# INCREASING SUSTAINABILITY OF FOOD PRODUCTION AND ENSURING HUMAN HEALTH THROUGH AGRICULTURE DIGITALIZATION

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A R T I C L E  I N F O

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A B S T R A C T

Ensuring safe food for a growing population is a challenge for agriculture. The current systems of intensive agriculture are based on important allocations of factors of production per unit area, like chemical fertilizers and pesticides, allocated in order to stimulate production. In doing so, food security is ensured, by obtaining high yields per hectare, but chemical residues may remain in food and human health is jeopardised. The aim of this research is to identify the role of digitalization in agriculture in balancing the binomial food security-organic farming, starting from the premise that smart agriculture has a significantly lower negative impact on the environment and human health compared to the conventional agricultural system. The relevance of research lies in raising awareness of the importance of smart agriculture in providing agricultural products obtained in accordance with the principles of sustainable development and moreover integrating it into policies and actions at all levels: individual, local, national and global.

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## Introduction

Worldwide, population growth is putting pressure on food resources, and ensuring food security for 7.8 billion persons (UN, 2022) is becoming a challenge for agriculture, which needs to identify new solutions and technologies for providing sufficient, quantitative, and safe food for human health. On the one hand, the current models of intensive agriculture provide large quantities of food necessary to ensure food security, but they are criticized from the point of view of food safety, because large quantities of chemicals are used to obtain the output. However, yields need to continue to rise, given that the population will increase to 9.7 billion people (UN, 2021) by the end of 2050, requiring a 70% increase in agricultural production, according to FAO estimates (2009), to ensure food security. On the other hand, the current models of intensive agriculture contribute with 21% to greenhouse gas emissions, as indicated by FAO studies (2016). Other reports (IPCC, 2007) show that agriculture contributed with 13.5% and forestry with 17.4% to greenhouse gas emissions. In addition, methods of increasing production per hectare and combating diseases and pests are based on chemicals, pesticides and fertilizers, medicines and other synthetic products that can determine contamination of water, soil and food, causing disease among people (Lang et al., 2021).

Such “results” run counter to the strategic directions of the European Green Deal, which aims to transform the European Union into a modern, competitive and resource-efficient economy (European Commission, 2021). This strategy paper sets out actions such as investments in green technologies and support for innovation. Organic farming subscribes to these actions and has development potential in Romania, as shown by Stoian and Caprita (2019), due to the existence of favourable natural conditions: a large area occupied by pastures and hayfields, the use of a quantity of pesticides and chemical fertilizers much smaller compared to other countries, the existence of areas that were not collectivized and, consequently, the agriculture practiced was less industrial than in collectivized areas and so on.

One type of agriculture that subscribes to ecological principles is smart agriculture. The digitalization of agriculture has transformed the agricultural sector, both quantitatively and qualitatively, and can be a solution for the quantitative provision of the population with safe food. This category also comprises organic and traditional agro-food products, included in the model of the economy towards which the principles set out in the European Green Deal tend.

This piece of research aims to identify the role of digitalization in agriculture in balancing the binomial food security - organic farming, starting from the premise that smart farming is a model of agriculture in which agricultural work and the administration of chemicals, being controlled, have a significantly lower negative impact on the environment and human health than intensive agriculture and provide cleaner agricultural products, which can later be certified as organic.

As Namani and Gonen (2020) show, the Internet of Things, a revolutionary technology that foreshadows the future of informatics and communications, penetrates all economic and social fields - agriculture, industry, services. Thus, the use of new technologies has many advantages, being able to monitor with the help of phones or computers agricultural work, costs and performance, using satellite and aerial images, sensors that provide information such as temperature, humidity, soil pH, amount of nutrients in the soil, water level and so on (Mekala and Viswanathan, 2017). The Internet of Things (IoT) is a concept that defines a world in which all objects (cars, appliances, lighting systems, mobile devices, laptops) are connected to each other via the Internet (Ilie, 2018). The Internet of Things does not just rely on computers to exist; every object, even the human body, can become part of the Internet of Things, if it is equipped with certain electronic components. The objects certainly vary, but, besides their nature, they must accomplish two requests: the object must be able to capture data, usually through sensors; the object must be able to transmit this data via the Internet. A sensor and a connection, therefore, are the two primary electronic parts of an object included in the Internet of Things (Savu et al., 2017).

