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DIGITALIZATION OF AGRICULTURE – A BIBLIOMETRIC ANALYSIS

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Abstract

This study aims to complete the previous studies and to create an overview of the interest given to the field regarding the digitization of agriculture. The analysis was carried out on a sample of 604 scientific documents published on the Web of Science (WoS), using the VOSviewer software. The study first analyzes the annual trend of publications, the annual trend of article citations as well as the trend of keywords and co-authorship by country. In many studies, the process of digitalization of agriculture is discussed in which various technologies capable of facing the current challenges regarding the agri-food sector are proposed. However, bibliometric studies on the digitization of agriculture are few. The results emphasize the methodological approach, obtaining maps with the terms that appear frequently in the analyzed studies, being grouped into 6 clusters, two of which are representative. The yellow cluster consists of terms related to digitization, climate change, and machine learning while the red cluster consists of terms related to agriculture, performance, management, and big data. Out of the total of 604 published documents, Romania has a percentage of 26% of published articles, being the leader in the ranking.

Key words**:** *digitalization of agriculture, Romania, smart agriculture*

INTRODUCTION

The phenomenon of globalization has a direct impact on agriculture, forcing farmers to use new agricultural models instead of traditional ones, the reason being the implementation of sustainability in the field [3].

Digitization represents a new direction to increase the efficiency of the agro-industrial structure and the sustainable development of the agricultural sector. Technological innovation in the agricultural field is considered to be a solution for agro-industrial countries, agricultural technologies based on computer systems, automation, and robotization, used on a large scale accelerate the increase in productivity and profitability of agricultural holdings [11].

The digitalization of agriculture has as its main objective the implementation of IT technologies [15] and innovations in agricultural production, the protection of the environment, as well as ensuring the food security of people and animals. The sustainable development of agriculture through its digitization primarily involves the development and use of new management models that are based on information technologies and that ensure the increase of yield in agricultural holdings, the preservation of biodiversity by reducing the negative impact on the environment, thus ensuring a level sustainable production and profit [4]. The digitization process consists of improving production and transport systems, improving the implementation of support measures in the sector, and optimizing the use of resources so that the continuous flow of products can be ensured [6].

Currently, the digitization of agriculture can represent a viable solution for solving the problem of the lack of labor force, because in agriculture this lack is acutely felt, and the rural population is on the decline. Thus, the implementation of new management concepts, automation, sensors, and robots in agricultural production processes will reduce the need for labor, while at the same time increasing agricultural productivity and efficiency [16]. According to the European Commission, the most relevant technologies and techniques to be exploited are the following: satellite technologies for image delivery, the use of agricultural robots, as well as the use of unmanned agricultural vehicles/machines (UAVs) to collect conclusive/demonstrative

data on the real situation from agricultural holdings [6].

MATERIALS AND METHODS

Bibliometrics is considered a method of quantitative measurement of scientific publications in a certain field and appeared in the scientific world as early as 1969, in a documentary note by Alan Pritchard. The bibliometric analysis includes various mathematical and statistical methods for evaluating bibliometric data [7]. Through the use of this technique, we sought to understand the interrelationships between the number of documents published in the field of digitalization of agriculture, an existing research topic, the frequency of citation of articles, and the interest given to a specific topic/research area by country. Through the VOSviewer software, the data were presented graphically, through category maps. The data were collected from the Web of Science database, and a query was made for the term "Digitalization of Agriculture", resulting in a total of 604 documents.

RESULTS AND DISCUSSIONS

Figure 1 shows the annual publication trend from 1987 to 2022 with a total number of published papers of 604, excluding the inactive publication years of 19987-1992, and 1992-1997.

Fig. 1. Annual trend of publications of bibliometric papers from 1987 to 2022.
Source: Own representation based on data provided by Web of Science.

