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QUANTITATIVE APPROACH TO INFLUENCING DRIVERS FOR SUSTAINABLE AGRICULTURE DEVELOPMENT

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Abstract

The need to address the complex exchanges between natural resource efficiency and economic growth has become increasingly discussed in worldwide strategies and position papers. Resource depletion, environmental challenges and climate change are just a few topics related to fast industrialization and economic expansion. The question is how information regarding crops, climatic factors, or solutions used in plant treatment are managed. The purpose of this paper is to provide an overview of the scientific environment regarding quantitative indicators and models for the assessment of sustainable agriculture practices. The study is based on a bibliometric analysis made using Web of science database and processing using biblioshiny environment from R package. The most relevant works and influential authors in the field of quantitative modelling for sustainable agriculture were identified and a set of indicators and metrics for evaluating efforts in transitioning towards sustainability were synthetised. Integrating practical data into quantitative models can provide insights into trends, correlations, or even predictions, and the results obtained serve as inputs for decision-makers.

Key words**:** *sustainable agriculture, econometric methods, multicriteria indicators, strategic thinking*

INTRODUCTION

Sustainable agriculture plays a fundamental role in fostering economic development on local, national, and global scales, as highlighted by its substantial contribution to the gross domestic product and added value. Over the years, agriculture has undergone paradigm shifts, evolving into a sector driving economic growth and addressing various societal challenges, including food security, environmental degradation, and population growth [14].

Sustainable agriculture is defined as managing renewable and non-renewable resources in order to meet the food demands of a growing population.

On a societal level, sustainable agriculture works towards providing enough food for current and future generations while also protecting the environment [9]. As a result, sustainable agriculture and the circular economy are seen as ways to address problems like hunger, food insecurity, and climate change [7, 18]. According to statistics from the United Nations Food and Agriculture Organization, around 9.2% of the global population is currently facing hunger, and it is expected that about 600 million people will be chronically undernourished by 2030 [6, 22]. Not only do sustainable agriculture practices pose challenges at the macroeconomic level, but farms also encounter optimization issues when pursuing sustainable economic activities. While profit remains the primary outcome of economic activity, achieving it necessitates a combination of modern technology with traditional land maintenance and crop rotation methods [2].

Different methods to assist farmers in sustainable production management range from simple approaches based on saving money in the supply chain [5, 4], to more advanced strategies like precision agriculture using technologies like GPS, IoT, satellite imagery, and robots to track soil quality and

plant health [21, 19].
Romania, being a European nation, is required to implement policies that will facilitate the shift towards a sustainable economy.
Nevertheless, Popescu (2018) points out that Romanian farmers' technological resources are nearly 26 times below the European average [16]. In this situation, advanced techniques like precision farming are difficult for the majority of Romanian farmers to achieve. Analysing influencing factors, as well as examples of best practices from literature and statistical data can be used as future strategies for sustainable growth [3].
Econometric models may be used at the intersection of economics, environmental science standing as tools for assessing the economic, social, and environmental impacts of sustainable agriculture. Econometric models offer a systematic framework for analyzing relationships within agricultural systems, incorporating variables such as inputs and outputs together with environmental factors [23], policy interventions and socio-economic dynamics [20, 15]. By quantifying the resulting interdependencies, the quantitative models enable researchers to provide the interested parties, such as policymakers and business environment to evaluate the effectiveness of various sustainable agriculture strategies, from precision farming techniques to organic practices, agroforestry, and water management initiatives [11, 24, 25].
In this context, the purpose of the paper is to provide an overview of the scientific environment regarding quantitative indicators and models for the assessment of sustainable agriculture practices.

MATERIALS AND METHODS

The study is based on a bibliometric analysis made using the web of science database. In the first phase, a query was carried out including the search terms "quantitative method sustainable agriculture". This query returned a number of 1,815 documents. Analysing the annual production of articles on the searched topic, it was observed that starting with 2013, there was an increase in interest in this field. so that, for the bibliometric analysis, the previous years were excluded. Furthermore, only documents in English were selected. Editorial material (5 documents), correction (1 document) as a document category was excluded from the selection. Following the analysis of the resulting documents, those titles that were not relevant for the sphere of interest proposed in this study were eliminated.
The PRISMA flow diagram used in the research is given in Figure 1.

