production in a farm is a complex process, which requires much knowledge. Farmers have to make complicated decisions during a short time. This process includes the choice of decisions about agrobusiness strategy and technology, technological operations and production quality management, resources distribution etc., which helps to get farm revenue, and, simultaneously, to maintain soil productivity and to grow the agricultural produce with minimal negative influence on environment.

In the age of intensive development of new technologies farmers encounter increasing amounts of information. The Internet provides the farmers with various data, including textual and graphic information. However, weather forecasts and answers to frequently asked questions are most often used to satisfy the needs with no analysis of economic activities, decision support, reasoned conclusions and suggestions.

Modelling the agrarian ecosystem enables to foresee the system response to the impacts, hindrances and at the same time reduce the uncertainties of the system behaviour. The modelling approach contributes to a successful combination of competent specialists' experience and computer possibilities.

Mathematical programming was started to be used in agricultural economics more than 30 years ago. The format of mathematical programming, sometimes known as process analysis or activity analysis, is extremely suitable for agriculture. Recently, the importance of modelling and optimization-based decision support has significantly increased in agriculture (Shim *et al.* 2002; Pranevičius and Kurlavičius 2003; Strauss *et al.* 2008). Optimal or nearly optimal solutions provide relevant information, employed to resolve complex agricultural and environmental decision problems (Makowski *et al.* 2001; Khabirov and Nikitina 2007). In agriculture, operational research methods are used in order to find optimal characteristics of the objects investigated, considering time, resources, technological and other restrictions. The methods of mathematical programming method are successfully applied to improve agricultural system planning (Glen and Tipper 2001; Martins and Marques 2007).

Sustainable development of farms requires the development of farming systems that contribute to the increase of farmer's income, reaching socially acceptable levels, the reduction of soil erosion and the improvement of physical and biological soil fertility (Ten Berge *et al.* 2000; Kropff *et al.* 2001). Farmers seek to evaluate projects of farm sustainable development management quantitatively and select the best possible scenarios before they make expensive investments into agricultural machinery or solve ecological problems. Farmers want to optimize production structure and quality as well as to minimize the consumption of chemicals, energy and a negative impact on the environment. Farmers' important objectives are related to the increase of income and to reduced use of fertilisers and pesticides. Today it is important for every farmer to know how much and what kind of agricultural production to produce; i.e. what areas of agricultural production should be developed to be able to meet complicated technological and environmental requirements and not to exceed environmental pollution norms as well as obtain the greatest possible profit. The methods of linear programming are often applied when solving such optimization problems in agriculture (Annetts and Audsley 2002; Xiang *et al.* 2004). Hundreds of variables are interrelated with each other by complex functional interrelationship within the planning problem of optimum agricultural production structure.

The farmer must have comfortable information environment in order to plan rational production and to make strategic and operative decisions. New effective Web technologies of information search and dissemination are adjusted to agriculture. Web portal technology may solve the problem of common agricultural information management by government and consulting firms. Web portal-based knowledge management architecture opens wide possibilities for dissemination of common agricultural information to farmers. Moreover, a web portal gives a user an easy access to information sites, services and other information resources via the unified interface device – user-friendly web browser.

When geographic information system (GIS), global positioning system (GPS), and agricultural machinery with various sensors is used in a farm, a farmer receives information about every square metre of his land. The only way for the farmer to master this enormous amount of information is to use decision support system with relevant software.

Decision Support System (DSS), which estimates the efficiency of possible decisions and reduces uncertainty in management by means of analytical calculation or modelling methods, can help evaluate and select the best possible decisions (Kaklauskas *et al.* 2005). DSS provides a farmer or consultant with a possibility to choose proper variants of farm management by evaluating dynamically changing weather conditions, new technologies, changes in the fields and general agricultural policy. DSS may consist of many subsystems, each of them has its specific task. Various expert systems are widely used in agriculture; however, they are often developed for autonomous computers and aimed at solving highly specific agricultural problems. DSS must satisfy users' requirements as much as possible; the data it contains must be easily updated. Convenient on-line systems serve the purpose (Kaklauskas *et al.* 2007).

