УДК 004.93

Роман Куц[1], А.І. Шевченко[2], Ю.П. Чаплінський,[3] І.В. Качур, О.С. Звенігородський [2]
[1] Yale University, USA,
15 Prospect Street, Becton Center 511, New Haven CT 06511-6816
[2] Інститут проблем штучного інтелекту МОН і НАН України,
пр. Глушкова, 40, Київ, Україна, 03187.
[3] Інститут кібернетики ім. В.М. Глушкова,
пр. Глушкова, 40, Київ, Україна, 03187

ІНТЕЛЕКТУАЛЬНІ WEB ЗАСОБИ ЗБІЛЬШЕННЯ ПРОДУКТИВНОСТІ, ЕЛАСТИЧНОСТІ І СТАБІЛЬНОСТІ ФЕРМ УКРАЇНИ І США

Roman Kuc [1], A. Shevchenko.[2], Y. Chaplinskyy.[3], I. Kachur, O. Zvenigorodskyi.[2]
[1] Yale University, USA,
15 Prospect Street, Becton Center 511, New Haven CT 06511-6816
[2] Institute of Artificial Intelligence Problems MES Ukraine and NAS Ukraine,
Glushkov ave., 40, Kyiv, Ukraine, 03187.
[3] Glushkov Institute of cybernetic of NAS of Ukraine,
Glushkov ave., 40, Kyiv, Ukraine, 03187

INTELLIGENT WEB FACILITY TO ENHANCE YIELD, RESILIENCE AND SUSTAINABILITY UKRAINIAN AND USA FARMS

This paper proposes to implement a computational model and intelligent software for farms, that give the farmer a set of robust and viable options for crop, soil, and water management, enhance crop resiliency to climate change, the effects of pests, plant diseases and other environmental factors. Model and intelligent software for farms includes the following tasks: search, analysis and storage in a dedicated base of relevant data gleaned from the Internet, the interaction with the farmer through a dedicated interface, the development of the farmer's solution by database and integrated knowledge base for plant protection.
Keywords: farm, computational model, plant protection, database, smart phone.

Introduction

Currently, Ukraine and the U.S. derive significant economic benefits from their agricultural sectors. Essential agriculture techniques incentivizes both countries to seek scientific solutions toward sustainable agriculture, soil and water management, as well as enhance crop resiliency to climate change and other environmental factors. Solving these problems depends largely on the use of advanced information technology, a knowledge-based decision support system, and intelligent analysis of a large number of factors that take into account predicting crop yields and decision-making for selecting the best crop options for a particular farmer. For the farmer it is important to have viable options for crop selection and distribution that are based on local data: location, previous crop planting and rotation, market demand, state of the current crop, use of fertilizer, crop image information etc. Selecting the optimal models of yield, sustainability, and resilience by farmer and risk assessment does not guarantee achievement of the farmer's goal because these models do not take into account the loss of crops from pests and plant diseases and the measures taken to combat them in the period of harvest ripening.

Therefore, the solution lies in a combination of mathematical models that predict yield, sustainability, and resilience, and the development of models and databases of plant protection, search and analysis of relevant information gleaned from Internet data.

To provide convenient access to the system that will be implement the solution of these problems, local data must be input on the farmer's smart phone through interactive communication with the farmer by using an understood and natural language interface.

Farmer's problems

An optimum farm configuration can be found with existing Internet calculators for simple farms and crops that compute crop yield [3] and farm income [1]. Farm income calculators use current factors, including costs of seeds, fertilizer, pesticides, etc., while crop yield calculators include historical factors, such as past crops, to determine their impact on the current crop. Nevertheless, calculators do not currently consider the selection of crops that are appropriate for the particular farm region, factors that can be gleaned from the Internet, and factors of plant protection that make up the complex agricultural system.