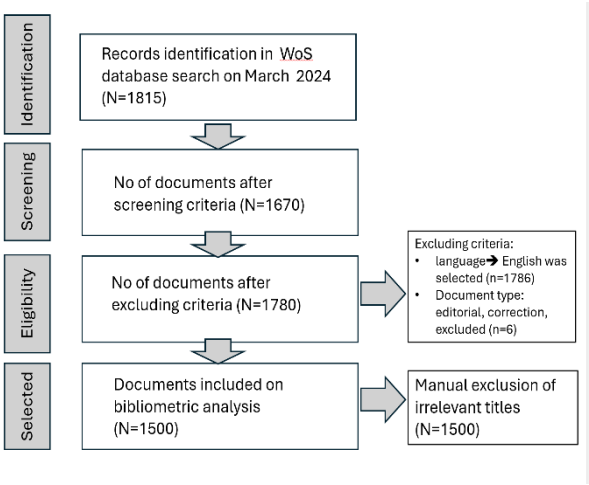

Fig. 1. Prisma FLOW diagram of the bibliometric analysis.
Source: authors own processing.

The bibliographic data including authors, publication titles, journal names, publication years, abstracts, and citation counts were collected in a separate file. The retrieved date were analysed using biblioshiny environment from R package [1]. Citation analysis techniques were applied to identify most relevant works and influential authors in the field of quantitative modelling for sustainable agriculture. Keyword analysis was conducted to uncover prevalent themes and emerging trends within the literature, aiding in the identification of knowledge gaps and areas for further investigation. The findings of the bibliometric analysis are synthesized in the following sections and interpreted to provide an overview of the scientific environment regarding quantitative indicators and models for the assessment of sustainable agriculture practices.

RESULTS AND DISCUSSIONS

The annual scientific production of articles on a quantitative approach to sustainable agriculture has shown a notable trend of growth over the years (Figure 2).

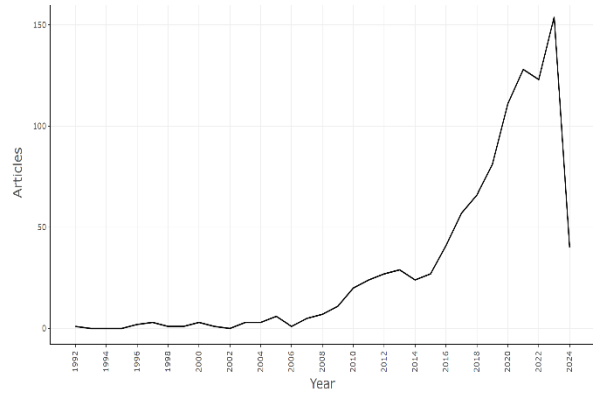

Fig. 2. Annual production of scientific literature on the quantitative approach to sustainable agriculture
Source: authors processing after Web of Science data.

Starting from the year 1992, there were intermittent periods of stagnation or minimal output until the late 1990s. From the late 1990s to the early 2000s there was a gradual increase with occasional fluctuations, reaching 20 articles by 2010.

The increase became more evident in the following years, particularly from 2013 onwards, with an exponential rise in publications.

This data suggests a growing interest and emphasis on employing quantitative methodologies in addressing sustainability challenges within agriculture.

Analysing the literature landscape, the ten most relevant sources for the documents retrieved regarding quantitative approaches to sustainable agriculture are presented in Figure 3.

The Journal "Sustainability" from Mdpi publisher stands out as the primary source, with 71 articles dedicated to exploring various quantitative methodologies applied within sustainable agricultural contexts. "Frontiers in Sustainable Food Systems" and "Journal of Cleaner Production" contribute significantly, with 18 and 17 articles, respectively, offering insights into quantitative techniques for enhancing sustainability in agricultural practices.

This selection includes a Romanian edited Journal as well. "Scientific Papers-Series Management Economic Engineering in Agriculture and Rural Development" contributed with 13 articles, exploring quantitative insights into management strategies and economic aspects of sustainable agriculture.

These sources provided a framework for understanding and improving quantitative methodologies within the area of sustainable agriculture, gathering diverse research interests and interdisciplinary perspectives.

The discussions focused on sustainable development of agriculture sector and environmental stewardship revealed the key terms that emerged as essential to designing a quantitative framework for understanding and evaluating the challenges of sustainability of the agricultural system.

Among these, "strategy" stands out with 118 occurrences, indicating a strong emphasis on careful planning and deliberate actions as well as design of appropriate policy measures and application of integrated management of crops in agriculture.

The concept of "cause and effect" was also a cornerstone within the documents retrieved. This is highlighting the recognition of the need to understand the repercussions of the practical approach agricultural production systems within environmental systems.

“Conceptual model" and "system thinking" are also frequently mentioned highlighting the importance of creating conceptual frameworks as model for quantitative assessment while implementing holistic approaches in analysing and addressing environmental and societal issues occurred on the pathway to achieve sustainable development of the agricultural systems.