The data reached its maximum level in the year 2022 with 126 documents, of which the majority of articles were published at the Multidisciplinary Digital Publishing Institute (MDPI) and Elsevier (Fig. 1).
This reflects the growing interest in research related to the digitization of agriculture as well as the progress made in the context of the implementation of digital technologies, even if the pace is still low compared to other fields [5]. Digital agriculture (agriculture 4.0)[1] provides farmers with a complex set of tools for food production challenges associated with farm productivity, environmental impact, crop losses, and sustainability [12].
Publications cannot be relevant if the documents are not cited in turn by other studies. Thus, the total annual citations are represented in Figure 3. During the period 1987-2006, there was no observable trend in terms of citations. In the following period, the total number of citations began to increase, reaching in the last period a total number of 925 citations (2022) (Fig. 2).
Figure 3 shows the links between keywords (nodes), providing an overview of the main research topics and trends. Those nodes represent highly cited publications or highly prolific researchers, who may have more connections than their less popular counterparts.
In bibliometric network analysis, a normalization is usually performed for these differences between nodes. The lines between the nodes represent the connections between these keywords. After the network has been normalized, the next step is to position the nodes in the network in a two-dimensional space in such a way that strong nodes are connected, while weakly connected nodes are located far from each other.
For this purpose, VOSviewer uses the VOS mapping technique, where VOS stands for "similarity visualization" (Fig. 3).
The yellow cluster consists of topics related to digitization, climate change, and machine learning. It is believed that future climate change will further amplify already existing risks and even create new ones, making the measures taken crucial for managing new environmental challenges [14].

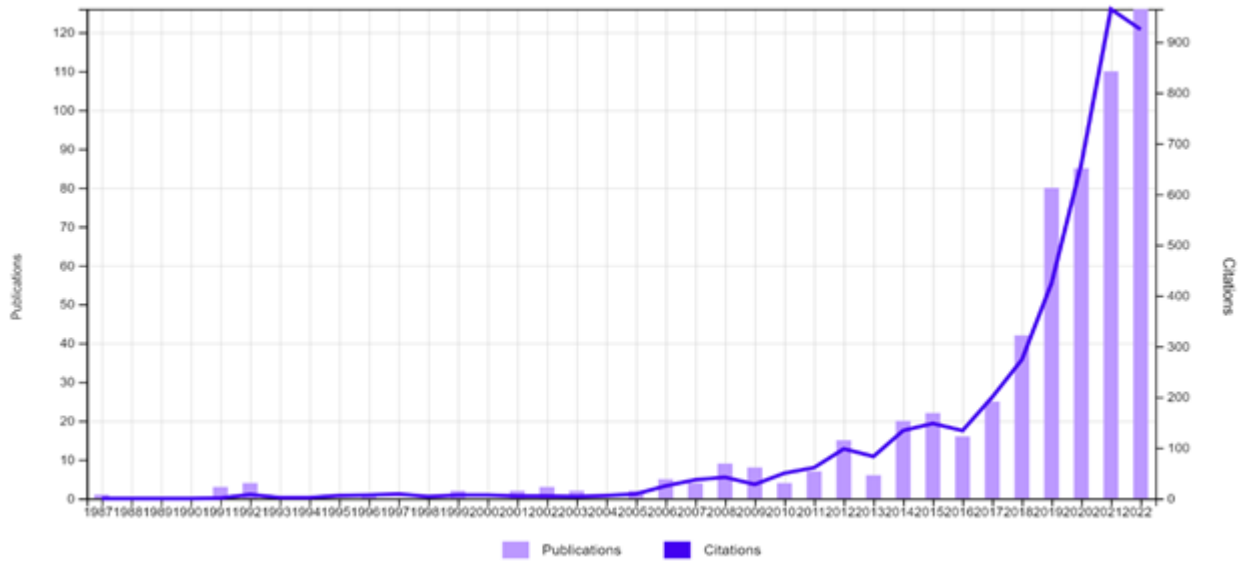

Fig. 2. Annual trend of bibliometric article citations
Source: Web of Science.