There are many individual DSS for crop production and livestock farming developed, yet their integration is complicated. Simplified models do not suit detailed analysis of agricultural production. The complexity of integrated model system depends on the objectives of agriculture specialist, the data they possess and the required precision of decisions. Having structured a universal model system that reflects a standard farm rather precisely, it could be effectively used to make decisions in other similar farms either.

The lack of appropriate integrated tools has forced many researchers to develop so-called hybrid systems, combining different tools within one integrated application. These tools originate from different disciplines such as operation research, simulation, artificial intelligence, fuzzy reasoning etc. The integration of simulation and optimization methods allows decision-makers to master the dynamics of complex systems (Iassinovski *et al.* 2003). The integration of mathematical programming and expert system extends the possibilities of decision support system (Azadeh *et al.* 2006).

Many internet-based systems process and submit exclusively economic information for decisions. Alternatives under consideration have to be evaluated not only from the economic position, but also take into consideration qualitative, technical and other characteristics. It is important to reduce negative impact that chemical plant protection products and fertilizers have on the environment. For this reason, it is proposed to combine environmental and economical objectives. Consequently, the range of decisions that a farmer has to name is increased, and there appears a greater need for DSS that flexibly integrate agro-environmental knowledge of specialists with a farm management model. Therefore, the efficiency of e-business and Web-based systems may be enhanced by applying multiple criteria decision support systems (Kaklauskas *et al.* 2005; Naimavičienė *et al.* 2007; Banaitienė *et al.* 2008; Zavadskas *et al.* 2006, 2008).

Having accumulated the subject knowledge of the best management specialists working in the sphere of crop production and livestock farming, that is necessary to implement the most important agricultural establishment processes, the possibilities of agricultural establishment DSS can be expanded substantially. The more exhaustive knowledge will be accumulated in the base, the more effective decisions a farmer or other specialists will be able to make. The knowledge base should also contain derivation rules, according to which conclusions are drawn from the facts available, standard solutions and analogues may be kept in the base either. It is important to select a relevant form of knowledge rendering, as it has an impact on system characteristics and features. Although the mechanisms of well-known expert system shell and nucleus ensure a convenient way to manage knowledge, their integration into an operative model base becomes complicated.

Relevant software is indispensable for a farmer to make scientifically based decisions on strategic and operative farm management in real time. The investigation of optimization and decision-support means, suggested for farmers, indicated that the choice is rather limited. Simplified models of farms estimate only narrow restrictions, which lack an integrated approach to the interaction of internal farm elements as well as to the interaction with the environment. One model, although it is large, cannot solve all problems of the farm; therefore, a system of related models has to be created. The existing programs, utilizing the algorithms of mathematical programming, require high qualification of users, as they contain complex user interface, which is difficult to understand for a farmer. Besides, they do not provide any tools, necessary for integrating into agricultural information systems. Some of decision support systems, proposed to farmers, did not reach the required level or were not user-friendly, whereas others were too complicated or narrowly specialized. Therefore, the creation of a flexible decision support system, satisfying wide demands of farmers, remains a significant issue (McCown 2002; Kurlavičius, A. and Kurlavičius, G. 2004; Kurlavičius 2005; Nguyen *et al.* 2007).

Seeking to aid the development of sustainable farming system, the usage of linear programming and knowledge-based and integrated DSS is proposed. The article describes a prototype of DSS that helps optimize the structure of agricultural production and choose the best solutions for sustainable development planning within farm and agricultural business management. So that DSS could be used by a wider number of agricultural specialists, a user-friendly and easily understood interface was created.

2. Model for optimization of agricultural production structure

The mathematical model, introduced for optimising the production structure in agricultural enterprises, reflects technological, economical, and organizational aspects of agricultural production and estimates initial farm conditions. The main variables of plant growing applied in the model are as follows: the areas used for growing different varieties of agricultural multi-purpose crops; the quantities of various kinds of agricultural production, the quantities of fertilizers, pesticides and other chemical materials for plant cultivation; and the quantities of agricultural equipment, technical and power resources necessary to perform various works. The main variables of animal husbandry are as follows: animal quantities in terms of different breeds, age and purpose groups; the capacity of the main buildings; and the quantities of various fodders. Production expenses for different kinds of agricultural products, income and the scope of production, pollutant quantities and other items could be used as variables of the model.

