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Impact of agricultural policies: outstanding themes, thematic trends, and methodologies according to systematic review and NLP analysis

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ABSTRACT

The objective of this study was to perform a systematic review on the impact assessment of agricultural public policies, applying the natural language processing (NLP) techniques. Themes, methodologies, and conceptual trends were identified in 1043 articles. Six thematic classes stood out, as follows: public health and socioeconomic development in rural areas; technology and agricultural production; environmental conservation and ecosystem management; climate change and agricultural sustainability; research and development in sustainability policies; and water resource management and environmental impact. The trends showed a growing interest in agricultural technology, climate change, and sustainability research policies. Quantitative analyses were predominant, including statistical regression and Markov´s decision processes. The research also highlighted the presence of studies related to the Sustainable Development Goals and the COVID-19 pandemic, showing the relevance of agricultural policies in addressing global challenges. Limitations include reliance on specific databases and the inherent constraints of NLP techniques. The research suggests the need for more comparative and global studies on agricultural policies, as well as more investigation of emerging methodologies for new perspectives in this field.

Index terms: mission-oriented policies, agricultural sustainability, text mining, topic modeling, natural language programming.

Ideias centrais

- Utilização de técnicas de Processamento de Linguagem Natural (NLP) para identificar tendências e metodologias em avaliações de impacto de políticas públicas agrícolas.
- Identificação de seis áreas temáticas de destaque, apontando um foco crescente em tecnologia agrícola, mudanças climáticas e políticas de sustentabilidade.
- Utilização de métodos de análise de dados quantitativos na avaliação do impacto das políticas agrícolas.
- Importância crescente das políticas agrícolas na resposta a desafios globais, sinalizando a necessidade de estudos mais abrangentes e comparativos.
- Necessidade de integração de metodologias emergentes e abordagens mais holísticas na avaliação de impacto.

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Impacto de políticas agrícolas: temas, tendências temáticas e metodologias destacados por meio de revisão sistemática e PLN

RESUMO

O objetivo deste estudo foi realizar uma revisão sistemática para a avaliação de impacto de políticas públicas agrícolas, por meio de técnicas de processamento de linguagem natural (PLN). Temas, metodologias e tendências conceituais foram identificados em cerca de 1043 artigos, em que seis classes temáticas se destacaram: saúde pública e desenvolvimento socioeconômico em áreas rurais; tecnologia e produção agrícola; conservação ambiental e gestão de ecossistemas; mudança climática e sustentabilidade agrícola; pesquisa e desenvolvimento em políticas de sustentabilidade; e gestão de recursos hídricos e impacto ambiental. As tendências mostraram um crescente interesse em tecnologia agrícola, mudança climática e políticas de pesquisa em sustentabilidade. Análises quantitativas, inclusive a regressão estatística e processos de decisão de Markov, foram predominantes. A pesquisa também destacou a presença de estudos

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relacionados aos Objetivos de Desenvolvimento Sustentável e à pandemia de COVID-19, mostrando a relevância das políticas agrícolas no enfrentamento de desafios globais. As limitações incluem a dependência de bases de dados específicas e as restrições inerentes às técnicas de PLN. A pesquisa indica a necessidade de mais estudos comparativos e globais em políticas agrícolas, bem como a exploração de metodologias emergentes para novas perspectivas neste campo.

Termos para indexação: políticas orientadas para missão, sustentabilidade agrícola, mineração de texto, modelagem de tópicos, processamento de linguagem natural.

INTRODUCTION

Over the last six decades, the relationships between the agricultural sector and government policies have become increasingly significant (Carvalho, 2021). These policies have been essential to promote advances in production and productivity, contributing to income increase and improving living conditions in rural communities. In this regard, various public policies have been implemented, aiming at food security, sustainable development, and growth of the agricultural sector (FAO, 2018; Gomez San Juan et al., 2019). Such policies include investments in research, development, and innovation (RD&I), as well as tax incentives, subsidies, rural extension programs, and improvements in infrastructure, besides market regulation measures (Távora, 2003; Souza Filho et al., 2004; Carvalho, 2021). Moreover, to fostering economic growth, agricultural policies are essential to improve living conditions and to reduce social inequalities, contributing to social and environmental well-being (Gehlen, 2004; Costa & Silva, 2016).