Smart agriculture aims to optimize and improve agricultural processes to ensure optimal yields, providing farmers with information on ongoing production scenarios in growing areas (Kour and Arora, 2020). These practices have low energy consumption and generally consist of climate monitoring (Ma et al., 2020), data analysis (Daissaoui et al., 2020), early detection of diseases (Puengsungwan and Jirasereeamornkul, 2020), intelligent irrigation (Al-Ali et al., 2019) and so on. By implementing the Internet of Things in agriculture, field conditions can be monitored remotely at regular intervals, without any human intervention, and, after analysing the data, farmers can make favourable and efficient decisions, which will help both the environment and producers and consumers, supplying the market with agricultural products for which smaller amounts of chemicals are administered and only when necessary (Kour and Arora, 2020).

The hypothesis from which starts our research is that smart agriculture, compared to conventional agriculture, has a significantly lower negative impact on the environment and human health and can provide certified organic products, contributing to the sustainable development of agriculture. The research aims to formulate answers on the extent to which digitalization in agriculture can be expanded so that the agricultural system provides products obtained with lower amounts of chemicals and subsequently certified as organic.

The paper is structured in six parts. After the introduction, the methods used to verify the hypothesis are presented. The section three reviews the literature and discusses the main results found in numerous papers related to smart agriculture and organic food products. The section four presents an overview of the organic farming in Romania, while the section five bases the economic, ecological and social approaches to smart agriculture, discussing the theoretical findings and empirical data. Finally, the conclusions of the research are drawn.

## Methodology

This article presents a conceptual framework of the smart agriculture in relation to organic farming, presenting how digitalization is used in agriculture and describing its effects in sustainable development approach – economic, social and ecologic. For this attempt, two bibliographic analyses have been developed, one for smart agriculture and one for organic agro-food products, inquiring Web of Science database. The results have been analysed by year and by clusters, identifying the main topics linked to smart agriculture. The linkages have been discussed considering the results of numerous researchers who studied the topics related to the keyword smart agriculture.

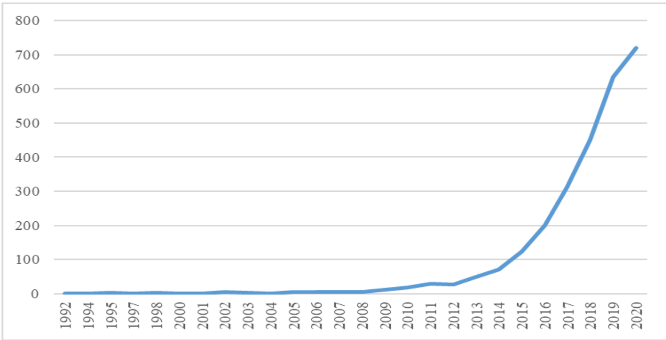
In order to support the claim that smart agriculture has a significantly lower negative impact on the environment and human health compared to the conventional agricultural system, statistical data have been analysed and empirical evidence has been provided from previous studies.

## Review of the scientific literature

Starting with the digitization of a significant number of processes and activities taking place in economy and society, the scientific world has begun to be concerned with research into smart agriculture and its role in the sustainable development of the agricultural sector.