The aim of our paper is to investigate modern scientific approaches to enhance resilience and sustainability of farms and develop a tool for US and Ukraine farmers that provide them with a viable and profitable set of planning options based on mathematical models and intelligent knowledge methods. The initial data are the local data on the farm and past harvests and data retrieved from the Internet, which are processed in accordance with the problem that is being solved.

Farm model

Our current model estimates yield, resilience and sustainability of a specific farm. ***Resilience*** is the capacity of a system to absorb disturbances and reorganize while undergoing change to still retain essentially the same function, structure, identity, and feedback. Agricultural ***sustainability*** is defined as practices that meet current and future societal needs for food and do so by maximizing the net benefit to society when all costs and benefits of the practices are considered [13]. Balancing productivity, profitability, and environmental health is a key challenge for agricultural sustainability [4]. Sustainability implies both high yields that can be maintained and agricultural practices that have acceptable environmental impact by means of efficient use of nitrogen, phosphorus and water use along with pest management that minimizes use of toxic pesticides [13].

Preparing for the next growing season requires prediction of weather and other environmental conditions, crop performance, and world demand, which are provided by probing relevant databases on the Internet. Important for our project such databases include weather reports, crop yields, and satellite imagery of plant state.

For providing additional local data, we propose to employ smartphones as mobile sensors that provide location, time, and image information about a particular farm crop state. For example, smartphone camera images of plants can estimate leaf area index, which measures the radiation intercepted by the canopy and crop water requirements [2]. Hence, a farmer with a smartphone can enter initial data and also monitor crop progress, while adding to the database to enable an evolving model of his farm, as well as an enhanced database that can be used for other similar farms.

The following figure shows our farm model. It includes features that involve the flexibility of planting different crops in particular sections specified by the farmer. The model inputs include relevant factor values as well as past crop plantings.

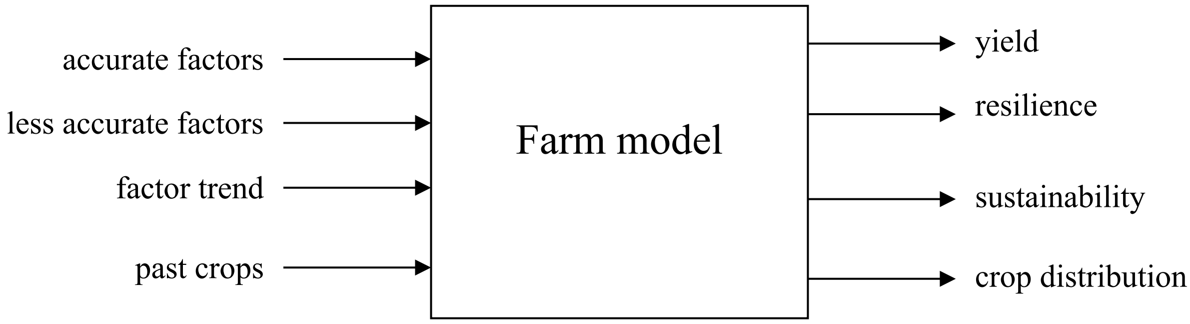

Figure 1. Farm model

The values of relevant factors are grouped by their accuracy: highly accurate, less accurate (modeled as having random deviations with zero mean and predicted standard deviation), and known only in trend (modeled by predicted values of both mean and standard deviation). These predicted values are gleaned from Internet data, assessed as to their reliability, organized, and stored for future use.

The following table contains an initial list of typical factors ranked by their accuracy along with their source and output feature that is primarily impacted.