Currently, the balancing of agricultural production with environmental sustainability to mitigate climate change (FAO, 2022b), the monitoring and evaluation of such policies have become crucial, to ensure the success of the intended transformations and make adjustments as necessary. Therefore, the evaluation of impacts emerges as a strategic tool, providing detailed data on the effects of agricultural practices in different dimensions (Evenson & Gollin, 2003; Maredia et al., 2014; Gertler et al., 2018). This means that not only these evaluations allow farmers, legislators, and scientists to better understand the impact of their actions, but also that they promote transparency and accountability by providing information to the public and stakeholders about the progress made.

Characterized as analyses of planned, ongoing, or completed actions, these evaluations aim to answer specific questions about the implementation, outcomes, and effects of these actions (Almeida et al., 2016; Fabiani et al., 2018; Gertler et al., 2018). However, despite the established relevance of these evaluations in the academic literature, there is a lack of systematized studies that address how the evaluation of the impacts of agricultural policies is carried out, presenting the main themes, methodologies, and trends in this field. There are specific studies, such as those conducted by DeBoe and Mogues et al., which address important aspects with focus on specific issues in the context of agricultural policies, such as sustainability and economic return (Mogues et al., 2012; DeBoe, 2020). However, a study is still needed to investigate which themes have been prioritized, and how policy interventions in agriculture have been measured.

Against this backdrop, the present work seeks to fill this gap, bringing a novelty in the systematic review process: the application of natural language processing (NLP) techniques. For this purpose, it uses the PRISMA protocol and unsupervised data analysis (Silge & Robinson, 2017), aiming to answer the following question: “What are the predominant themes, methodologies, and thematic trends in studies on the impact evaluations of agricultural public policies?” The structure of the present article includes a literature review on the impact evaluation of public policies, followed by methodological procedures, results, discussion, and concluding remarks.

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THE IMPACT EVALUATION OF PUBLIC POLICIES – A BRIEF CONTEXTUALIZATION

The impact evaluation of public policies is an essential tool for understanding the effects and efficacy of governmental interventions across various sectors. This practice, has evolved over the decades and, as previously mentioned, allows policymakers, academics, scientists and the general public to evaluate whether intended objectives have been achieved and at what cost (Cruz-Castro & Sanz Menéndez, 2007; Fischer et al., 2017; Cairney, 2023). Historically, impact evaluation has its roots in the social sciences (Rossi et al., 2018), where it initially focused on welfare policies and social development programs (Weiss, 1998). Over time and with the introduction of new issues, the practice expanded to encompass a broader range of public policies, including agriculture, education, health, infrastructure, and the environment (Bamberger & Mabry, 2020).

The core of impact evaluation lies in identifying and measuring the direct and indirect, intended, or unintended effects that a public policy has on society and economy (Pawson & Tilley, 1997; Tilley, 2000). This process involves collecting data related to the context of the intervention, identifying and applying appropriate analytical methodologies, and interpreting the results in the light of the policy objectives (Fischer et al., 2017). In this aspect, one of the challenges of evaluation is the choice of appropriate methods that can deal with the complexity and heterogeneity of the contexts in which policies are implemented (Yin, 2009). On one hand, quantitative methods such as statistical analyses and econometrics are essential for providing measurable and generalizable results, as highlighted by Gertler et al. (2018). On the other hand, qualitative methods such as case studies and interviews offer a deeper understanding of social contexts and individual perceptions, as emphasized by Stake (Stake, 2003, 2010). Similarly, Weiss (1998) proposes this type of approach assuming that many aspects cannot be quantitatively measured, as they involve context and the need for a more detailed understanding of the environment in which the intervention occurs.