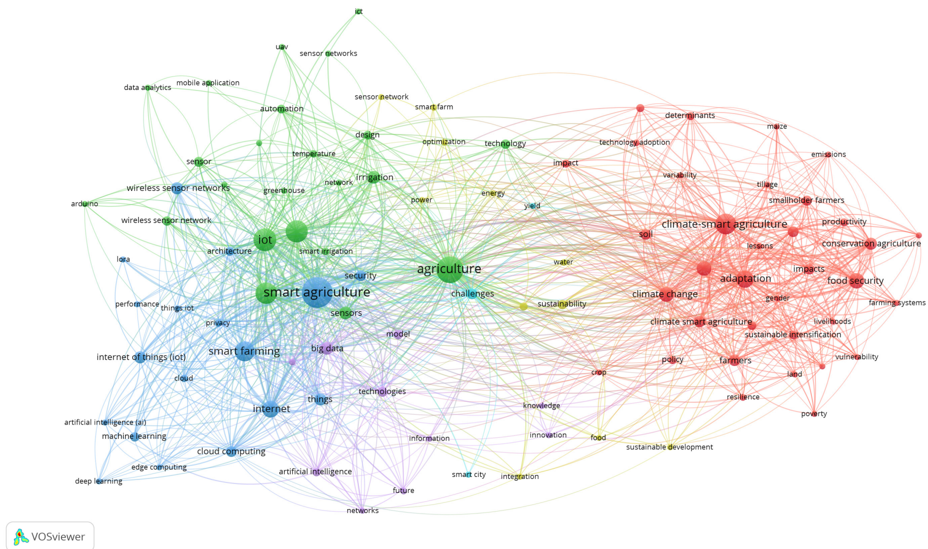
The integration of the Web of Science database on the subject of smart agriculture reported 3093 publications, in the period 1991-2021. Their dynamics can be seen in figure 1: scientific concerns on smart agriculture began in the 1990s, at that time 1-2 articles were published per year; interest in this topic increased in 2011, when the number of articles reached 29; since 2015, their number has increased significantly, reaching a maximum of 720 publications in 2020. Out of the publications reported after inquiring the Web of Science database, 12 focus on smart agriculture in Romania or the countries of the Southeast European Union, the authors presenting the results of scientific research in areas such as: biotechnology (Dettenhofer et al., 2019); creative economy (Mazilu et al., 2020); the Internet of Things applied in agro meteorology (Suciu et al., 2016); intelligent systems for maize production (Croitoru et al., 2020); the social economy and its development directions, including the intelligent one (Virlanuta, 2015); intelligent animal husbandry systems using artificial intelligence (Micle et al., 2021); sustainable development of agriculture (Panait and Cucu, 2020); intelligent systems applied in forestry (Dinca and Dinca, 2020); agriculture precision versus digital agriculture (Fertu et al., 2019); digitization of the agricultural sector (Florea et al., 2019).

**Figure 1.** Dynamics of the number of publications on smart agriculture




*Source:* authors' processing based on WoS data

**Figure 2.** Links between smart agriculture and other related notions




*Source:* authors' processing WoS results using VOSviewer

Using the VOS viewer program, the analysis of the results of the Web of Science database inquiry on smart agriculture continued with the identification of the connections between the terms with which this topic was associated in the written articles, resulting in the map in figure 2. Thus, five different clusters have been identified, with the most common topics related to smart agriculture being: agriculture; climate; the Internet of Things; precision agriculture; adaptation; food security; climate change; conservation; farmers; technology; impact; changes; sensors; irrigation; architecture; system; soil; sustainability; artificial intelligence; cloud; temperature; resilience; agro-ecology; block chain; food and so on.

Given the links between smart agriculture and sustainability, our research aims to identify the role of smart agriculture in the sustainable development of the agricultural sector in general and the market for organic agro-food products in particular. In fact, Mekala and Viswanathan (2017) call the model of agriculture that uses the Internet of Things "sustainable smart farming", thus associating the meaning of the notion of "sustainable" with smart agriculture.

The query of the Web of Science database on the topic of organic agro-food products reported 46,458 publications, in the period 1991-2021, of which, in the first 1,000 ordered by relevance, 16 refer to Romania. Petrescu (et al., 2016) makes a profile of the Romanian consumer of organic agro-food products and shows that the main reasons for buying them are related to health and taste. In another study, the same authors demonstrate, through the results of a survey, that the motivation for consuming organic food is related to consumer care for environmental protection (Petrescu and Petrescu, 2015). Oroian (et al., 2017) indicates the link between the consumption of organic food and sustainable development, identifying three types of consumers: gourmets, concerned about the environment, concerned about health. Bobe (et al., 2016) shows that Romanians are not fully aware of the benefits of organic food and production methods and also that they do not understand the cost-price relationship. Barna (et al., 2010) pays special attention to organic farming, considering that it is a sector with many business opportunities in Romania, given that organic farming has been practiced continuously, due to long-standing and well-preserved food traditions, in despite any cultural, economic or political influence. Moreover, the results of the survey show that Romanians are very attached to traditional agriculture and associate organic products with the traditional way of cultivating the land, which is for them a certification that the products are organic. Last but not least, Romanian authors (Istudor et al., 2014) show the links between food security and sustainability, through organic food, which can be considered a direction for the development of a sustainable agricultural economy.