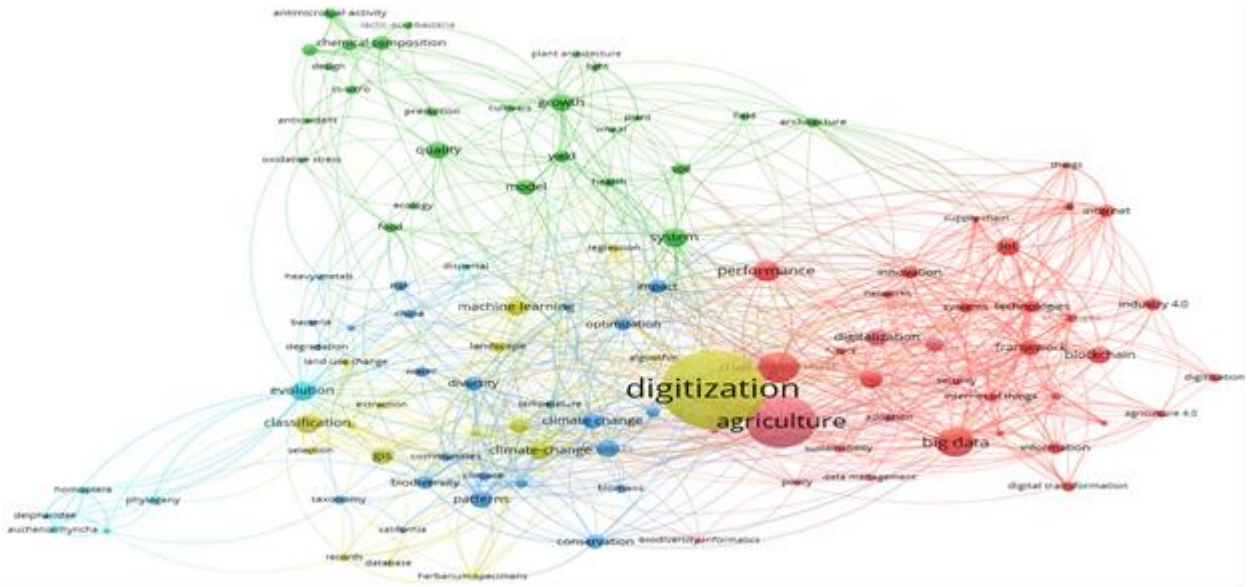

Fig. 3. Network view of the keyword "digitalization of agriculture".
Source: Own representation based on data provided by Web of Science.

The application of digital technology in agriculture was, is, and will be an essential and primary element to promote, generate data and analyze it advanced, allowing all farmers to make intelligent decisions in agriculture, but also to benefit from the economic use of all inputs and labor. Together with the connectivity between mobile devices and other platforms, the digitization of agriculture will generate a high volume of data and information that will serve as the basis for future decision-making. It is also argued that the digitization of agriculture can bring substantial improvements worldwide, in terms of increasing the productivity and efficiency of agricultural systems, adapting to climate change, but also reducing food waste, and making the use of natural resources more efficient in a sustainable way [5]. In this context of climate change, digitization is an important management tool to prevent agriculture develop a protection plan to combat pests and maintain soil quality [9]. In addition to the ability to intensify the work process, the use of digital technologies helps to improve vulnerabilities related to seasonality. Following this logic, German farmers consider the use of digital

technologies in the long term as a tool to reduce farm costs, including labor costs in the horticultural sector [2].

The red cluster indicates topics related to agriculture, performance, management, and big data. Big data in agriculture gives all farmers the ability to view detailed data on specific elements such as rainfall, water cycles, soil fertilizer requirements, and more. By using this technology, farmers can make smart decisions to plant the best crops to get the best return [13]. Recent studies have demonstrated that big data will have a substantial impact on the development and application of digital technologies in agriculture, even if this field is still in its infancy [10]. The high potential of digital applications for agriculture is generating excitement about the future of agriculture. Some people in the field claim that the intelligence offered through these digital tools is a way to solve the still persistent problems in agriculture [8].

604 articles on the digitization of agriculture from over 100 countries were retrieved. Table 1 shows a list of the top 10 countries with the largest number of published documents, representing 96.19% of all publications. As of 2022, Romania had the most articles published in this field, followed by China and Germany. In addition to the global dominance in research related to the digitization of agriculture, Romania continues to lead the ranking for the last 5 years, as a result of the involvement of the European Union in balancing the agricultural sector by encouraging farmers to use and apply digital technologies (Table 1).

Table 1. Top 10 countries with the highest number of publications

Country	Documents	Citations
Romania	157	415
USA	98	1,404
China	85	641
Germany	59	560
India	43	285
Italy	34	492
Russia	28	77
France	27	881
Czech Republic	25	454
Spain	25	357

Source: Web of Science.

Figure 4 represents bibliographic cooperation where countries are used as the unit of analysis.