The areas of crops grown in agricultural enterprises and the quantity of animals in the farm are limited by available or possible to be obtained land, workforce, agricultural machinery and other resources. Technological, organizational, economic and environmental requirements should also be estimated in the model of agricultural production. Specific number and content of limitations depends on the quantity of existing initial data, characterizing the status of an agricultural enterprise and the vision of farm development. Optimization goal is to find the values of variables that conform to the greatest possible gain under initial input conditions and satisfied limitations.

When formalizing the problem of optimal combination for agricultural production branches, the variables are marked x_j, $j = \overline{1,u}$. A shortened mathematical description of farm resource limitation system is expressed as follows:

$$\sum_{j=1}^{u} a_{ij} x_j \leq R_i \quad (i = \overline{1,q}; \quad j = \overline{1,u}), \tag{1}$$

where a_{ij} – demand for resource i to produce the production unit j; R_i – amount of the existing i-type resources.

The limitations of production volumes are expressed with upper and (or) lower bounds:

$$LB_k \leq \sum_{j=1}^{u} b_{kj} x_j \leq UB_k \quad (k = \overline{1,p}), \tag{2}$$

where LB_k – lower bound of production k; UB_k – upper bound of production k; b_{kj} – coefficient of production k output when resource j is used.

Environment protection norms define the environmental requirements in the following way:

$$\sum_{j=1}^{u} d_{nj} x_j \le Q_n \ \ (n = \overline{1,e}\ ), \tag{3}$$

where d_{nj} – quantity of n-type pollutants or limited waste when manufacturing a production j unit; Q_n – permissible norm of n-type pollutants or limited waste in the enterprise during production manufacture.

Technological limitations are expressed by inequalities and equalities:

$$\sum_{j=1}^{u} h_{mj} x_j \le \sum_{j=1}^{u} v_{mj} x_j \ \ (m = \overline{1,g}\ ), \tag{4}$$

where h_{mj}, v_{mj} – technological coefficients.

Goal function is used to evaluate an optimal plan:

$$F = \sum_{j=1}^{u} c_j x_j \to \max, \ \ x_j \ge 0 \ \ (j = \overline{1,u}), \tag{5}$$

where c_j – contribution coefficient, characterizing the contribution of change of the variable x_j to the efficiency of the plan. The system of constraints (1)–(4) and the goal function (5) describe the optimal static structure of farm production completely and comprise the model of farm strategic development planning. Coefficients of this constraint system are the meanings of areas under arable land, pastures and meadows existing in the farm, parameters of technological efficiency, recommended maximum share of grain crops and minimum share of perennial grasses in the structure of crops, forecasted productivity of crops, the need for separate fodder for an animal per year, forecasted expenses according to the types of production, and forecasted selling prices.

Production planning problem is solved by using a modified simple method. Two main cycles are distinguished in the solution of the task. The first cycle is a search for a possible production structure with non-negative values of variables. If the limitation system is inconsistent, the farm production plan with non-negative values of variables does not exist with values of initial input data. In this instance, the user receives a set of recommendations necessary for changing the corresponding initial input data in order to eliminate contradictions. At that moment the calculation is terminated and returned for the input of correct initial data. If a consistent system and an initial possible farm production plan with non-negative values of variables are found, the cycle of plan improvement is implemented. This cycle is repeated and the plan is improved until the highest farm effectiveness is achieved.

The optimization module, which realizes described modified simplex algorithm, provides the possibility for users to get detailed intermediate results in each calculation cycle. This intermediate information helps an expert to analyze the results conveniently, as well to reveal and eliminate the observed incompatibility of initial data and farmer's needs and demands defined by restriction system. Having solved the problem for the optimization of farm production structure, the obtained values of variables x_j show what crops and in what area should be grown, what animals and how many of them should be kept, what resources and what amounts of them should be used, so that the farm would get the biggest benefit under the indicated environmental constraints and technical-economic coefficients entered. The values of additional variables x_l, obtained during the course of optimization, indicate what recourses the farm uses insufficiently or the ones it lacks.