Considering the terms that occurred most, it can be concluded that the selected articles reflect the study towards understanding of interconnected systems and the need for broad strategies in tackling challenges like climate change, which is referenced 48 times.

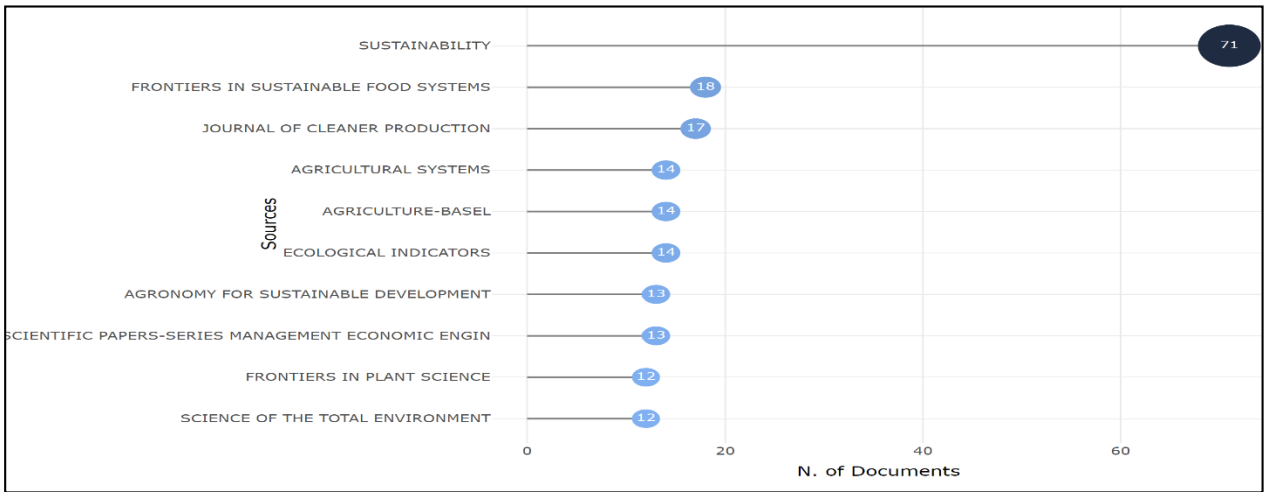

Fig. 3. Most relevant Journals that published research on the quantitative approach to sustainable agriculture
Source: authors processing after Web of Science data.

Sustainable growth" is a core theme as well, pointing the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This is closely tied to considerations of "environmental quality" (34 occurrences) and "conservation" (29 occurrences), indicating a commitment to preserving natural resources and ecosystems.

Occurrence of terms such as “water”, “soil”, and “biodiversity” are further demonstrating the recognition of the natural resources cornerstone roles in sustaining life and ecosystem functioning [13, 11, 10].

In Figure 4 it was plotted the thematic map of the keywords included in the retrieved documents. The keywords were grouped by synonyms and irrelevant terms were excluded from the map.

The thematic map is organised in four sectors comprising the niche themes, and motor themes in the upper part.

These two themes are including word with high density over the selected documents, meaning they are linked to many other keywords, and their occurrence in the selected literature is high.

In the lower quadrants are situated the terms belonging to basic themes and emerging or declining themes.

The lower the word is situated in the thematic map, the interest for the concept is decreasing over the studied articles.

Therefore, motor themes were found to be climate change as related to environmental quality, water efficiency and soil conservation.

Strategy is seen as a concept integrating policy measures, integrated management of agricultural sector.

Niche themes are related to grain-yields, resistance, crop pests and diseases, and genetic traits.

It is interesting that organic matter, carbon, nitrogen and plant diversity are rather basic themes, giving a recognition of the fact that evaluation of any production system should be done by applying a systemic thinking, imbedding multiple criteria indicators and metrics.

Analyzing the articles from the database, it was observed that in the application of some methods for evaluating the development of sustainable agriculture systems, aspects such as economic yield, efficient use of resources, biodiversity conservation, carbon sequestration, food safety and social equity are included.

By integrating these indicators across multiple development areas, multicriteria methods provide a comprehensive perspective on the global performance of agricultural systems in terms of sustainability [8, 17].

In Romania, the agriculture sector plays an important role in the country's economic development providing essential resources for both local communities and the global market. With a rich agricultural potential and fertile soil, Romania has emerged as one of the key

players in the European Union's agricultural ecosystem.