In recent years, with the advent of the big data era, the analyses of large data sets have allowed for more accurate and real-time assessments of policy impacts (Höchtl et al., 2016; Athey, 2017). This approach is supported by the argument that big data offers new perspectives for predictive and adaptive analyses of public policies (Athey, 2017; Pencheva et al., 2020). Furthermore, experimentation through methods like randomized controlled trials (RCTs) and quasi-experimental models such as the difference-in-differences (DID) method have played a relevant role in policy evaluation (Banerjee & Duflo, 2011; Gertler et al., 2018).

Social network analysis and participatory approaches have also gained prominence in the evaluation of public policies (Zhang et al., 2023). Social network analysis allows of the identification of the interaction among different groups affected by policies, as explored by Borgatti et al. (2018). Concurrently, participatory approaches, which involve stakeholders in the evaluation process, ensure greater relevance and acceptance of the results (Cousins & Leithwood, 1986; Preskill & Boyle, 2008; Cousins et al., 2014).

Emerging technologies such as artificial intelligence and machine learning are also transforming the field of policy evaluation. These technologies enable deeper analyses and the identification of complex patterns; however, it is important to recognize the need for caution regarding data quality and the risk of biases inherent in algorithms (Agrawal et al., 2022). The integration of different methods, whether quantitative or qualitative, is also discussed as a means to provide more consistent and realistic evaluations, representing a current trend; combining quantitative analyses with case studies, for instance, can provide a more comprehensive understanding of policy impacts (Bamberger & Mabry, 2020; Mertens, 2023).

Specifically, agriculture impact evaluation requires special attention, due to its inherently linked nature to environmental, economic, and social variables (Maredia et al., 2014; Weisshuhn et al., 2018). Some authors emphasize that agriculture plays a significant role not just in the economy, but also in environmental and social aspects (Pretty & Bharucha, 2014; Pretty, 2018). Thus, it becomes vital that policy evaluations in this sector transcend mere quantification of economic success, also

encompassing environmental and social impacts. This multifaceted approach is crucial to ensure the long-term sustainability of agricultural practices, and to align agricultural policies with global sustainable development goals (FAO, 2022a).

Additionally, in line with the concept of 'mission-oriented', the impact evaluations of agricultural policies should broaden their scope to measure progress of interventions (Mazzucato, 2018a, 2018b). This implies not only the evaluation of direct outcomes of the policies, but also their alignment with broader social objectives, such as sustainability, equity, and resilience against climate change. The integration of emerging technologies and a variety of evaluation methods, as previously discussed, presents a potential to achieve a balance in the evaluations of public agricultural interventions. Therefore, the procedures and techniques used to identify and analyze the predominant themes, methodologies, and trends in studies of impact assessment of agricultural public policies are detailed in the next section, providing a broad and current understanding of this constantly evolving field.

MATERIALS AND METHODS

This study employed a descriptive-exploratory methodology (Cervo et al., 2006), based on systematic mapping and unsupervised analysis of textual data, aiming to identify themes, methods, and thematic trends for the impact assessment of agricultural policies. Two NLP techniques were adopted: tokenization and topic modeling (Silge & Robinson, 2017). Tokenization involves segmenting texts into smaller units, called "tokens," which can be words, phrases, or other linguistic elements (Silge & Robinson, 2017). Topic modeling aims to discern and categorize the prevalent topics in a set of documents. This approach allows of a synthesis and deep exploration of textual content, facilitating the classification of documents based on underlying themes. Machine learning algorithms are used to reveal latent topics within data corpora (Grün & Hornik, 2011). The specific methodological procedures adopted in each analysis phase are detailed as follows.

Data Collection and Selection

For data collection, the Scopus and Web of Science databases were used, given their breadth and quality as sources of scientific information (Harzing & Alakangas, 2016). The search was performed in April 2023, using boolean operators, truncation (*), and quotation marks ("") to capture lexical variations and identify relevant intersections (Table 1). The search string retrieved 3,415 publications.

Table 1. Search terms and results obtained from databases.