The constructed linear programming model serves as a constituent of the decision support information system. The use of the model includes sensitivity analysis of different market conditions, different resource and improved or new ecological technology usage. The results of the optimisation indicate that the introduction of environmental limitations leads to a lower net farm income and better performance with all ecological indicators. Model outputs help decision makers to predict the influence of their decisions within a long-term plan. Conclusions, obtained during the process of modelling, could be useful while understanding the behaviour of agricultural sector.

3. Integration of optimization and conclusion formation

The analysis of optimization results is based on the coefficients of the simplex table and dual estimations. Additional values of variables, acquired during calculations, indicate those farm resources that are not completely used, whereas the values of dual variables inform about the deficit of resources. The analysis reflects greater compatibility between the model and the reality as well as the stability of optimal solutions. The impact of change in model parameters (e.g. environmental limitations) change on the profit can be defined during the analysis either.

Time is needed to implement a structural change in farm production, due to the limitations in crop rotation and the production lagging in animal husbandry because of specific features of animal herd formation. The farm simulation model is used to estimate the dynamics within the consequences of the adopted optimal solutions. When applying the method of simulation modelling, dynamic characteristics of animal herd are calculated and the possibilities to manoeuvre agricultural machinery resources in space and time are verified as well.

A set of the initial data and the data of optimization and simulation modules are used to form structured facts and actions (Fig. 1). Indigenous and exogenous factors affecting sustainable strategic planning are categorized and translated into "if-then" style rules, which are stored in the knowledge base. "If-then" style rules are applied to a set of data while forming a conclusion module. In the described system, a prototype for rule processing is tested Friedman-Hill expert system shell Jess (Friedman-Hill 2007).

The structured facts that have named slots are used to form the conclusions. Fact fields with data are defined using "deftemplate" construct. For example, structured facts of resource groups are described by the following structure:

deftemplate **resource** *(*slot *name) (*slot *status) (*slot *means).*

"If-then" style rules are applied to the processing of structured facts, because they are simple and easy to understand. An agricultural specialist-expert defines the rules. The rules are identified by a unique name. The first part of the rule, which is separated by the sign =>, is created according to the template, whereas the second part of the rule describes an action. A simple rule of production, indicating the fact that *Z1* means should be applied, when the shortage of *RM* resource is determined, could be expressed as follows:

(**defrule-R**
(**resource** (name *RM*) (status *lack*) (means *Z1*))
(**means** (name *Z1*) (content *V1*))
=>
(**give-means-plan** *RM Z1 V1*)).

A similar expression is used to describe the rule of production when *Z2* means should be applied because *RM* resource is used insufficiently (status "*surplus*"). Actions like „give-means-plan *RM Z1 V1*" are defined by Java User functions.

The status of different resources (excess or shortage) is determined during the course of optimization and simulation. The status of means is stored in the knowledge base. Having processed the structured facts, while applying the set of rules, the following actions are taken: a plan of actions is presented; conclusions concerning the possibilities to change one kind of fodder into another are drawn; the shortage of resources that stops the production development in the farm most of all is determined; suggestions to purchase technical resources for the development of profitable production are given; the possibilities to manoeuvre the resources of agricultural machinery are indicated; the parameters of the model are changed; and new facts are saved in the knowledge base.

The possibilities of the DSS could be greatly expanded when the knowledge base accumulated the knowledge of various domains of the best specialists such as agriculturalists, veterinarians and agro-business managers for the successful implementation of farm processes. The expert system can perform functions, the fulfilment of which requires the utilization of specialist experience or the assumption of the role of a person-assistant who makes decisions.