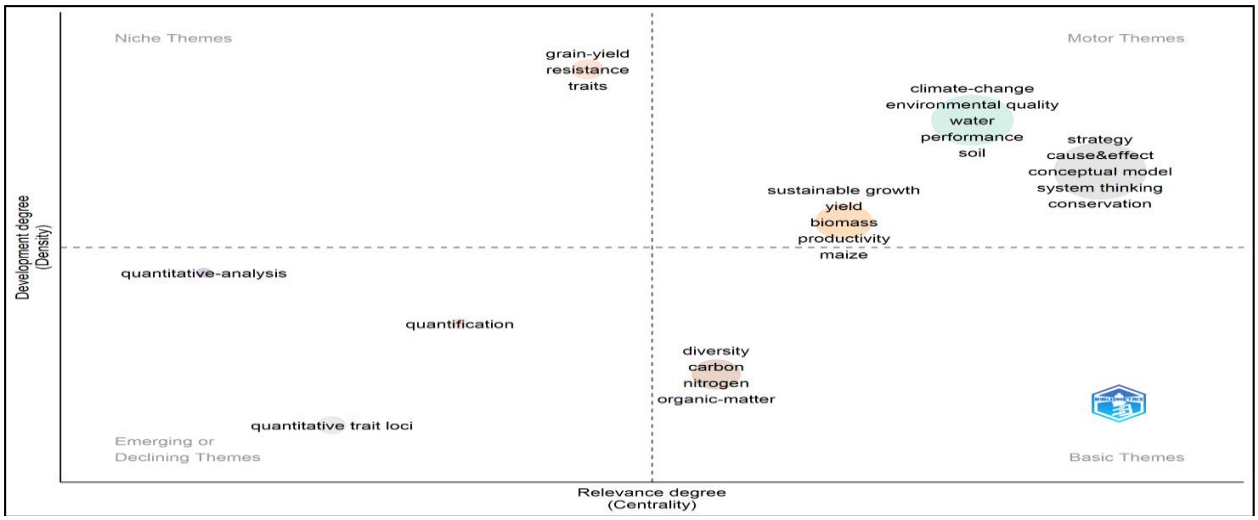

Fig. 4. Thematic map of keywords extracted from selected documents
Source: Biblioshiny own processing.

The development of modern farming techniques and the adoption of digital technologies have contributed to an increase in the average size of agricultural holdings, reflecting a shift towards more efficient and productive farming methods [12].

However, the agricultural sector in Romania still comprises a significant proportion of small, subsistence farms, highlighting the importance of recognizing their role in the development of rural areas.

As Romania continues to cross economic, social, and environmental challenges, sustainable agriculture remains a cornerstone of its growth strategy, promoting resource efficiency, resilience, and equitable development across rural communities.

The emphasis on non-financial indicators and the role of small farms in local development drives to the conclusion that we need to take into consideration the multi-layered nature of agricultural sustainability, which extends beyond economic profitability to include social and environmental considerations.

Analysing available data from various sources (official statistics, farm level surveys, literature, expert opinion) and using quantitative and qualitative analysis methods in research studies it can be provided to stakeholders a proof of concept of the dynamics of agricultural development.

The integration of multiple indicators covering economic efficiency, the use of available resources, actions towards the conservation of biodiversity, the techniques for carbon sequestration are aspects that need to be considered.

The economic efficiency and productivity may be measured by indicators such as yield, land equivalent ratio (LER), water use efficiency and eco-efficiency scores. Furthermore, several metrics were identified, such as net income, disposable income, and benefit/cost ratio (BCR).

The environmental dimension was described by indicators related to soil quality, nutrient cycles, carbon sequestration rates, nutrient status (N, P, K, Mg, Ca), soil microbial biomass, and soil organic matter.

Social aspects were tackled by investigations related to knowledge dissemination, awareness, gender balance, and youth inclusion. In the same category, indicators related to the involvement of farmers within professional networks emphasize the importance of community engagement and equitable development.

Therefore, considering the above bibliometric analysis, a set of indicators are provided in Figure 5.

This set of indicators and metrics cover various categories related to economic efficiency and productivity, environmental conservation and preservation, and social

sustainability within the context of sustainable agriculture.