## Organic agriculture in Romania

The activities specific to intensive agriculture need industrial capitalization to the detriment of maintaining the ecological potential, which generates, over time, the need to recover it from economic sources, with effects on reducing economic efficiency. It is true that intensive agriculture increases production by 50-60% compared to organic farming, but at some point, according to marginalism theory, any additional allocation of factors of production in the form of chemicals leads to a decrease in marginal output, which does not justify making additional expenditures with these factors. The result of applying additional chemical substances is the decrease of the total production, the assurance of food security from domestic sources being affected. By default, the negative effects of the administration of chemicals are found in the environment and food safety. Counteracting these effects in the chain is done by practicing organic farming, a system in which the permission to use chemicals is limited. This demonstrates the complexity of the economy-environment relationship, Commoner's (1980) statement being suggestive in this respect: "no economic system can be considered stable if its functioning seriously violates ecological principles."

The distinctive elements of organic farming as a niche of agriculture are of a technological, economic and social nature. The activities specific to the technological process of obtaining ecological products: maintenance of plant residues on the land surface, crop rotation and alternation, allocation of natural (organic) fertilizers, application of irrigation water avoiding polluted waters, control of diseases and pests by biological processes, land conversion are the independent variables from which positive results on the environment and human health are expected.

From an economic point of view, organic farming assumes larger volumes of variable expenditures, especially with seeds, fertilizers (organic, high cost generators), as compared to intensive agriculture. The average production per unit area (in the case of vegetable farms) is lower, but the high selling price has a strong effect on the profitability relative to the resources consumed. Moreover, the selling price stimulates farmers to practice this type of agriculture and increases the value of the product.

From a social point of view, organic food has beneficial effects on human health, and those obtained in intensive agricultural systems are criticized for the content of chemicals from pesticides and fertilizers. According to the definition proposed by the World Health Organization, pesticides are chemicals or mixtures of biocidal chemicals intended to eradicate potential pests such as insects, rodents, fungi or other microorganisms, and are widely used in agriculture (WHO, 2008). The major disadvantage of pesticides, namely the negative impact on human health and the environment, has made them a subject of intensive research in scientific literature. The main classes of pesticides considered to influence public health are represented by organochlorines, organophosphates, carbamates and neonicotinoids, among others. Exposure to pesticides can occur through direct contact with the skin, ingestion or inhalation. The determinants of the possible health impact of pesticides are the type of pesticide, the duration of exposure and the route of exposure; to these is added the individual health status. For example, the presence of nutritional deficiencies or the integrity of the skin barrier are elements that can promote the adverse health effects of pesticides. Therefore, dermatological, gastrointestinal, neurological, respiratory, endocrine toxicity and even the induction of carcinogenesis and reproductive disorders may be seen (Nicolopoulou-Stamati et al., 2016). Furthermore, acute occupational, accidental or intentional exposure may result in hospitalization or, in severe cases, even death (WHO, 1990). Consequently, at the present moment, there is an imperative need for the development and implementation of innovative strategies in the field of agriculture, strategies that may ensure product quality, while being as harmless as possible to the human body and the environment.

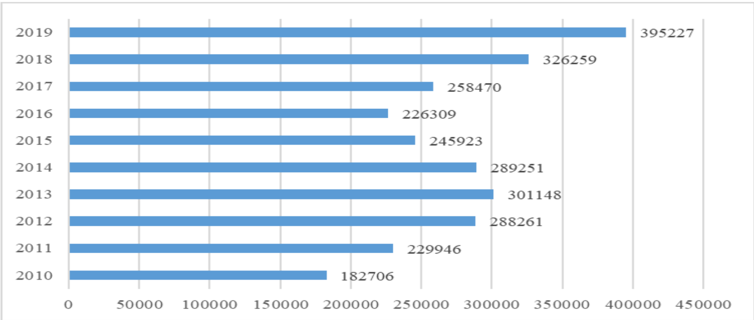
The combined technological, economic and social aspects have a direct impact on production and economic results and, indirectly, on the environment and human health.

The presented considerations make necessary the analysis of the stage in which the ecological agriculture is in Romania, as surface and number of operators, either producers or processors.