Source	String	Searching date	Amount
Scopus	TITLE-ABS-KEY (agric* AND "public polic*" AND ("impact" OR "evaluat*" OR "assess*" OR "ex ante" OR "ex post"))	04/03/2023	2624
Web of Science	TS=(agric* AND "public polic*" AND ("impact" OR "evaluat*" OR "assess*" OR "ex ante" OR "ex post"))	04/03/2023	791
Total			3415

In the screening and selection of articles, the preferred reporting items for systematic reviews (PRISMA)[3] protocol (Page et al., 2021a, 2021b) was adopted to ensure the process quality. The inclusion criteria were defined with basis on systematic literature reviews (Austin et al., 2022; Viana et al., 2022) consisting of the following text types: articles in English (352 excluded); articles with complete metadata (89 excluded); relevance to the study question, as defined by regular expression[4] (1371 excluded); and articles published up to 2023 (62 excluded). Additionally, 498 studies were

[3] The PRISMA protocol offers a sequential approach that helps with the search, collection, analysis, and organization of reviewed works (Galvão et al., 2015), reducing biases and improving the quality of results (Moher et al., 2009).

[4] Method of searching for patterns in texts. In this case, carried out through the code: policy <- "(policy|policies).*\\b(evaluation|impact|assessment)\\b|\\b(evaluation|impact|assessment)\\b.*(policy|policies)"

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removed for being duplicates. Thus, from the initial 3415 articles, 2372 were excluded for not meeting the established criteria. Additional inclusions comprised a prior study by DeBoe (2020) and another, identified via citations, by Mogues et al. (2012), resulting in 1045 analyzed studies (Figure 1).

