International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Methodology for Selection and Placement of Agricultural Crops using Artificial Intelligence

Vladimir K. Kalichkin, Roman A. Koryakin, Tatyana A. Luzhnykh, Vera S. Riksen, Anastasia S. Rudneva

Abstract*:The conceptualization of the domain knowledge "selection and placement of a crop" was carried out. The model contains ontological entities – classes and the relationships between classes, presented in the Unified Modeling Language format. The model describes five classes – "Crop", "Crop biology", "Conditions for growth and development", "Control actions", and "Placement", as well as a list of characteristics that affect the performance targets of factors. An algorithm based on the control matrix has been proposed. With the participation of an expert, values from zero to one were assigned for seven factors of "Control actions", based on the assumption that the control actions affect 22 factors of three other classes: "Crop biology", "Conditions for growth and development", and "Placement". A crop selection can be performed by comparing these matrices with each other. A flow diagram for the preparation of decisions for crop cultivation management, which includes 84 control action chains, has been proposed. Each of these chains was also rated from zero to one for conformity with a certain ideal agronomic strategy. According to these estimates, it is possible to obtain the strongest and weakest strategies for the decision-maker. The structural management of crop selection and placement does not include changing of the models that calculate numbers in the final tables for each crop, but rather is the development of criteria for the presence of the class characteristics in the table for the domain knowledge. Adding or removing characteristics for each crop changes ratings and total values. Artificial intelligence identifies a set of strategies according to the algorithm of their evaluation, which was developed with the participation of an expert.

Keywords*: crop selection and placement, domain knowledge conceptualization, structural management, UML diagrams, artificial intelligence.

Manuscript published on November 30, 2019.
***** Correspondence Author

Vladimir K. Kalichkin*, Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, Krasnoobsk, Russia.

Roman A. Koryakin, Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, Krasnoobsk, Russia.

Tatyana A. Luzhnykh, Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, Krasnoobsk, Russia; Novosibirsk State Agrarian University, Novosibirsk, Russia.

Vera S. Riksen, Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences, Krasnoobsk, Russia; Novosibirsk State Agrarian University, Novosibirsk, Russia.

Anastasia S. Rudneva, Novosibirsk State Agrarian University, Novosibirsk, Russia

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

I. INTRODUCTION

The selection of optimal placement of agricultural plants in a specific territory factoring in the necessary growing conditions is one of the main challenges in crop production [1].

There are several widely-known approaches to solving this problem: decision-making based on the selection of significant influence factors; development of evaluation criteria based on fixed reference data; stochastic modeling of the processes; compile time series based on the geospatial data; simulation modeling, etc.

Scenarios for practical application of these approaches have the following common features: the use of mathematical models and the selection of key parameters and an acceptable variability range. The values of the predicted results are controlled by varying the parameter values within the range boundaries. Such a control method in system analysis is called "regulation", or fixed value control [2]. In a situation where no parameter value variation within the chosen model predicts acceptable results, researchers have a choice: either admit that the used model in its existing form is incorrect and attempt to change it within the framework of the regulatory paradigm, or choose another model within the same paradigm, assuming the risk that the new one can be inapplicable in certain conditions, or switch from the fixed value control method to structural management [2].

The concept of structural management is associated with modification of the structure and content of the data that forms the input for the regulatory model [3-5]. Such data that form the input of a model, its origin, types, and coupling are collectively called the domain knowledge [6]. Its modification in order to obtain better predictions of the results is called the conceptualization of the domain knowledge. For example, Dunin [7] proposed a new conceptual construct – the concept of immunogenesis – to describe the development of a plant organism in time-varying ecocenoses, which has led to the formulation and solution of plant genetic modification challenges in recent years. Similarly, domain knowledge conceptualizations were developed by such famous scientists as Mechnikov [8], Michurin [9], Vavilov [10], von Liebig [11], Sjörs [12], Baker [13], and Mendel [14]. All these results formed the basis of the accepted scientific paradigm of the study of the interaction of society and nature.