In 2018, at European level, an area of 12,980,789 ha was cultivated based on the principles of organic farming, representing 8% of the total EU agricultural area. On the first place as organically cultivated area of the total agricultural area is Austria, with a percentage of 24.1%, at the other extreme is Malta, with a value below 1%, Romania being the penultimate country in this ranking, with a share of 2.4%. In absolute values, Romania cultivated in 2018 an area of 326,260 ha, while Austria reported an area of 639,097 ha (European Commission, 2018).

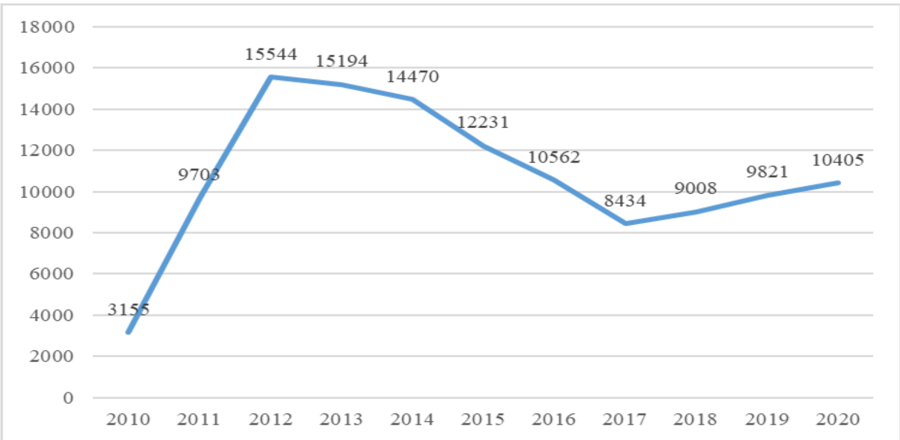
In 2020, the official data (County and Bucharest Agriculture Directorates) show that the total agricultural area registered in organic farming was 471,927.8 ha (certified and in conversion), with different distributions by counties and development regions (figure 3). Significantly larger cultivated and organic certified areas are in Constanta 6.9%, Galati 5.05%, Gorj 2.59%, Teleorman 2.25%, Timis 11.84%, and Tulcea 12.79%. There are, therefore, "exponents" from each development region, which demonstrates the ecological potential of agriculture in Romania.

**Figure 3.** Total area in organic farming in Romania (ha)




*Source:* Ministry of Agriculture and Rural Development, 2021

**Figure 4.** Number of certified operators in organic farming




*Source:* Ministry of Agriculture and Rural Development, 2021

In those regarding the trend of the number of operators managing organic agricultural activities, it manifests into two directions: increasing, in the periods 2010-2013 and 2017-2020, and decreasing from 2013 to 2017, respectively (figure 4).

By counties and, implicitly, development regions, the number of operators is different. The total number of operators in organic farming registered in agricultural statistics is 10,405 individuals and legal entities, the least being in Ialomita (38), Dambovita (49), Calarasi (41), Teleorman (96), Ilfov (57), Giurgiu (27). The large areas favourable for vegetable production found in these counties represent a strong potential for the development of organic agriculture, especially since the production structure is an extremely permissive landmark from an economic point of view (vegetables, cereals, legumes). If we add to these the introduction of digitization elements in the processes of irrigation, fertilization and harvesting, we can confirm the role of organic farming in sustainable development.

In this context, in order to achieve the target proposed by the European Green Deal, respectively a percentage of at least 25% of the organically cultivated agricultural area, a very consistent financial allocation from the European Union is needed. Romania has a very high potential for the development of the ecological sector (Ilie, 2021a), but the deadline, 2030, may be quite short. The elements previously presented and analysed call for the need to apply public policies as attractive as possible for farmers who benefit from competitive advantages for the conversion of cultivated areas to organic production.

## Sustainable approaches to smart agriculture

Agriculture must take active and reactive measures to prevent and identify environmental damages, to ensure food security and a certain level of economic performance for farmers; these efforts are found in the general and specific objectives of the sustainable development of agriculture, namely, the maintenance of agriculture as a support for long-term economic, ecological and social activities. Smart agriculture, which is in line with the principles of the European Union’s Green Deal, is based on these arguments.

Considering the results of previous research and the links between smart agriculture and sustainability, food security, organic farming, organic food, human health, smart agriculture converges to achieve the goals of sustainable development of agro-food sector.