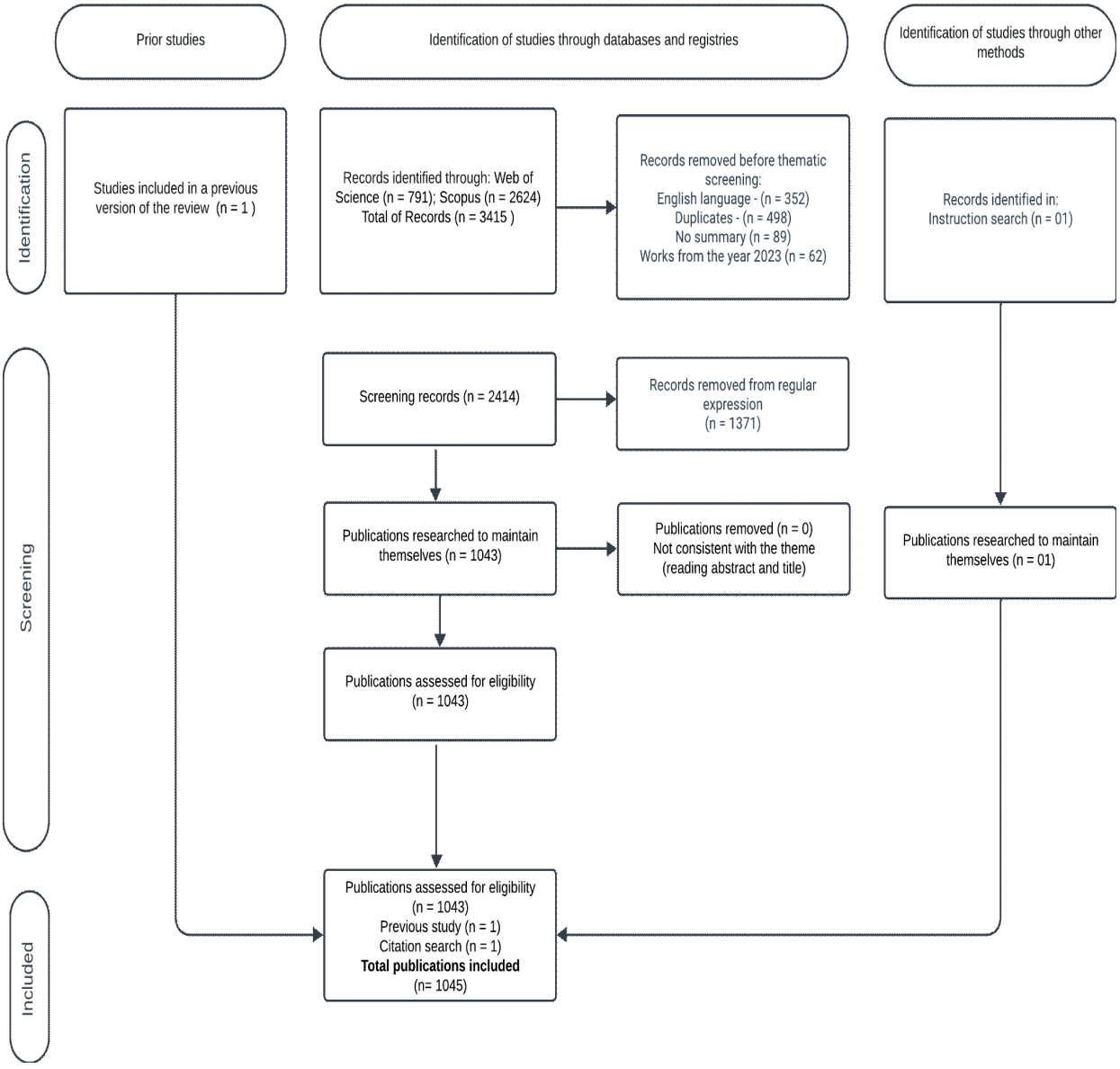

Figure 1. PRISMA flowchart for screening and selection of documents to be analyzed.

Data preparation

For the preparation of textual data, recommendations by Silge & Robinson (2017) were followed and consisted of:

1) Text transformation, removing, and replacing of unwanted characters. Application of normalization techniques, such as correcting typos and standardizing abbreviations, to ensure data analysis uniformity and accuracy.

2) Separation of words by tokens, bigrams, and removal of unwanted words (stopwords[5]) and stemming[6] of data.

3) Creation of a frequency matrix to categorize "stems" and associate them with their respective occurrence frequencies in the texts, allowing of inferences on proximities, distances, synonyms, and related terms.

4) Creation of two *corpora*[7] for topic extraction, formed from the "Abstract" variable, and methods, from the combination of variables "Abstract, Keyword, and Author Keyword."

Identification of Themes

Tokenization techniques were employed through the bigram[8] analysis and topic modeling, to identify and confirm the themes and methods addressed in the context of impact evaluations of agricultural public policies. Bigram analysis was used to detect frequently occurring pairs of words, providing initial insights into the thematic content. Subsequently, topic modeling was applied to group the publications based on thematic similarities, leveraging machine learning to uncover latent structures. We incorporated Zipf's theory (Zipf, 1949) alongside the bigram analysis (Silge & Robinson, 2017), to account for the frequency of word pairs in the studied corpora. Furthermore, topic modeling was conducted using the latent Dirichlet allocation (LDA) method (Grün & Hornik, 2011; Silge & Robinson, 2017), establishing six topics[9]. The number of topics was obtained from the Elbow method (Fávero & Belfiore, 2017), while also conducting a topic coherence test[10] (Röder et al., 2015).

Identification of Techniques and Methodologies

To identify the techniques and methodologies adopted in the captured studies, the following procedures were used:

5) Firstly, an attempt was made to identify methodologies through trigrams, via frequency analysis and manual validation, which amounted to approximately 90 techniques; this stage was conducted in the context of an Embrapa's project.

6) Subsequently, additional techniques from the literature of Ruegg & Feller (2003), Bamberger et al. (2010), Norton & Alwang (2016), Fischer & Miller (2017), Gertler et al. (2018), Weisshuhn et al. (2018), Arruda et al. (2021), Menezes & Pinto (2021), and Reed et al. (2021, 2022), were incorporated, culminating in a dictionary[11] of 103 techniques by the end.

7) Development of an algorithm for cross-referencing data related to the methodologies organized in the dictionary and the following variables: title, abstract, keyword, and author keyword.

[5] Stopwords are very common and frequently used words in language, such as articles, prepositions, and pronouns, which generally do not contribute to the specific meaning or context of a text (Silge & Robinson, 2017).

[6] The process of reducing words to their base form or root, called "stem." This is done by removing suffixes and prefixes from words, keeping only the central common part, facilitating the analysis and comparison of related words (Silge & Robinson, 2017).