Table 1. Initial list of typical factors of farm model

factor	Source	accuracy	primary impact
past crop	Farmer	high	sustainability
crop planting history	Farmer	high	sustainability
fertilizer use	Farmer	high	sustainability
crop diversity	Internet	high	sustainability
fixed costs	Farmer	high	yield
seed cost	Internet	high	yield
fertilizer cost	Internet	high	yield
pesticide cost	Internet	high	yield
crop compatibility	Internet	high	yield
pesticide use	Farmer	medium	sustainability
water use	Internet	medium	sustainability
soil potential	Farmer	medium	yield
irrigation costs	Internet	medium	yield
water availability	Internet	trend	resilience
climate change	Internet	trend	resilience

The model outputs include viable and robust options for crop plantings, which for farms are distributions of crops, along with confidence intervals (CIs) for yield, resilience, and sustainability. Yield, sustainability, and resilience are estimated by applying appropriate factor weights, initially set by early discussions with agricultural members of our teams and altered by having these members observe and interpret the results. Crop options can be produced to exhibit the optimum values, or those that have either the largest mean values or smallest CI interval of yield, sustainability or resilience. The agricultural members will also analyze the option to determine a rank ordering that a farmer should consider.

We propose to model inaccurate inputs as being random and apply Monte Carlo methods to compute measures of the crop yield, resilience and sustainability values. Hence, these values need to be expressed as a CI, whose size is determined by the accuracy (standard deviation) of the data. The *robustness* of a particular option is related to the CI size: A tight CI indicates a robust option, or one that does not vary significantly as the input values of the factors change with the normal climatic variations, while a large CI indicates options that are more fragile with respect to changes in factor conditions.

To produce quantitative rankings the model needs numerical measures of factors and their contribution. In addition, because the quantification of qualitative factors typically uses a coarse scaling having random rounding errors, and because quantitative factors may include errors, the results must be expressed using confidence intervals, which will be computed using Monte Carlo methods, as described below.

Given the parameters of a particular farm, our model would provide a farmer the choices that would improve farm yield. Because crops may interact, breaking a farm into acre-sized segments produces a multi-dimensional problem having dependent components. Optimizing a complex system described by multiple parameters typically produces several local optimum solutions, each of which produces a suggested plan for next year's planting strategy. Since models are always approximations of the actual situation, the farmer plays a crucial role in deciding which suggested solution is best suited for his farm.

Tasks of plant protection

The number of pests and diseases that need to be considered is large and is increasing. Many initially harmless species of insects and microorganisms have attained the status of serious pests/diseases in recent years. For example, plant diseases cause significant loss of valuable food crops throughout the world. Diseases account for at least 10% of crop losses globally and are, in part, responsible for the lack of adequate food [12].

Integrated plant disease management advocates the use of multiple control measures, including, if possible, a rational system for predicting the risk of disease outbreaks. Therefore, a decision-making support system can be an appropriate tool for farmers aiming for integrated disease management [6].

Information technologies can incorporate different factors of integrated pest management (IPM) to deliver either general or site-specific information to the users via extensive personnel, telephone, fax, e-mail, SMS, PC and websites on the Internet [10]. The increasing complexity of decision-making aspects of IPM and the accumulation of heterogeneous data from applied and fundamental research activities introduce new challenges related to processing and usage of data and knowledge.

One of the many challenges facing agricultural research within IPM is the understanding of the complexity and functionality of farm systems. This fact enables the access to several types of data and related information that can be further used to model IPM tasks, optimize crop productivity, and assure rational use of natural resources for rural sustainability. Data accessibility is also a prerequisite for modelling species ecology including agroecology (*e.g.* pests and diseases) [7], spatiotemporal food web evolution [15], and crop productivity [9].

Another typical feature of IPM problems is its *ad hoc* nature. In order to solve this problem appropriate and rational decisions must be made by the farmers in a timely fashion. The information systems that meet these requirements must have a dynamic knowledge base that can update itself using data from distributed web resources.

Knowledge-based decision support system for plant protection

Within the proposal, we consider integrated pest management as a decision support system that integrates data and knowledge, procedures for their processing and for decision-making. These will address problems of plant protection with regard to targeting farmer efficiency indicators while minimizing economic, social, and ecological risks.

In this context, we consider the farmer as an element within an industrial infrastructure (plant growing, agro-industrial technologies, economy, resources, etc.); as an element of an environment (soil, climate, landscape, hydrography, etc.); and as an element of a socio-economic infrastructure (trade, processing, storage, commerce and intermediary).

