Food Security as an Element of Social and Economic Security in Bulgaria

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Abstract: The use of unmanned aerial vehicles for monitoring agricultural crops, assisting in land reclamation, effective herd control, land inventory, controlling the parameters of agro-technological processes, spraying chemicals, guarding facilities, etc. is already a practice in a number of countries. Constant full monitoring of the conditions for carrying out agricultural processes, the dynamics of changes in the state of agricultural lands, and the characteristics of technological processes using technical means for real-time monitoring is the most important prerequisite for the implementation of highly productive and effective agricultural technologies. The expert method of hierarchical analysis can be used to substantiate groups of factors and the system of food security indicators. Based on the obtained system of indicators, the structure, relationships, and membership functions of fuzzy cognitive maps are formed. For parameterization of cognitive maps, the construction of infological and information models is used, providing justification for the structure of the relational database for the analyzed statistical indicators. We have constructed and tested a family of predictive econometric models based on private indicators for food product groups. Methods for integrating the obtained econometric models into a cognitive map have been developed based on membership functions and fuzzy logic. To support numerical studies and scenario analyses, the methodology of developed cognitive maps is used, a software complex is required. Such a software complex includes a computer program, a knowledge base for building membership functions for factors, and a statistical database for conducting research based on the use of an intelligent system for assessing and forecasting the integral level of food security.

Key-Words: Food Security, Cognitive Maps, Fuzzy Logic, Econometric Models, Agricultural Monitoring, Unmanned Aerial Vehicles (UAVs), Intelligent Systems.

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1 Introduction

Bulgaria's food security is an integral part of its economic well-being and a fundamental element of its national security. The global world economy, or rather its state, today determines the level of global and national food security. Thus, countries that accept global challenges for food security must take into account the totality of a set of factors that influence natural and climatic features, soils, economic and scientific, technical, and technological development. All of the listed groups of factors form the potential and capabilities of Bulgaria in terms of food self-sufficiency or food independence.

The global food problem is one of the most acute in the modern world and in the medium term may develop into a global food crisis. In this regard, the government of each country is faced with the question of how to solve it and prevent the situation from worsening. The level of food security allows one to assess the availability, sufficiency, and quality of food products in the country. These are fundamental elements of the social and economic stability of any country, which determines the relevance of the research topic.

2 Food Security is the Basis of the Country's Economic Security

The European Union, which unites twenty-seven countries, forms its own agrarian and food policy.

The European Union, like many other countries, approaches the problems of regulating agriculture from the position of its multifunctionality, implementing effective legislation. Many scientists and researchers today are trying to move away from the principles of multifunctional agriculture. If we rely only on the theoretical essence of the concept of "multifunctionality of agriculture", which reflects the fundamental nature of the food sector, taking into account the state of ecology, politics, social and economic development in the country, we can offer an effective strategy regarding agrarian and food policy in the European Union. Choosing this position, the European Union seeks to preserve the culture and traditions of all nations that it has united through integration. Thus, the European Union, when forming and strengthening food security, is characterized by a common agricultural policy (Common Agricultural Policy) with characteristic elements of agrarian protectionism.

The concept of air monitoring is aimed at achieving sustainable agriculture while optimizing material costs and reducing the negative ecological impact on the environment. The scientific and technological changes that have occurred are leading to a transformation in the operations and business processes of the agricultural industries.

In the development of our society, all branches of the agro-industrial complex are experiencing significant scientific and technological changes, each of which increases the level of production organization and work efficiency. During the transition from one scientific and technical change to another, the means and objects of labor are being improved, the organization of production is being improved, which leads to an increase in crop yields, animal productivity, an increase in labor productivity and other significant economic and financial results in agricultural sectors [2-4]. The main problem created by social and economic transformations is the sharp stratification of agricultural producers into small parts of big business, which enjoys a major share of state support, and a significant share of microbusiness (personal farms and family farms), which do not receive any or very little state support, do not have conditions for the sale of their products and very often become a donor of raw materials for large enterprises, which leads to low-income business based on outdated technologies. In most modern studies in the field of agricultural modernization, attention is focused primarily on technical and technological modernization and the renewal of the material and technical base of production, and the problem of the transition to the use of digital technologies remains isolated and fragmentarily studied.

Forecasts for future development are reduced to the digitalization of agriculture, which would allow satisfying the needs of the population for agricultural products by changing the connections of agriculture with the introduction of "smart" technologies, which will ultimately transform agriculture and animal husbandry, towards more precise agriculture and animal husbandry [1, 7-8]. Some of the applications of these technologies can be defined as follows:

- Precision agriculture – navigation systems, geographic information systems, separate fertilization;
- Robotics – unmanned aerial vehicles (UAVs) – for monitoring specific areas, digital sensors;
- Artificial intelligence systems – for controlling and processing data collected from various sensors;
- Big data – for analyzing information from sensors, for developing preliminary plans and strategies.