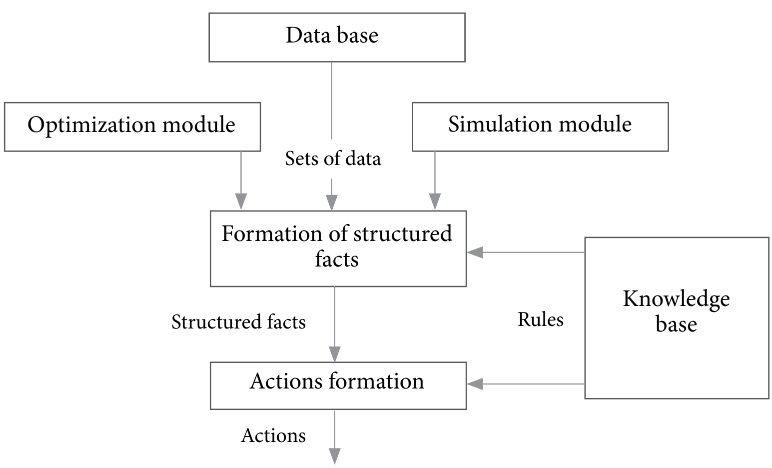

Fig. 1. Flows of data and knowledge

4. Optimization and knowledge-based DSS

The need to effectively integrate decision-making tasks, together with knowledge representation and visualisation tasks, inference procedures that model an expert's thinking process, has strained research attempts to integrate DSS with Knowledge Systems (Kaklauskas *et al.* 2008; Kaklauskas and Zavadskas 2007).

The framework of the integrated optimization and knowledge-based DSS contains database, knowledge base, model formation, optimization, simulation and conclusion formation modules (Fig. 2). Program modules operate in the server, which is easily accessible by users via the Internet.

DSS interface contains 3 main parts: (1) a universal form, which helps to get information from the user; (2) a mechanism for communication with expert system that forms conclusions; (3) a universal form, presenting the results of the system work on the user's screen.

The farmer enters the initial data about the farm while answering questions, generated by the system and filling in the templates, presented on the screen (Fig. 3). The data entered is processed using real-time regime and the user receives the results of data consistency analysis. Constants and rarely changing data, similar to many farms of the region, are stored in the system database. There are different fodder nutritious indices, fodder demand for different age animal groups, parameters of technological parameters, productivity of various agricultural machinery and other characteristics. These coefficients are specified, entered and modified by agricultural specialist-experts. Analytical information, collected during optimization and simulation, can also be stored in the database. Forecasted market prices, standard expenses can be entered by a farmer or an expert or calculated using the data from the knowledge base of the distant server.