Retrieval Number: D8638118419/2019©BEIESP
DOI:10.35940/ijrte.D8638.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Conceptualization is a methodological procedure for the introduction of certain ontological representations into a certain array of empirical data, which is aimed at the systematization of knowledge (conceptual identification) and theoretical organization of knowledge, as well as a schematization of the connections between concepts. The current challenge of the scientific conceptualization of a domain knowledge is the selection of appropriate observed and measured conditions and factors affecting agricultural results that need to be used in any regulatory model that is assumed to yield adequate solutions. The subject of our domain knowledge research was "the assessment of crops according to their biological requirements for growing conditions" and the construction of a conceptual model for the selection and placement of crops in a particular area. This domain knowledge is considered in various aspects in the previous papers [1, 15, 16] and we believe that it can be abbreviated as "crop selection and placement".

Aim of the study: Conceptualization of the domain knowledge and development of a methodology for crop selection and placement using the methods of artificial intelligence.

II. MATERIALS AND METHODS

To visualize the conceptual model of the domain knowledge "crop selection and placement" with the use of diagrams, the Unified Modeling Language (UML) was used. The UML is a graphical notation that is designed to model and describe processes taking place in the subject field. We used one type of diagram – class diagrams. Class diagrams are used to represent the static structure of a system model in the terminology of classes of object-oriented programming. These diagrams reflect the structure and composition of the subject field through the description of its individual entities – classes – and describe the internal architecture of classes and the relationships between them.

III. RESULT AND DISCUSSION

The conceptual model of the domain knowledge "crop selection and placement" contains ontological entities – classes and the relationships between them, depicted in the form of a UML diagram (Figure 1). The class is depicted in the form of a rectangle with its name and a list of characteristics – attributes, the values of which vary for different objects – members (or instances) of the class; each of these characteristics is a factor that affects the target indicators. The central class in the model is "Crop", the other four classes characterize the factors that influence the decision-making on the selection and placement of a crop on a given territory.