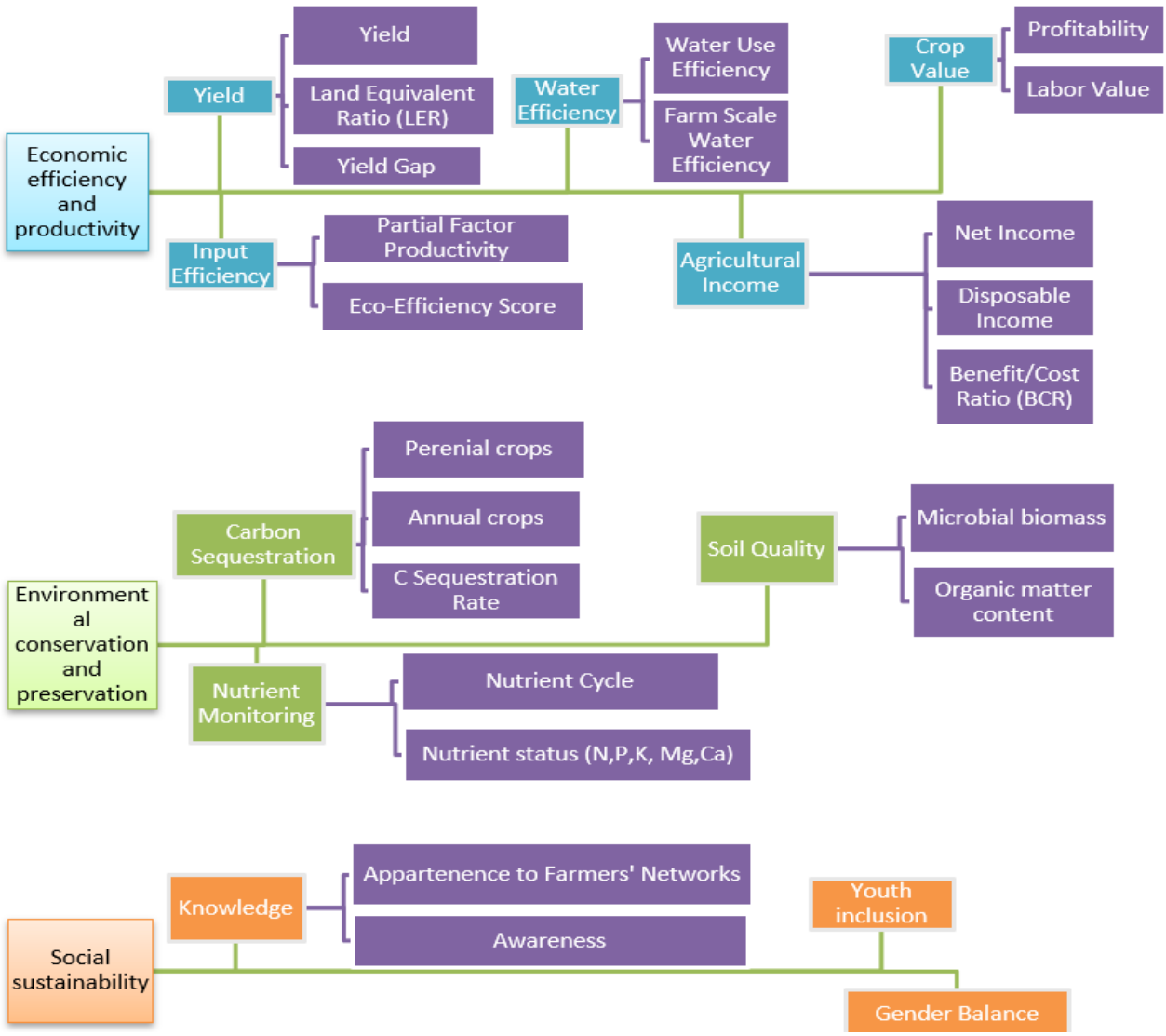

Fig. 6. Three pillars indicators for quantitative assessment of sustainable agriculture
Source: authors own processing.

CONCLUSIONS

So far, the literature on quantifying sustainable agriculture contains a rich variety of indicators and metrics for evaluating efforts in transitioning towards sustainability. These define relevant concepts for sustainable agricultural practices. Metrics represent critical tools for assessing progress towards these objectives and for evaluating trade-offs between them. However, some of the frequently cited indicators currently have few associated metrics, especially regarding the social aspects of sustainability. As future recommendation, an integrated approach that considers economic, environmental, and social indicators is for sure essential for the quantitative evaluation of the sustainability of the agricultural sector. Such perspective ensures that all relevant aspects are taken into consideration.

Furthermore, development of platforms that incorporate these multidimensional indicators identified above, and other metrics and various works as well as continuous data collection and analysis will provide better projection of the dynamics of agricultural development and inform evidence-based decision-making.

As the debate on sustainable development continues and gaps in the literature are addressed, it will remain the responsibility of researchers and stakeholders to select quantitative approaches for the objectives, constraints, and specific local context of each individual effort in sustainable agriculture.

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