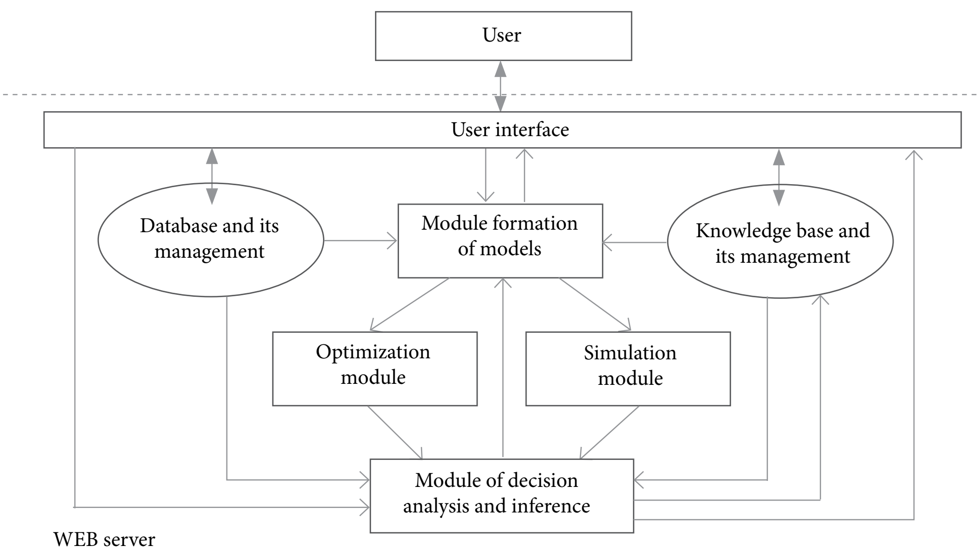

Fig. 2. The architecture of farm management knowledge-based DSS

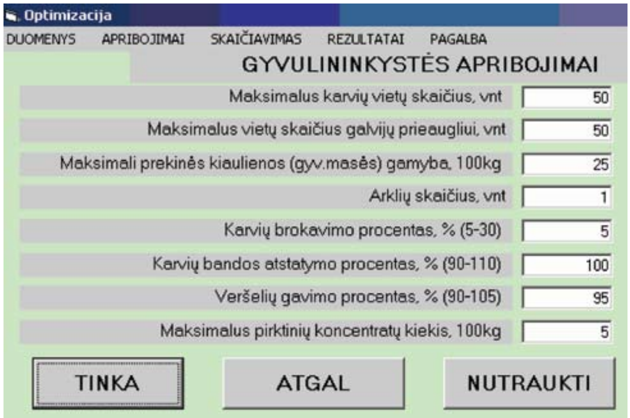

Fig. 3. Screen form for the input of major limitations of livestock farming

Having entered all the necessary data, the model formation program, which includes editor of model formation rules and interpreter of the rules, is called. This program sets the interaction of model formation actions and events. On a user's request, the model formation system automatically forms a constraints system; therefore, the farmer can possess no knowledge about the composition of the mathematical model of the farm. In this case, coefficients of the model are specified by the system of model formation according to the "if-then" style rules, stored in the knowledge base. For example, if a user plans to specialize only in plant-growing production and selects the corresponding menu line, he does not need to enter any data that characterizes the production of animal husbandry. In such a case, functions describing animal husbandry automatically disappear from the model and the time needed to solve the problem decreases. Similarly, if a user chooses to keep animals of certain breeds or to apply new feeding technologies and scientist-recommended ratios, corresponding coefficients of the model are automatically selected from the knowledge base according to expert suggestions.

A more experienced farmer or a specialist expert has a possibility to choose a desired frame of a farm model with the help of menu, and to modify it in different ways as well as develop and evaluate the desired variants of farming. Besides, the program of model formation allows the expert to enter new desired constraints and set digital values of coefficients.

The knowledge base is integrated into the DSS. A specialist-expert has a possibility to review and supplement the set of production rules and facts. Having applied the set of production rules to the given facts and modelling results within the module of decision analysis and inference, conclusions and suggestions are formed and the results obtained are presented to the user.

Having solved the task of farm production structure optimization, the values of variables indicated the type of crops and the area needed to grow them (Fig. 4); the type and amount of cattle to be kept so that the biggest possible profit is obtained under the present conditions (initial input data). Moreover, the scope of production and economic indices are calculated. Calculation results are presented in the screen or printed.

Barley	54.74 ha
Fodder roots	1.88 ha
Potatoes	4.00 ha
Annual grasses for fodder	11.28 ha
Perennial grasses for hay	31.09 ha
Pasture land	12.00 ha
Grassland for silage	5.00 ha

Fig. 4. A fragment of crop production structure calculation

The analysis of optimization results is based on the coefficients and dual assessments of the last simplex table. It allows performing deeper assessment of conformity between the model and the reality as well as that of optimal solution reliability. The values of additional variables obtained in the course of calculation indicate enterprise resources that have not been used fully. The values of dual variables inform about the deficiency of resources. Furthermore, in the process of analysis, the outcome of change in individual model parameters (such as barley price increase) for the farm may be determined. If a production plan is not stable in terms of some parameters, the guarantee to reach its optimum diminishes; and therefore, the plan stability determination is performed while altering initial data.

The changes in productive activity are often planned. When one production is anticipated to be produced instead of another (for example, instead of marketable barley, marketable oil seed rapes or other crops are projected to be grown), it is necessary to assess the benefit of foreseen changes. The proposed system is convenient for anticipatory assessment of foreseen changes as it forms conclusions according to the production rules and presents comprehensive explanations on the screen or in print on a user's request. According to the values of major, additional and dual variables obtained in the course of calculation, the DSS forms conclusions and proposals on the possibility to change one type of fodder with another, indicates the deficiency of enterprise resources that impede production development most, submits proposals on material-technical resources that are necessary for the development of profitable production (Fig. 5).