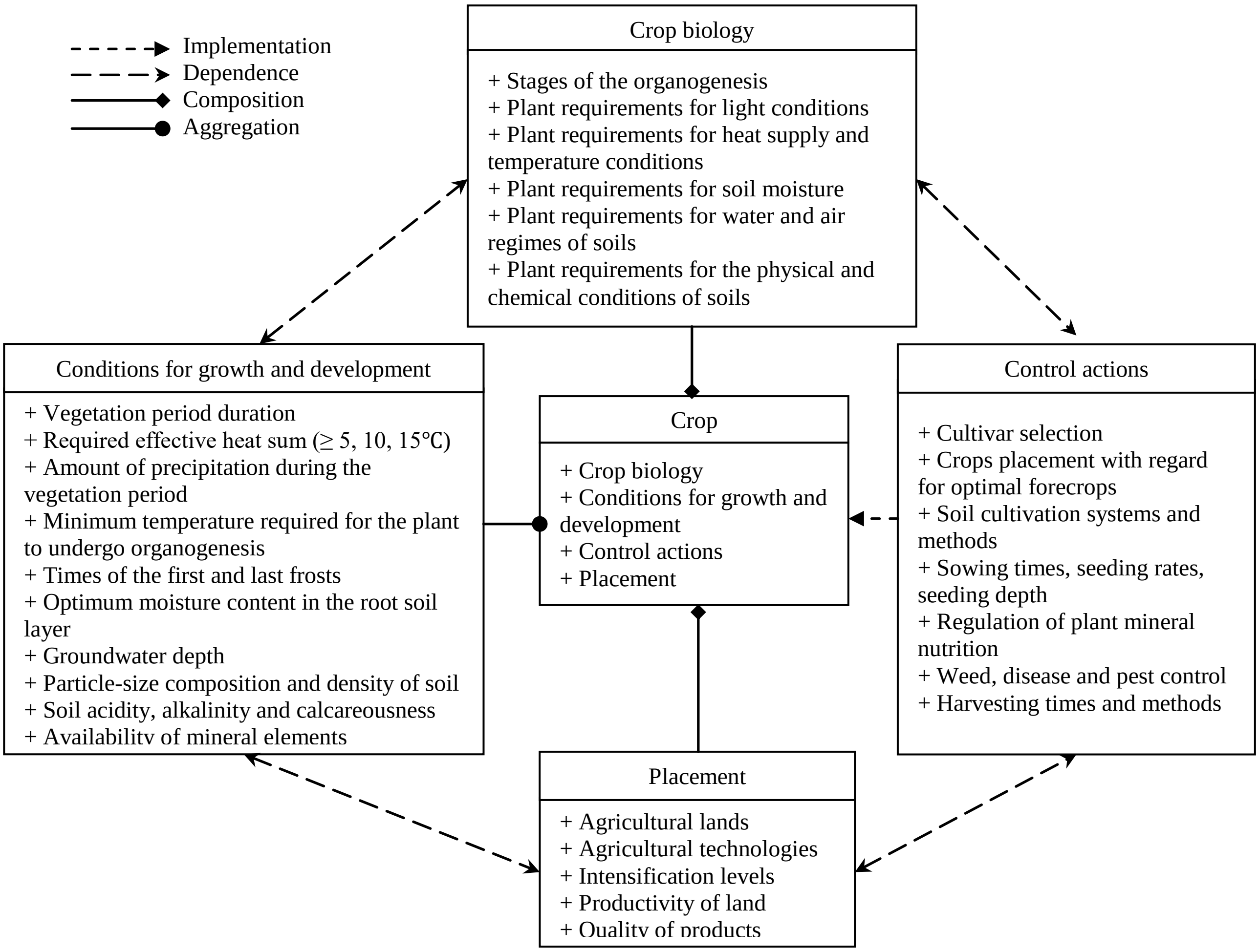

Fig. 1: The diagram of the conceptual model of the domain knowledge "crop selection and placement"

The conceptual model "crop selection and placement" can be used in a certain algorithm for the selection and placement of a crop, regardless of the number and composition of class characteristics within each block. The simplest technique in the framework of the structural management of the decision-making process involves the addition or rejection of subject field elements that directly or indirectly affect the performance targets. In the future, it will be possible to obtain various decisions for the choice and placement of a crop, depending on changes in the contents of the classes without changing this algorithm itself. We give an example of such an algorithm below.

Using the seven blocks listed in the class "Control actions" (CA) in the management, we assume that we affect 22 factors in the other three classes: "Crop biology" (CB), "Conditions for Growth and Development" (CGD), and "Placement" (P). A table can be compiled for each crop connecting seven control functions with plant development (CA 1 – CA 7) and the other 22 factors (CB 1 – CB 6, CGD 1 – CGD 11, P 1 – P 5) with a total of 154 cells (Table 1).

Table 1: Control matrix for a crop

	CA 1	...	CA 7
CB 1			
...			
CB 6			
CGD 1			
...			
CGD 11			
P 1			
...			
P 5			

Zero is assigned to each cell if the block of the "Control actions" class does not affect the factors of a particular class and if it does, a number from zero to one is assigned. The sum in the block column should be equal to one. These values are assigned according to known reference or experimental data with the involvement of experts. For example, if by the beginning of the vegetation season in spring the haulm stand density is insufficient or there is a delay in the development of crops (late sowing, late development of seedlings due to lack of moisture, winter killing of winter crops, etc.), it is advisable to apply an increased dose of nitrogen fertilizers for the first top dressing as soon as possible, which will stimulate tillering. The second top dressing using nitrogen fertilizers and early (at the beginning of the reasonable time) treatment with retardants (which, while promoting resistance to lodging, also stimulate tillering) serve the same purpose [17]. This example illustrates the effect of fertilizers on the growth and development of plants, which is mentioned in the class "Control actions".