Modern IPM tasks are formulated as a multidisciplinary problem (at the junction of two or more disciplines or domains). It is necessary to consider various aspects of IPM that can be modeled and studied independently of one another. From the point of view of interdisciplinary integration, IPM will considered through the interaction of biology, agronomics, entomology, phytopathology, gerbology, economics, and other sciences. These sciences should be put in a basis of consideration and development of the knowledge-based decision support system for plant protection.

At realization of IPM within a knowledge-based decision support system for plant protection it is important that software enable the user to carry out the developmental strategy and tactics for the realization of IPM, which basically is realized through monitoring; identification; methods of analysis and prognosis of a condition of harmful organisms; and methods of pest control and their influence on useful organisms. Thus, one may accomplish the realization of IPM with following necessities:

- System consideration of harmful organisms in ecological systems, in particular consideration of harmful organisms as members of a community on groups of ecological equivalents.
- System consideration of the mechanism of action of protective receptions about the beginning of a specific population of a harmful organism, and then groups of ecological equivalents of communities of harmful and useful kinds of ecological systems.
- Long-lasting, instead of temporary, stabilization of the number of harmful organisms.

The main types of harmful organisms in agrocenoses (outdoor, indoor) as harmful organisms that are considered are diseases, insects (entomofauna, small rodents), and weeds. It is necessary to describe the characteristics of each of these harmful organisms, which primarily concern the conditions of occurrence and growth; life expectancy; methods of transfers; assessment methods and forecasting; economic threshold of harmfulness; control methods, etc. To realize a strategy of realization of IPM from the point of view of the critical periods of development of an agricultural crop, all types of harmful organisms become objects of consideration of influence of protective methods via soil, air, seed, and transmission.

Thus, for the decision of IPM problems it is necessary:

- To identify a harmful organism;
- To define criteria of monitoring and to lead the analysis of development of the situation connected to the given harmful organism;
- To investigate what tactics of the pest control against the given harmful organism exist;

- To estimate advantages and risks of application of individual tactics or their combinations for realizing IPM;
- To choose the strategy that is most effective against harmful organisms, that is compatible to the quality and quantity of agricultural production, and that is least harmless to the person and the environment;
- To estimate the actions concerning the state and regional legislative requirements, which relate to the given problem.

Integrated pest management is the combination of appropriate pest control tactics into a single plan to reduce pests and their damage to an acceptable level. Based on the previous discussion, for the realization of a knowledge-based decision support system for plant protection we will consider technological operations of the system of plant-growing that influence IPM; the knowledge-based factors influencing IPM, including parameters and constraints; methodology of considering interconnections of communities of harmful organisms and crops. A model of out methods for plant protection is presented in Figure 2.