The majority of farmers make decisions without considering how they do that; thus it is not easy to use their experience while improving or developing a new DSS. It was noticed that farmers seek for efficient work with minimum usage of formal apparatus and in complicated cases they address consulting services. Although farmers acknowledge the usefulness of DSS, they are often disappointed while trying to understand its functioning. Consequently, farmers' training is integral part of DSS implementation. Most of principal knowledge describing complex biological and physical processes may be hidden from DSS user, yet the results of system operation must be presented in a form clear to a farmer. The farmer should be able to pose a question clearly and to perceive the information presented by the system correctly in order to use the DSS conclusions. It is important to introduce system limitations to the user.

Modular nature of the system eases the system of modification and its application when treating new situations and problems. When assessing DSS, its usefulness and expenses related to its implementation and exploitation are important factors.

There will be a lack of 15 places for calves in the cattle shed for young calves.
It is proposed to enlarge the shed for young calves.
12 places for cows will be vacant in the cattle-shed.
Cattle will receive only necessary amount of digestible proteins.
Cattle will receive only necessary amount of concentrates.
Minimum amount of hay necessary in cattle fodder ration is exceeded by 16 578 kg.
Cattle receive only necessary amount of green fodder in May.
Minimum amount of green fodder necessary in cattle fodder ration is exceeded by 1201 kg in July.
Cattle receive only necessary amount of green fodder in September.
It is recommended to establish additional pasture land of 8 ha.
Maximum area of fodder roots.

Fig. 5. A fragment of DSS conclusion

The system was tested with a medium-sized farm and good responses were obtained. The introduced DSS enables to perform thorough qualitative and quantitative assessment of foreseen changes in agricultural production structure and to make effective decisions; it also reduces decision-making costs. Flexibility is characteristic to the described system: having altered fixed data of the system and production rules, it can be easily adapted to any specific farm, i.e. that of gardening or horticulture. It is advisable to introduce the system in agricultural enterprises and consulting services. With a constant supply of the latest knowledge on plant growing, animal husbandry and agro-business, the intelligence and usefulness of the system is increasing. It is purposeful to continue work with integration of optimization system into accounting information system, its supplementation with operative planning sub-system, knowledge-base complementation with the latest knowledge on agricultural manufacturing and environmental technologies.

DSS is useful to a farmer when he experiences the lack of knowledge and the need for help. While new technologies appear and economic environment changes, the need for DSS increases. One needs a doctor when in pain and similarly DSS is needed when a farmer faces the changes in accustomed environment or unclear situation and experiences uncertainty. DSS serves as a tool to improve decisions and helps a farmer to select the most efficient production plan, to make economic-based decisions that enable him to reduce production costs and preserve nature.

Farm DSS is a convenient tool that helps to acquire knowledge on agricultural manufacturing processes and to train farmers. It is noticed that having found a solution applicable to a certain situation in DSS, a farmer remembers it when facing a similar case in the future, i.e. when a solution becomes customary, he does not need the help of the system. Thus, DSS helps the farmer to acquire new experience. Training may become distance learning when using the Internet. The basis for a successful application of DSS is collective teamwork between a farmer and a consultant with the help of scientists at the initial stage.

5. Conclusions

1. Agricultural production is a complex process, which requires much knowledge. Agricultural specialists need safe and reliable information environment for strategic and operative decision-making. Farmers want to optimize production structure and quality, minimize the consumption of chemicals, energy and negative impact on the environment. Programs and software applications that are used in farms for decision-making often are of narrow specialization and do not satisfy users' needs for information completely. Established programs that realize agricultural production optimization algorithms require high qualification of the user, as they have complex user's interface and do not provide integration into farm management information system and knowledge management.

2. In order to aid the development of sustainable agriculture in the farm level, the usage of linear programming model system is proposed. The model system reflects technological, economical, and organizational aspects of agricultural production and initial farm conditions. An experienced agricultural specialist has a possibility to choose a desired frame of the farm model with the help of menu, and to modify it in different ways as well as to develop and evaluate the desired variants of farming. Besides, the program of model formation allows the expert to enter the desired new constraints and set digital values of coefficients. Modelling the agrarian ecosystem enables to foresee the response of the system to the impacts, hindrances and at the same time to reduce the uncertainties of the system behaviour. The modelling approach contributes to a successful combination of the experience of competent agricultural specialists and computer possibilities.