Therefore, there is a table with 154 numbers from zero to one (the sum of which is seven) for each crop. By comparing these tables for different crops or their individual rows, one can choose a crop. Each time it will be a different argument. A sum of seven allows considering a separate matrix space with such a common property. In three-dimensional space, it looks like a 22 × 7 "platform" with columns corresponding to the ratings. The total volume of columns on the "platform" is seven. A comparison may be performed in different ways, mathematically, this will mean the introduction of a measure on the space of these matrices. One measure may be a comparison of the densities in the "productivity" line. A measure may be complex – productivity and several other factors (other lines). However, a complex measure may not include rows, but a set of table cells. The concept of our approach is that the measure is different depending on various conditions. Therefore, during the search for the solution of a task of selecting and placing a crop in a function of an agricultural intelligence system, it will also be necessary to introduce a space of measures over the space of these matrices. The shift in the space of measures will occur depending on the distribution of conceptualized domain knowledge within the general knowledge. A domain knowledge structure with higher capacity in any part of the general knowledge gives reason to use a measure that takes this depth into account. Therefore, an infinite four-dimensional set of models is created. The model can change in four coordinates (dimensions): the number and composition of control factors, the number and composition of controlled factors, the method and principles of rating, the method of comparing matrices. This is the main advantage: the rejection of a specific fixed model and the mobility of the model in four-dimensional space, depending on the problem definition, data available for analysis, and random factors taken into account. The correct filling of the table and choice of the operator (function, criterion) for tables comparison are of substantial significance in this algorithm. In practice, first, an expert does this and then machine learning technologies are applied [18, 19]. With a range between the highest and the lowest estimates for each crop, various criteria can be used to select a crop for placement.