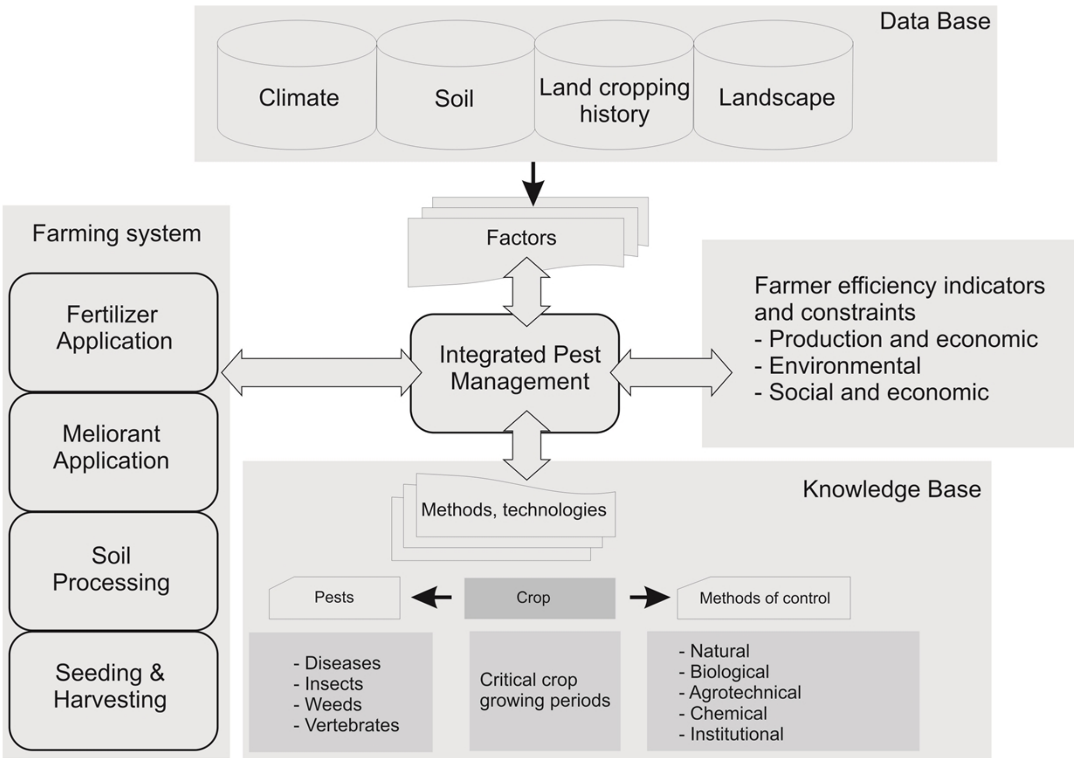

Figure 2. Aspects of integrated pest management

The knowledge-based decision support system for plant protection provides options for the farmer to deal with IPM problems with various degrees of accuracy determined from the level of generalization of the initial data. In the absence of detailed initial information of a concrete form, it is replaced by a simpler model or with the information from the knowledge base containing data gleaned from the analysis of the previous experience (both statistical and scientific data).

The result of the work of our knowledge-based decision support system for plant protection is IPM that concerns the given crop, the given yield, the given economy, etc. Optional variations for achieving IPM with corresponding consequences are generated to allow the farmer to choose the most comprehensible option.

Implementing an effective interaction between the farmer and IPM information and delivering knowledge to the farmer are major needs of IPM decision-making. Currently the most effective environment of knowledge-based decision support system for plant protection is that using mobile phones to access the Internet.

The database of the knowledge-based decision support systems for plant protection integrate attributive (crops; machinery; fertilizers; chemicals; weeds; pests; diseases; climate; yields, soils, etc.), cartographical (digital maps, such as administrative, topographic, soil, etc.), and multimedia (pictures, demonstration movies, etc.) information.

Development of effective IPM solutions will based on knowledge, which can be described by ontologies. Ontology is the modern tool for developing intelligent decision support systems. Ontology can provide decision making, including components and relationships between elements of the decision-making process, and used in the formation and selection of decisions and for the specification of horizontal/vertical links between tasks, models, methods, implementations and different layers of decision making. These ontologies were considered as a basis for construction of knowledge-oriented technologies, including the complex of the formalized methods for searching and extraction, structuring and systematization, analysis, actualization and generation.

Web facility

The project provides the opportunity to use and access the results to the users with the use of Web technologies. In this regard, there are problems of development of intelligent search tools and analysis of large amounts of data and related software. Fig. 3 presents the general structure and composition of such intellectual Web facility.