In Romania, smart agriculture is developing according as technological discoveries increase and farmers’ willingness to use smart technologies grows. Identifying the degree of farmers’ perception regarding the digitalization of agricultural activities is a topic of concern in the field. Thus, a case study was conducted on a sample of 52 farms in Romania, of different types, physical and economic dimensions and various production activity (Dobre et al., 2021). The preponderance of the units participating in the survey is given by the type (societies and physical persons), with areas between 11 and 50 hectares and over 50 hectares (40.4%, respectively 44.2%), with specialized activity in cereal production. When asked about the farmers’ willingness to use smart technologies, 92.3% of respondents show a growing interest in digitization and implementation of new technologies in the field in which they operate. Of all those concerned with this direction of agricultural development, 82.4% support the benefits of smart agriculture as a necessary step in order to increase the economic performance of the activities they manage. It should be mentioned that 53.8% of the respondents are in the age group 18-30 years, which is not to be neglected in the perspective of the agriculture development through innovation.

Other research has identified the agricultural methods and practices used by farmers and thus established the size of smart agriculture. A study conducted by VitalFields (2018) shows that the use of digital applications on the computer and, especially, the phone is made daily by a significant percentage of farmers, generally entrepreneurs with economic or technical training. This reveals the role of digitalization in increasing trend of the farms' conversion to commercial units.

The computerization of the economic activity must be approached in two ways: inside the farm and outside the farm. In the first case, the entire activity (production obtained, expenses incurred, income generated) is to be "managed" by computer, so the producer has the opportunity to verify, at any time, the results of the farm he runs. In the second case, monitoring can be done through computerized accounting networks at the county level, which take over the data from each farm (Dobre et al., 2021).

Smart agriculture utilizes specific satellite remote sensing services using drones, geolocation (GPS), climate analysis and weather forecasting, IoT (Internet of Things), integrated farm management services, soil analysis, foliar analysis and online input purchasing. The digitization of activities also aims to monitor the soil, weather conditions, workflow in the field, diesel consumption on each machine and in each soil on which a particular agricultural work is performed, fertilization and irrigation systems, soil work and so on.

The effects of digitalization of agricultural activities envisage all three approaches of sustainability – economic, ecological and social; they are interdependent and synergic. Some of these were identified by a study evaluating the use of digital agriculture services in Romania (Amazag, 2021). The main economic, social and environmental effects refer to the visible improvement of the degree of profitability of economic activities and management; optimization of the production structure, starting from the ecological factors; reduction in diesel and other inputs, which generates cost savings; reduction of costs due to the application of a personalized fertilization plan and more efficient distribution of fertilizers; reducing soil compaction through less use of mechanical works; reducing overlaps in the processes of sowing, fertilizing and applying treatments, by using tractor guidance systems using GPS; incorporation of plants' waste through surface soil mobilization; maintaining soil quality and maintaining the level of acidity so as to ensure high productivity; increasing the production and reducing the consumption of seeds, through the uniform emergence of cereal crops; reducing the consumption of chemicals, applied according to the need for nutrients in the soil, which leads to positive effects on the environment and human health.

All these effects demonstrate that smart agriculture, through its production methods, is close to organic farming, having a significant role in applying the principles of sustainability in the agricultural sector.

## Conclusions

The research revealed the links between the digitization processes specific to the agricultural sector and organic farming, demonstrating the importance of smart agriculture for sustainable development, implicitly generating beneficial effects on the environment and human health. This validates the hypothesis that smart agriculture, compared to conventional one, has a significantly lower negative impact on the environment and human health and has the potential to supply organic products.

Withal, the research revealed the effects of intensive agriculture, mainly from the perspective of pollution of different types and the growth in the incidence of diseases, due to increased use of chemicals and excessive mechanization. Although intensive agriculture models ensure food security due to high yields, they do not subscribe to the principles and strategic directions of sustainable development. The organic farming model, although it achieves lower yields per hectare than intensive agriculture, provides products that are beneficial to the environment and human health, ensuring safe food for population.

We conclude that smart agriculture, through the methods used, which are less invasive on the environment and human health, compared to intensive agriculture, is closest to organic farming, and digitalization is the compromise between conventional agriculture, whose main function is to ensure food security, and organic farming, which provides food beneficial to the environment and human health.

### Conflict of interests

The authors declare no conflict of interest.

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