In addition to the algorithm of "crop selection and placement", we propose a flow diagram for decision-making on managing the crop cultivation process (Figure 2). Before applying a control action, simulation modeling is performed to predict the effects of this action. This is a standard feature of the decision support system [20-22]. The diagram presented in Figure 2 allows tracing the possibilities of control of the cultivation process from the class "Control actions" to the class "Justification and formulation of the optimal final result" (JFOFR).

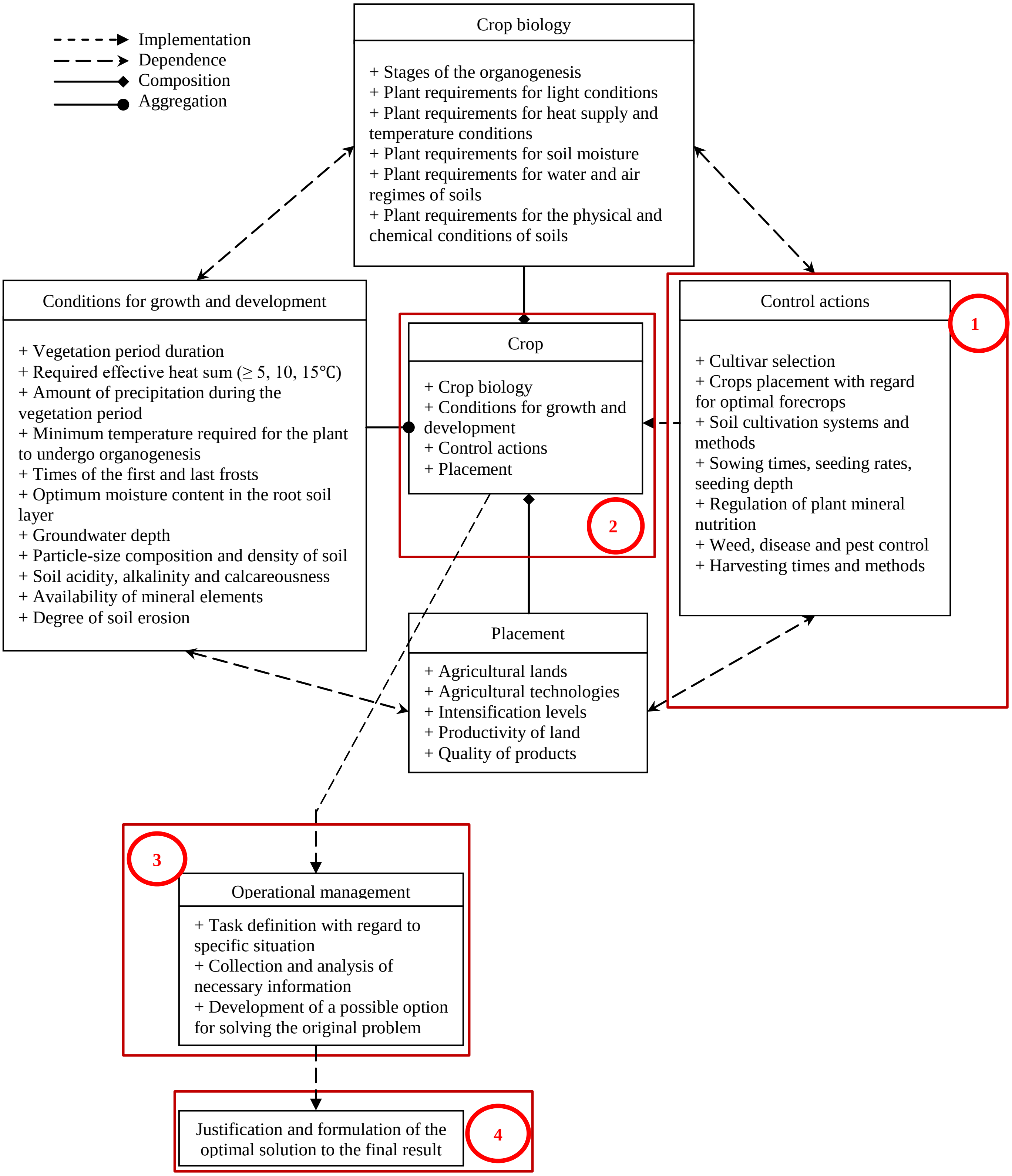

Fig. 2: Diagram of the decision-making process

The control links are indicated by the numbers 1 to 4 in red frames. The entire control chain, which forms the basis of simulation modeling, passes through the following classes: “Control actions” (7 attributes), “Crop” (4 attributes), “Operational management” (3 attributes), and JFOFR (1 attribute). Evidently, the total number of the control action chains will be 84 (7 × 4 × 3 × 1). Each of these chains (we will designate them using the first three components, as the last link will be the same for all chains due to the lack of attributes in the JFOFR class) can be rated from zero to one for conformity with a certain ideal agronomic strategy.

According to these ratings of control chains, it is possible to obtain the strongest and weakest strategies for the decision-maker (agriculturalist). The weakest strategy provides the least control effect and the strongest strategy provides the greatest control effect.

The weakest strategy is a limited, albeit guaranteed management factor – if this strategy may be used for management, then other, stronger strategies will also work. The indicators obtained or evaluated for this strategy may be used as the lowest estimates. The same can be done for the strongest strategy. If the strongest strategy does not work when certain indicators are reached, then the weaker ones will not work either. Due to this principle, upper estimates for the indicators can be obtained. Using a similar mechanism, J. von Liebig [11] formulated the law of the limiting factor.

The efficiency of this approach depends on the correct assessment of the strategies of the agriculturalist, i.e. chains of control. The computer will easily identify the entire set of strategies, but the algorithm for their evaluation and rating should be developed with the participation of an expert. It is possible that the rating of strategies may be constantly updated, depending on various random factors, as well as on the emergence of new data on the use of these strategies in other areas and regions.

IV. CONCLUSION

The implementation of the structural management of crop selection does not include changing the models that calculate numbers in the final tables for each crop (although this is important, it is done once and the result remains unchanged), but rather is the development of criteria for the presence of the subject field elements in the table. Adding or removing elements for each crop will change ratings and total values. Account must be taken of the fact that exclusion from the analysis of a factor that may be insignificant for one crop can greatly corrupt the final result for another crop. From these considerations, it may be concluded that all factors or elements of the domain knowledge must be present in the management matrix for the crop. This is not a problem for modern computing tools. The conceptualization of the domain knowledge or even its part outlined by certain criteria is an endless problem and with the growth of the volume of structured and detailed information, the risk of not taking into account any data tends to zero. However, the risk to spend resources on the solution of an unnecessary problem always remains, even with all input data.

The presented options that offer solutions are the specific positions of the decision support system. A decision-maker (agriculturalist) relies on such positions with a certain degree of confidence for the selection and placement of a particular crop in a given territory. The domain knowledge “crop selection and placement” is only one of the factors that are taken into account when a managerial decision is made in an agricultural enterprise.