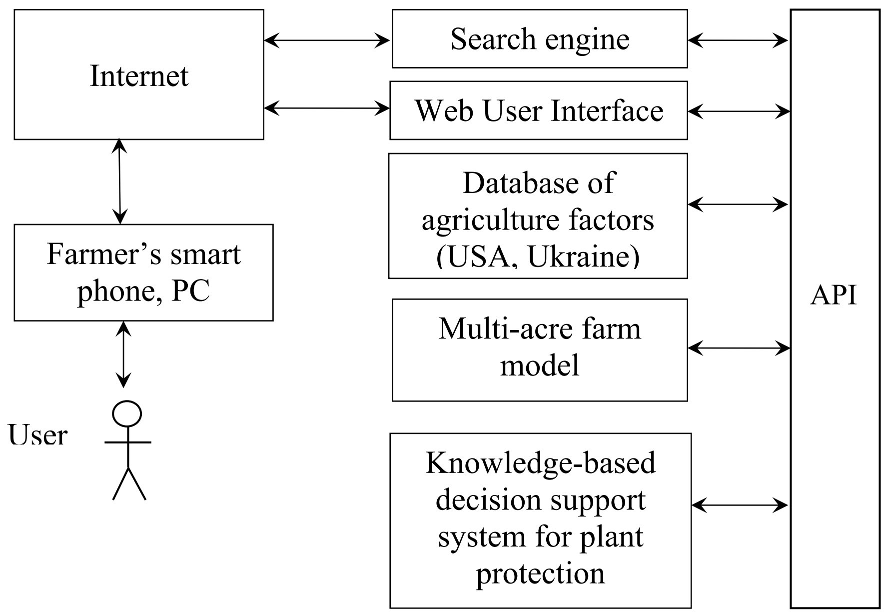

Figure 3. The general structure and composition of the intellectual Web facility

The structure of the facility includes:

- **Search engine.** It provides quick search of the principles of the semantic analysis of documents related to the tasks, and the filtering of weather information, demand, prices and other data for the regions and individual sites where farms are registered and stores them in an Agriculture data base (USA, Ukraine) for the further rapid access, analysis, and use of other components of the facility.

- **Database of Agriculture factors** (USA, Ukraine) performs structuring heterogeneous information for big data analysis for farm models and knowledge-based decision support systems for plant protection derived from Internet.

- **Farm model** implements the above-described model by using data from the Database of Agriculture factors and farmer data input.

- **Knowledge-based decision support system for plant protection** based on data from Database of Agriculture factors and Integrated Pest Management (IPM) described above.

- **Web User Interface** provides farmer a user-friendly and easily understandable interaction with the system through the Smart Phone or personal computer (PC).

- **API (application programming interface)** used for data exchange between the components of the facility, including the exchange with a farmer over the Internet.

Conclusion

The presented models and decision support system are targeted at small family-own farms, which are common in Europe and Ukraine. The average size of the farm, for example, is only 18 hectares in Germany. In other EU countries, this figure is as follows: Belgium - 15, Denmark - 32, Greece - 4, Spain - 14, France - 23, Italy - 6, Luxembourg - 30, Netherlands - 15, Portugal - 5, on average, EU - 13 hectares [5]. The average farm size in Ukraine is 92.1 hectares (227 acres) [14]. In USA large farms dominate, most farms having at least 1,100 acres with technology being a major driving force that increases in farm size [8]. Such multi-acre farms can be viewed as multi-component systems in which each component has some flexibility in crop selection to enhance resilience and sustainability. We propose to implement a computational model that provides a set of robust and viable options for crop, soil, and water management to a single-component farm, and to extend this capability to larger farms, for which varying crops will add another dimension for considering resilience and sustainability.

Enhanced yield, resilience, and sustainability of farms require the joint integration of the following three major scientific tasks.

1. Development of a computational model that provides a set of robust and viable options for crop, soil, enhance crop resiliency to climate change, the effects of pests, plant diseases and other environmental factors. Data for this model can be accurate, less accurate from Internet, or a trend.
2. Development of a knowledge-based decision support system for plant protection that considers data from the first task and specific data for plant protection. An optimal decision-making in this task needs to use knowledge-based technics.
3. Development of methods for quick search of relevant information using principles of semantic analysis of documents related to the tasks and the filtering of information for the regions and individual sites where farm are registered.