The rapid and widespread penetration of digital technologies, as the main model of functioning of economic systems in modern conditions, requires conceptual and methodological substantiation of the process of modernization of agriculture, taking into account the peculiarities of the transition to a digital economy, including by identifying the degree of readiness of agribusiness entities and the industry management system for digital transformation. In recent years, ground, aviation, and satellite systems have been increasingly used to solve a wide range of tasks in the agro-industrial complex, ecology, environmental monitoring, disasters, and accidents. When monitoring airspace, land and water surfaces, depending on the specific tasks to be solved, aerial photography, climate and atmosphere monitoring, hydro-meteorological situation control, radiometric control of disaster zones, in agrotechnology [1], monitoring the state of natural landscapes and vegetation, monitoring the state of glaciers and ice caps, research of seas and oceans, including observations of marine mammals, monitoring of agricultural and forest areas, spraying of chemical reagents for agricultural purposes, geophysical aerial surveillance, aerial photography and videography, aerial mapping can be performed. Technological regulations for agricultural processes (crop farming, animal husbandry, nature management) provide for the implementation of a large number of technological operations at different times in different points of agricultural land.

The use of satellite and aviation surveillance systems is justified only for large areas and requires serious material and technical costs. The practical use of helicopter-type UAVs (agrocopters), which are equipped with special technological bodies for local operational technological impact on bio-objects of food production, can be significantly expanded. The implementation of energy-efficient and environmentally friendly agricultural technologies using UAVs is one of the promising areas for their development. Traditionally, UAVs are used in agriculture for monitoring agricultural crops, assisting in land reclamation, effective herd control, land inventory, controlling the parameters of agro-technological processes, spraying chemicals, guarding facilities, etc. Constant full monitoring of the conditions for carrying out agricultural processes, the dynamics of changes in the state of agricultural lands, and the characteristics of technological processes using technical means of real-time monitoring is the most important necessary condition for the implementation of highly productive and effective agricultural technologies. Information about agricultural land is used to form real electronic soil and other maps, control the dynamics of changes in the state, characteristics of the bio subject of agricultural production, and operational regulation of ongoing technological processes [1, 13].

Constant and comprehensive monitoring of the conditions for the implementation of agrotechnological processes, the dynamics of changes in the state of agricultural lands, and the characteristics of technological processes through the use of technical means of real-time monitoring is an important prerequisite for the implementation of highly productive and effective agricultural technologies. Aerial monitoring complexes with UAVs are used to update and refine geospatial information. The resulting image is superimposed on a digital terrain model, after which the data can be used to measure distances, determine zones, as a substrate for overlaying other data.

UAVs are an effective and often indispensable way to collect high-quality data. The main means of data collection are the television channel (digital camera or video camera), thermal imaging channel (thermal imaging camera), geolocation channel (GPS receiver, etc.), and remote sensing devices (gas analyzer, laser rangefinder, etc.). Priority areas are interconnected and a complex of technological processes is carried out in parallel, such as animal health control; monitoring of pasture areas; veterinary assistance (using UAVs, you can remotely administer a sedative, vaccine, antibiotic, etc.); forensic expertise (assessment of damage caused to animals); safety and protection of animals during grazing; gathering livestock in a herd; monitoring of the nutrition and water balance of animals [9]. Priority areas in food production are related to inventorying agricultural land; creating electronic field maps; assessing the volume of work and monitoring performance; operational monitoring of the condition of crops; assessing the germination of crops; protection of agricultural lands; treatment of crops with pesticides to eliminate pests, crop diseases. Scanning crops, UAVs evaluate the parameters of agro-technological processes in online mode and can spray the required amount of liquid, adjusting the flight height and volume of liquid in real time and ensuring uniform coverage of the entire area [6].

Real technical solutions are provided by the remote participation of operators in making intelligent decisions. The peculiarities of modern complexes with UAVs are that these are automated complexes that have a built-in intelligent control system, which must independently solve basic functional tasks, so that the possibility of control and management with the participation of an operator, remote control, and monitoring from remote terminals, is carried out from ground points. Information for the operator in real time should be provided by onboard sensors, using a developed human-machine interface, which creates the effect of information presence on board, while at the same time removing real physical and psychophysiological loads from him. The degree of autonomy and the conditions for transferring powers and responsibilities in the "On-board control system to the operator" are determined by the specific conditions of the events being carried out, as well as by the achieved level of intellectualization of the on-board control system of the UAV. The work of the operators is ensured by transmitting the necessary information to the ground control points in real time. In this case, the UAV functions automatically, the operator's participation includes monitoring and controlling the level of change of the flight task, recognition, and confirmation of the anatomical and morphological parameters of the bio objects of food production.