REFERENCES

1. V.I. Kiryushin, A.L. Ivanov, “Agroekologicheskaya otsenka zemel, proektirovanie adaptivno-landshaftnykh sistem zemledeliya i agrotekhnologii. Metodicheskoe rukovodstvo” [Agroecological assessment of land, design of adaptive-landscape systems of agriculture and agricultural technologies. Methodical guide]. Moscw: Federal State Budgetary Institution “Rosinformagroteh”, 2005, p. 784.
2. F.P. Tarasenko, “Prikladnoi sistemnyi analiz”: uchebnoe posobie [Applied Systems Analysis: A Training Manual]. Moscow: KNORUS, 2010, p. 224.
3. G.N. Kalyanov, “CASE strukturnyi sistemnyi analiz: (Avtomatizatsiya i primenenie)” [CASE structural system analysis: (Automation and application)]. Moscow: LORI, 1996, p. 242.
4. J. Pfeffer, “New directions for organization theory: Problems and prospects”. Oxford University Press on Demand, 1997, p. 263.
5. A.M. Vendrov, “CASE-tekhnologii. Sovremennye metody i sredstva proektirovaniya informatsionnykh system” [CASE technology. Modern methods and means of designing information systems]. Moscow: Finansy i statistika [Finance and Statistics], 1998, p. 98.
6. G.V. Rybina, “Osnovy postroeniya intellektualnykh system” [Fundamentals of building intelligence systems]. Moscow: Finansy i statistika [Finance and Statistics], 2010, p. 432.
7. M.S. Dunin, “Immunogenez i ego prakticheskoe ispolzovanie” [Immunogenesis and its practical use]. Riga: Latgosizdat, 1946, p. 147.
8. I.I. Mechnikov, “Akademicheskoe sobranie sochinenii”: Statyi po zoologii i parazitologii [Academic Collected Works: Papers on zoology and parasitology]. Moscow: Medgiz, 1955, p. 391.
9. I.V. Michurin, “Sochineniya: Printsipy i metody raboty” [Writings in 4 volumes: Principles and methods of work]. Moscow, OGIZ, Selkhozizdat, Vol. 1, 1948, p. 715.
10. N. I. Vavilov, “Immunitet rastenii k infektsionnym zabolevaniyam” [Immunity of plants to infectious diseases]. Moscow: Ryabushinsky Printing House, 1918, p. 239.
11. Yu. Libikh, “Khimiya v prilozhenii k zemledeliyu i fiziologii” [Chemistry as applied to agriculture and physiology]. Moscow: State publishing house of collective farm and state farm literature, 1936, p. 408.
12. H. Sjörs, “On the relation between vegetation and electrolytes in North Swedish mire waters”, Oikos, 2, 1952, pp. 241-258.
13. O.E. Baker, “The increasing importance of the physical conditions in determining the utilization of land for agricultural and forest production in the United States”, Annals of the Association of American Geographers, 11(1), 1921, pp. 17-46.
14. G.I. Mendel, “Opyty nad rastitelnymi gibridami” [Experiments on plant hybrids], Trudy Byuro po prikladnoi botanike [Proceedings of the Bureau of Applied Botany], 3(11), 1910, pp. 479-529.
15. V.I. Kiryushin, “Ekologicheskie osnovy zemledeliya” [Ecological basis of agriculture]. Moscow: Kolos, 1996, p. 367.
16. V.I. Kiryushin, “Teoriya adaptivno-landshaftnogo zemledeliya i proektirovaniya agrolandshaftov” [The theory of adaptive landscape farming and the design of agricultural landscapes]. Moscow: Kolos, 2011, p. 443.
17. V.I. Kiryushin, A.N. Vlasenko, V.K. Kalichkin, “Adaptivno-landshaftnye sistemy zemledeliya Novosibirskoi oblasti” [Adaptive-landscape farming systems of the Novosibirsk region]. Novosibirsk: Sib. otd-nie RASKhN [Siberian branch of the Russian Academy of Agricultural Sciences], 2002, p. 388.
18. E. Alpaydin, “Introduction to machine learning”, London: MIT press, 2009, p. 538.
19. I.H. Witten, E. Frank, M.A. Hall, C.J. Pal, “Data Mining: Practical machine learning tools and techniques”. Morgan Kaufmann, 2016, p. 621.
20. J.W. Jones, G.Y. Tsuji, G. Hoogenboom, L.A. Hunt, P.K. Thornton, P.W. Wilkens, D.T. Imamura, W.T. Bowen, U. Singh, “Decision support system for agrotechnology transfer: DSSAT v3”, Understanding options for agricultural production.Springer, Dordrecht, 1998, pp. 157-177.
21. J.W. Jones, G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, J.T. Ritchie, “The DSSAT cropping system model”, European journal of agronomy, 18(3-4), 2003, pp. 235-265.
22. V.M. Kureichik, “Osobennosti postroeniya sistem podderzhki prinyatiya reshenii” [Features of the construction of decision support systems]. Izvestiya Yuzhnogo federalnogo universiteta. Tekhnicheskie nauki [Bulletin of the Southern Federal University. Technical sciences], 132(7), 2012, pp. 92-98.