Based on the theoretical framework discussed in the paper, authors propose a web technology for farmers of Ukraine and the USA that specialized for mobile devices. This technology represents a structure that integrates Search engine, Database of Agriculture factors, Farm model, Knowledge-based decision support system for plant protection and allows processing large amounts of data in order to optimize the activities of farmers and to increase yields.

Implementation of a computational model will be successful in reality when the farmer with a smartphone can enter initial data and monitor crop progress, while adding to the database model of his farm, as well as to an enhanced database that can be used for other similar farms.

References

1. Electronic resource: https://www.extension.iastate.edu/agdm/crops/html/a1-20.html
2. Confalonieri et al 2013. Confalonieri R, et al. Development of an app for estimating leaf area index with smartphone. *Computers and Electronics in Agriculture* 96, pp 67-74. 2013.
3. Crop Yield Calculator. Electronic resource: http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide
4. Davis et al 2012. Davis AS, Hill JD, Chase C, and Liebman M (2012) Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. *PLoS ONE* 7(10):e47149.
5. Electronic resource: http://econbooks.ru/books/part/17994
6. Fernandes JM, Pavan W, Sanhueza RM (2011) SISALERT—a generic web-based plant disease forecasting system. In: Salampasis M, Matopoulos A (eds) Proceedings of the international conference on information and communication technologies for sustainable agri-production and environment (HAICTA 2011), Skiathos, 8–11 September, 2011, pp 225-233.
7. Hannon, B., & Ruth, M. 2009: Dynamic modeling of diseases and pests. Springer, ISBN: 978-0-387-09559-2.
8. MacDonald 2013. MacDonald JM, Korb P and Hoppe RA (2013). Farm Size and the Organization of U.S. Crop Farming, ERR-152. U.S. Department of Agriculture, Economic Research Service, August 2013.
9. Pearson, C. J., Bucknell, D. & Laughlin, G. P. 2008: Modelling crop productivity and variability for policy and impacts of climate change in eastern Canada. Environmental Modeling and Software 23: 1345-1355.
10. Shtienberg, D., 2013. Will decision-support systems be widely used for the management of plant diseases? Annu. Rev. Phytopathol. 51, 1–16.
11. Sinclair et al. 2014. Sinclair K, Curtis A, Mendham E, and Mitchell M. Can resilience thinking provide useful insights for those examining efforts to transform contemporary agriculture? *Agriculture and Human Values*. DOI 10.1007/s10460-014-9488-4.
12. Strange, R. N. and Scott, P. R. (2005). Plant Disease: A Threat to Global Food Security. Ann. Rev. Phytopathol. 43:83-116.
13. Tilman D, Cassman KG, Matson PA, Naylord R, and Polasky S (2002). Agricultural sustainability and intensive production practices, *Nature* (418), 671-677.
14. Electronic resource: http://moyaosvita.com.ua/osvita-2/geografiya-fermerstva-ukrainy/
15. Verhoef, H. A., & Morin, P. J. 2010: Community Ecology: Processes, Models, and Applications. Oxford Scholarship Online, ISBN-13: 978-0-19-922897-3.

References

1. Electronic resource: https://www.extension.iastate.edu/agdm/crops/html/a1-20.html
2. Confalonieri et al 2013. Confalonieri R, et al. Development of an app for estimating leaf area index with smartphone. *Computers and Electronics in Agriculture* 96, pp 67-74. 2013.
3. Crop Yield Calculator. Electronic resource: http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/estimating-crop-yields-a-brief-guide
4. Davis et al 2012. Davis AS, Hill JD, Chase C, and Liebman M (2012) Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health. *PLoS ONE* 7(10):e47149.
5. Electronic resource: http://econbooks.ru/books/part/17994
6. Fernandes JM, Pavan W, Sanhueza RM (2011) SISALERT—a generic web-based plant disease forecasting system. In: Salampasis M, Matopoulos A (eds) Proceedings of the international conference on information and communication technologies for sustainable agri-production and environment (HAICTA 2011), Skiathos, 8–11 September, 2011, pp 225-233.
7. Hannon, B., & Ruth, M. 2009: Dynamic modeling of diseases and pests. Springer, ISBN: 978-0-387-09559-2.