Using video analysis to recognize the appearance of disease-infected or pest-infected areas, UAVs are capable of detecting such areas, classified as targets from the air. Often, the joint use of television and thermal imaging channels allows for effectively solving problems of detection and identification of objects, and the joint use of remote gas analysis instruments with geolocation tools solves problems of localization of atmospheric pollution.

UAVs can be used to search, detect, and determine the coordinates of objects. To conduct precise agricultural production, new robotic technical means are needed, especially in conditions of geographically dispersed distribution of agricultural objects and in the absence of sufficient human resources. It is also an optimal solution in terms of ergonomic, economic, and technical indicators for a large part of the tasks related to the rapid collection and analysis of information using UAVs.

Interest in UAVs is caused by their economy in operation and the elimination of risk to the life of the crew. The operating load limit is determined by the physiological capabilities of a person, the ability to monitor multiple points for a very short period of time.

UAVs can contribute benefits and savings not only in the military, but also in the civilian sphere, and with the wide application of their capabilities in agriculture, the food security of Bulgaria can be ensured. They can monitor everything that happens on a territory with an area of about tens of thousands of square kilometers, which makes them a kind of "aerodynamic satellite". Unmanned aerial vehicles can take over the functions of satellite groups and perform them in real time within an entire region.

In order to take photos from space or observe any objects, 24 satellites are needed. The difference is that the satellite is above the observed object for only 15-20 minutes, and then leaves its visibility zone and returns to the same place, having made a circle around the Earth. Also, the unmanned aircraft constantly accompanies the observation point, operates at an altitude of 20 km for more than 24 hours, but returns to the base, and its replacement in the sky is taken by another. Another machine is in reserve. This is a huge saving, because unmanned aircraft have a significantly lower operating cost than satellites and in comparison with manned ones, as well as significantly lower costs and time for training operators. Unmanned aircraft can compete with satellites in the field of creating telecommunications networks and navigation systems.

Unmanned aerial vehicles can be assigned continuous round-the-clock surveillance of the Earth's surface over a wide range. Using them, an information field of the country can be created, covering control and management of the movement of air and water transport, because these machines can have the functions of ground, air and satellite locators (modern information from them gives a complete picture of what is happening in the sky, on the water and on the ground).

In order to ensure maximum comfort of work for their users, manufacturers of various “smart” devices and developers of “digital” programs ensure that their developments are compatible with others. When building agricultural production management systems, combining various video surveillance tools in one environment will help to increase the efficiency and convenience of work many times.

Technological processes in agriculture have significant differences from industrial processes because they are associated with bio objects. These objects have the ability to self-organize and self-develop. It is particularly difficult to obtain information about the behavior of biological objects and interpret it through technical information and analytical tools for human understanding and decision-making. The use of video surveillance, technical, and computer vision in the management of agro-technological processes can become an effective way to improve agricultural production and, respectively, food security.

The main advantages are a significant increase in information content, reliability, visibility, identity, efficiency of real-time management, and development of biotechnical man-machine systems in one language through digital images with semantic-linguistic support. Video surveillance and imaging, as the most accessible way to obtain valuable information, involves the creation of large volumes of data, their long-term storage, rapid retrieval, and diverse analysis. These factors determine the development of innovative methods and means of aerial surveillance and management of objects and processes in agriculture to improve food security by ensuring stability, environmental friendliness, high quality, and quantity of production in animal husbandry and plant breeding. All this characterizes a wide range of tasks that can be very effectively and economically solved with the application of UAVs.

3 Cognitive Economic and Mathematical Modeling

To substantiate groups of factors and the system of indicators for food security, the expert method of hierarchical analysis can be used. Based on the obtained system of indicators, the structure, connections, and membership functions of fuzzy cognitive maps are formed. For parameterization of cognitive maps, the construction of infological and information models is used, providing substantiation of the structure of the relational database for the analyzed statistical indicators.

The construction and verification of a family of predictive econometric models is carried out on the basis of private indicators for groups of food products. Methods for integrating the obtained econometric models into a cognitive map can be developed on the basis of membership functions and fuzzy logic. It is advisable to construct, test, and debug a specialized software package that implements impulse modeling of the analyzed systems, based on incidence matrices corresponding to cognitive maps. As a result, a scenario analysis of the level of food security is carried out using the constructed fuzzy cognitive maps.

To support numerical studies and scenario analyses using the developed cognitive maps, a software complex is required. Such a software complex should include a computer program, a knowledge base for building factor membership functions, and a statistical database for conducting research based on the use of an intelligent system for assessing and forecasting the integral level of food security.