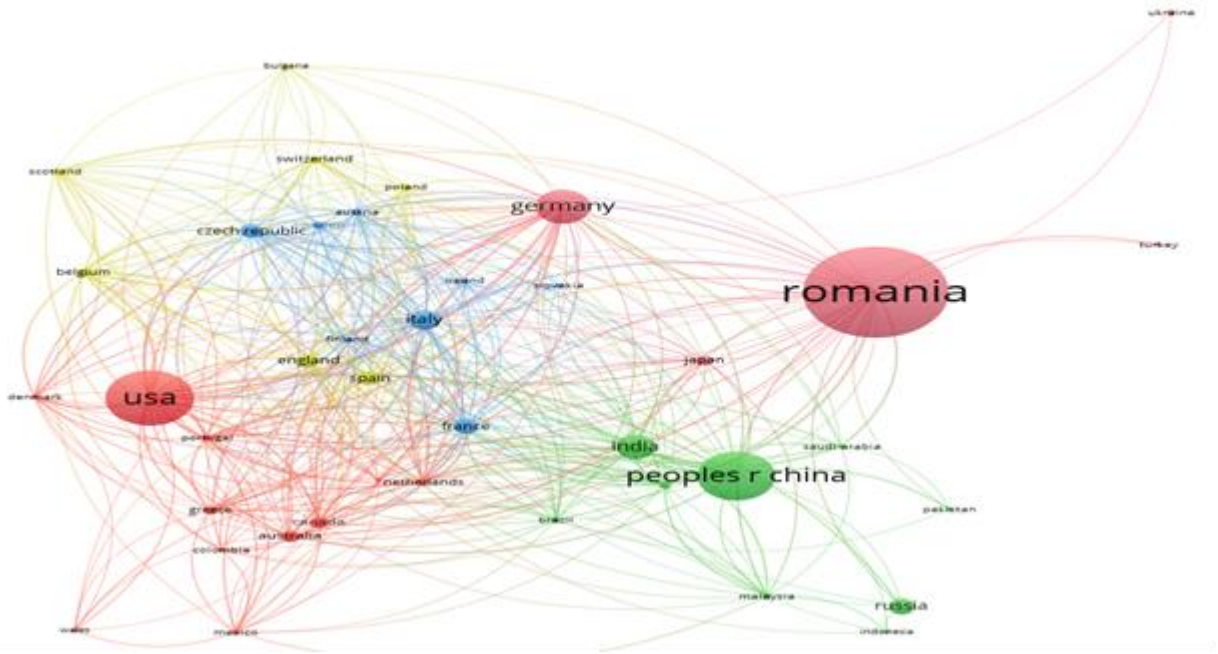

Fig. 4. The link between co-author countries on the concept of "digitalization of agriculture"
Source: Own representation based on data provided by Web of Science.

The study established certain limitations of the model, for example, a minimum number of 5 elements were required for a country to appear on the map. According to figure 4, it

can be seen that Romania has research collaborations, especially with researchers from Germany and the USA, but also with researchers from Japan, Turkey,and Australia (Fig. 4).

CONCLUSIONS

The purpose of this study was to complement previous studies, provide an overview of the field's interest in the digitization of agriculture, and extend the current literature for future research. Based on the bibliometric technique, the most relevant existing themes in the current research were identified, observing promising directions for future approaches.

When performing the analysis, 604 documents were selected to understand the relationships between the digitization of agriculture and the interest given to this field of research depending on the country. As a result, the analysis fulfilled its objective, by identifying numerous publications, from which several meaningful perspectives can be derived.

First of all, the number of documents related to the "digitalization of agriculture" increased substantially in the period 2017-2022, most of them being published in the Multidisciplinary Digital Publishing Institute (MDPI) and Elsevier, being some of the most important journals that contribute to the literature on digitization agriculture. Regarding the global impact, it was found that in the top 10 with the highest number of publications in this field, Romania is the leader in the ranking with a weight of 26% of the articles (157 documents).

By grouping the keywords resulting from the query of the database, 2 main topics from the specialized literature were noted: Digitization and Agriculture interconnected by various terms such as big data, management, climate change, etc. An alarming threat to agriculture is related to climate change that should be examined in such a way that practices and technologies that reduce the side effects are adopted.

Finally, the subject of the digitalization of agriculture needs special attention mainly in terms of developing objective metrics to demonstrate that the application of the technology can meet all the requirements related to maintaining the sustainability of the agricultural industry.

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