8. MacDonald 2013. MacDonald JM, Korb P and Hoppe RA (2013). Farm Size and the Organization of U.S. Crop Farming, ERR-152. U.S. Department of Agriculture, Economic Research Service, August 2013.
9. Pearson, C. J., Bucknell, D. & Laughlin, G. P. 2008: Modelling crop productivity and variability for policy and impacts of climate change in eastern Canada. Environmental Modeling and Software 23: 1345-1355.
10. Shtienberg, D., 2013. Will decision-support systems be widely used for the management of plant diseases? Annu. Rev. Phytopathol. 51, 1–16.
11. Sinclair et al. 2014. Sinclair K, Curtis A, Mendham E, and Mitchell M. Can resilience thinking provide useful insights for those examining efforts to transform contemporary agriculture? *Agriculture and Human Values*. DOI 10.1007/s10460-014-9488-4.
12. Strange, R. N. and Scott, P. R. (2005). Plant Disease: A Threat to Global Food Security. Ann. Rev. Phytopathol. 43:83-116.
13. Tilman D, Cassman KG, Matson PA, Naylord R, and Polasky S (2002). Agricultural sustainability and intensive production practices, *Nature* (418), 671-677.
14. Electronic resource: http://moyaosvita.com.ua/osvita-2/geografiya-fermerstva-ukrainy/
15. Verhoef, H. A., & Morin, P. J. 2010: Community Ecology: Processes, Models, and Applications. Oxford Scholarship Online, ISBN-13: 978-0-19-922897-3.

RESUME

Роман Куц, А.І. Шевченко, Ю.П. Чаплінський, І.В. Качур, О.С. Звенігородський
Інтелектуальні web засоби збільшення продуктивності, еластичності і стабільності ферм України і США

Досягнення прогресу у сільському господарстві на сучасному етапі потребує залучення фахівців не тільки сільського господарства й з суміжних галузей. Ми пропонуємо обчислювальну модель і інтелектуальні програмні засоби для multi-acre ферми, які дають фермеру набір надійних і життєздатних варіантів для підвищення врожаю, обробки ґрунту і управління водними ресурсами, що підвищують урожайність, еластичність і стійкість фермерського господарства до зміни клімату, впливу шкідників, хвороб рослин та інших екологічних факторів. Набір варіантів буде створюватись на основі даних від фермера, даних з інтернету, даних з математичної моделі спільно розробленої в Україні та США, даних бази та даних і інтелектуальної бази знань захисту рослин.

Дані про поточний стан урожаю і параметри ферми фермер вводить в модель і інтелектуальне програмне забезпечення multi-acre ферми за допомогою смартфону або персонального комп'ютера, відповідно до складності задачі, яку він хоче розв'язати. Модель і інтелектуальне програмне забезпечення multi-acre ферми пропонує життєздатні варіанти з оцінками доходу, еластичності і стійкості ранжуються, супроводжуються рекомендаціями та надаються фермеру. Остаточне рішення приймає фермер. Розробка моделі передбачає такі завдання: пошук, аналіз і накопичення в спеціалізованій базі відповідних даних з Інтернет, взаємодія з фермером через спеціалізований інтерфейс, розроблення бази даних прийняття рішень фермера і інтегрованої бази знань з захисту рослин. Ми зібрали команду, яка може приступити до розробки моделі multi-acre ферми та інтелектуального програмного забезпечення multi-acre ферми, що забезпечать можливості і кількісні рейтинги еластичності і стійкості ферм. Результати, отримані за допомогою проекту будуть оцінюватися членами команди фахівців в рамках процесу уточнення і перевірки моделі. Результати використання моделі і інтелектуального програмного забезпечення multi-acre ферми можуть бути застосовані до ферм в Україні і США.

Надійшла до редакції 14.06.2016