To create an intelligent system for multi-criteria assessment and forecasting of the level of food security of the state and individual regions based on a fuzzy cognitive approach, it is necessary to:

– Substantiation of the theoretical and methodological basis for an integral assessment of the level of food security;

– Formation of a system of indicators and a methodology for building fuzzy production cognitive maps for assessing and forecasting the level of food security, which should take into account the spheres of production, consumption, reserve, and import;

– Development of a methodology and construction of functions for the affiliation of the factors ensuring food security, including the production of cognitive maps;

– Building a system of fuzzy cognitive maps for assessing the level of food security at the state level and the level of individual regions;

– Modeling of self-development and management of the development of the food security system using the obtained cognitive maps for entities of different levels;

– Development of a software complex for monitoring, assessing the level of food security, and forecasting its dynamics.

The implementation of these subtasks will allow solving the problem of objective integral assessment of the level of food security based on an intelligent cognitive system, as well as assessing the dynamics of its change taking into account management by state authorities.

4 Empirical Assessment Model Based on Statistical Indicators

The use of economic and mathematical modeling in assessing and forecasting the level of food security allows the development of formalized, multi-criteria models for assessing food security. The modeling process includes a number of sequential stages, such as: formulating the subject and purpose of the analysis; determining the object of the analysis; identifying the factors influencing its functioning; forming criteria for assessment and optimization.

A model is proposed for assessing food security, which includes the use of statistical indicators and an integral assessment of the effectiveness of agrarian and food policy in ensuring food security. This is done by determining an effectiveness index (I_{eap} – Effectiveness Index of Agrarian and Food Policy), which is obtained by aggregating economic (i_e), financial (i_f), and social indicators (i_s) [5]: $I_{eap} = \sum(i_e + i_f + i_s)$,

Ensuring food security is one of the main economic factors influencing the effectiveness of agricultural policy. An established list of values for the agricultural policy efficiency index is provided in Table 1.

Table 1. *Agrarian policy efficiency index*

Value range (I_{eap})	**Efficiency level**
$0 < I_{eap} \leq 0{,}2$	Agricultural policy is ineffective
$0{,}3 < I_{eap} \leq 0{,}5$	Low
$0{,}6 < I_{eap} \leq 0{,}8$	Admissible
$0{,}9 < I_{eap} \leq 1$	Optimal

The regions of Bulgaria, where agricultural production is actively developing, potentially have advantages in providing food products for the population living in these regions, compared to other regions of the country. The differentiation of Bulgarian regions by their sectoral specialization determines the priorities of the agrarian policy for ensuring food security and raising the standard of living of the population.

“The analog period in agriculture is over, the industry has entered the digital era”, predicts Goldman Sachs, which means that by 2050 the application of new generation technologies will be able to increase the productivity of global agriculture by 70%. Agriculture is on the verge of a “second green revolution” [9]. According to experts, thanks to precision farming technologies based on the Internet of Things, a jump in yields on a scale that humanity has not seen even at the time of the advent of tractors, the invention of herbicides, and genetically modified seeds [11].

Through the development of technology, cost reduction has reached such a level that for the first time in the history of the industry it has become possible to obtain data on each agricultural object, the environment surrounding it, mathematically accurately calculate the algorithm of actions, and predict the result. In the industry, which is actually the most remote from the IT sector, data is arriving, and at the same time there are vacancies for specialists in the field of Big Data, Data Science, mathematics, analysis and robotics. The development strategy of the largest agro-industrial and engineering companies in the world is based on the digitalization and automation of the maximum number of agricultural processes. A new investment segment AgTech is being formed, which in 2014 overtook FinTech and CleanTech [10].

Huge opportunities for modernization of the industry are the transformation of agriculture from a traditional to a high-tech industry, capable of creating new markets for innovative solutions and developments, stimulating the adoption of management solutions that can provide high-quality and safe products not only for itself, but also for many countries around the world. Information and communication technologies used in e-agriculture include devices, networks, services and applications. These are the most advanced Internet technologies and sensor devices, such as Big Data, the Internet of Things, artificial intelligence, cloud technologies and machine-to-machine communication, as well as traditional technologies such as radio, telephony, mobile communications, television and satellites. The main trends are precision farming technology, cloud services for managing an agricultural enterprise, rolling stock monitoring systems and accounting for materials consumed.

5 Conclusion

The analysis shows that the factors for ensuring food security are not only ensuring the physical and economic availability of food, but a combination of internal and external factors, such as national agricultural production, creating a food reserve, export-import supplies of food, international food aid, etc.

The analysis allows us to identify a number of factors that hinder the provision of an optimal level of food security, and to propose optimization measures. Among the promising areas for improving agrarian policy in the field of providing and maintaining an acceptable level of food security, the following should be noted:

Organizing a set of measures to increase the level of self-sufficiency in dairy and meat products;

Ensuring economic accessibility of food for the population, which requires the formation of a set of measures to ensure growth in the population's income.

The assessment model used allows, based on real statistical data, to analyze food security with the aim of subsequently selecting measures to optimize agricultural policy in order to ensure an acceptable level of food security in the regions of Bulgaria.

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