3. Introduced farm management DSS includes database and knowledge base, optimization, simulation, decision analysis and conclusion formation modules. Optimization model enables to optimize agricultural production structure and quality, to minimize the consumption of chemicals, energy and negative impact on the environment under the entered conditions. The status of different available resources (excess or shortage) is determined in the course of optimization. The production simulation model verifies the effectiveness of operative decisions in plant growing and animal husbandry.

4. Farm management DSS possibilities are extended by the knowledge base. By using a set of production rules stored in the knowledge base, the module of conclusion formation identifies the lacking resources that impede production development most, forms conclusions about the possibility of change in resources and indicates the scope of resources manoeuvring according to optimization and simulation results.

5. The prototype of optimization and knowledge-based agricultural DSS was tested with a medium-size farm data and good responses were obtained. The introduced DSS enables to perform thorough qualitative and quantitative assessment of foreseen changes in agricultural production structure and to make effective decisions on farm production management. Flexibility is characteristic to the described system. Having altered fixed data of the system and production rules, it can be easily adapted to any specific farm, i.e. that of gardening or horticulture. With a constant supply of the latest knowledge on plant growing, animal husbandry and agro-business, the intelligence and usefulness of the system is increasing. It is purposeful to continue work with integration of optimization system into accounting information system,

its supplementation with operative planning sub-system, knowledge base complementation with the latest knowledge on agricultural manufacturing and environmental technologies. Modular nature of DSS eases the system modification and its application when solving new situations and problems.

6. Farm DSS is a convenient tool that helps acquire knowledge on agricultural manufacturing processes and to train farmers. It is noticed that having found a solution applicable to a certain situation in DSS, a farmer remembers it when facing a similar case in the future, i.e. when a solution becomes customary, he does not need the help of the system. Thus, DSS helps the farmer to acquire new experience. Training may become distance learning when using the Internet. The basis for a successful application of DSS is collective teamwork between a farmer and a consultant with the help of scientists at the initial stage.

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DARNI ŽEMĖS ŪKIO PLĖTRA: ŽINIOMIS GRĮSTA SPRENDIMŲ PARAMA

A. Kurlavičius

Santrauka

Pristatoma žiniomis grįsta žemės ūkio sprendimų paramos sistema. Ją sudaro duomenų ir žinių bazės, modelių formavimo, optimizavimo, imitavimo, sprendimų analizės ir išvadų formavimo moduliai. Žemės ūkio įmonės modelis sudaromas pagal įvestus duomenis, remiantis žinių bazėje saugomomis „jeigu–taip“ tipo taisyklėmis. Išsprendus optimizavimo uždavinį gautos kintamųjų vertės rodo, kokie javai ir kokiame plote turi būti auginami, taip pat kokie gyvuliai ir kiek jų turi būti laikoma, kokie ištekliai ir kiek jų turi būti panaudota, norint pasiekti didžiausią naudą ūkyje nurodytomis aplinkosaugos ir kitomis sąlygomis. Imitavimo būdu patikrinamas gamybos plano jautrumas orų ir rinkos pokyčiams. Išvadų formulavimo modulyje, pritaikius duotiems faktams ir modeliavimo rezultatams produkcinių taisyklių rinkinį, gaunamos išvados bei pasiūlymai. Sprendimų paramos sistema atlieka gamybos efektyvumo, išteklių rezervų bei išteklių trūkumo analizę. Ūkininkas internetu gauna išvadas bei pasiūlymus, kaip didinti gamybos efektyvumą. Optimizavimo skaičiavimų ir žinių bazės integravimas į žemės ūkio sprendimų paramos sistemą išplečia jos galimybes ir pagerina sprendimų kokybę.

Reikšminiai žodžiai: darni žemės ūkio plėtra, sprendimų paramos sistema, tiesinis programavimas, optimizavimas, imitavimas, žinių bazė.

Algimantas KURLAVIČIUS. Assoc Prof, PhD, Head of the Department of Informatics, Lithuanian University of Agriculture. Author and co-author of 2 monographs and over 50 scientific articles. Research interests include optimization for sustainable development, decision support information systems etc.