[7] A collection of written or spoken texts (Silge & Robinson, 2017).

[8] Bigrams can be more effective for capturing general themes, as trigrams can be more specific and, consequently, present a lower frequency of occurrence in the data. Furthermore, trigrams may be more subject to common word combinations, which can lead to the loss of relevant information (Silge & Robinson, 2017).

[9] In this work, group and topic are treated as synonyms for topic modeling.

[10] The topic coherence test is a useful tool to evaluate and adjust topic models, allowing of the quality identification of the generated topics and optimization of the model parameters to achieve better results (Röder et al., 2015).

[11] Available at: <https://github.com/danimaciel/agricultural_analysis_pp/blob/main/dictionary_methods.xlsx>.

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Procedure for Identifying Trend Patterns

To identify thematic trends over the coming years, a second-degree polynomial model was adopted, as per the formula below:

$y = ax^2 + bx + c$

where: y is the number of publications in a given year; x is the year; and a, b and c are the model parameters, which were adjusted to historical data.

This model is flexible and can be used to represent a wide range of trends, which is important because publication data may exhibit varied trends. Moreover, the polynomial model is relatively simple to interpret, allowing of the presentation of results in a clear and concise manner. The model was loaded in Python, through Google Colab, and its code is available at <Systematic_Review_Polynomial_Model.ipynb>.

Tools used

The R programming language (version 4.1.2 - 2021-11-01) and the RStudio work environment (version 2021.9.0.351) were used in the present study.

For identifying duplicates and cleaning samples, the following packages were employed: "stopwords," "tidyverse," "dplyr," "stringi," "readr," "writexl," "readxl," "textplot," "XML," and "readxl." For tokenization and topic modeling, the packages "textrank," "tibble," "gt," "topicmodels," "tm," "textplot," "caret," "tidyr," "quanteda," "stringr," "NLP," "curl," "tidytext," "cluster," "factoextra," and "knitr" were used. Python language, via the Google Colab environment, was specifically utilized, for identifying thematic trends through the packages: "numpy," "matplotlib," and "scipy."

For data visualization, the packages "owlcarouselR," "htmltools," "slickR," "gt," "ggplot2," "quanteda," "NLP," "curl," "wordcloud," "SnowballC," "RColorBrewer," "wordcloud2," "gridExtra," "plotly," "ggwordcloud," "webshot2," and "htmlwidgets" were used. Additionally, Tableau, version 2023.2.5 (20232.24.0115.0353), Excel's (online version, Microsoft 365) and Google Sheets' data analysis and visualization functionalities were also employed to complement the process. The data and algorithms used in this work are available in the Github repository (Maciel, 2023).

FINDINGS

The temporal coverage identified in the dataset spans 48 years, distributed across seven decades (Table 2). The first mapped study dates back to 1961 and was conducted by the Subcommittee of North Central Regional Research Committee NCR-20, focusing on analyzing the impacts of rapid and drastic changes to which the agricultural industries were subjected, affecting farmers, consumers, and businesses (A Report on Market Structure Research in Agricultural Economics, 1961).

Scopus provides the broadest coverage, representing all 48 mapped years. In contrast, WoS covered a total of 26 years, accounting for only 9.5% of all selected data. In regard to growth for specific decades, the 1970s, 1980s, and 2010s saw the highest concentration of publications. On average, publications recorded in Scopus were done by two authors, while in WoS, this number reached four (Table 2).

Table 2. Growth of publications by decade.

Database	Decade	Amount	Growth (%)	Average Authorship
Scopus	1960	2	0	2
	1970	9	350	1
	1980	30	233	2
	1990	76	153	2
	2000	194	155	3
	2010	378	95	4
	2020	255	-33	4
Web of Science	1990	10	-96	3
	2000	12	20	4
	2010	37	208	4
	2020	40	8	5

It is noteworthy that, when normalizing the decades by the elapsed years, 2020 represents the one with the highest potential for growth for both databases. The year with the highest number of publications in both databases was 2022, with 90 publications in Scopus and 20 in WoS. Randomly selecting[12] 10 titles from this year showed that the focus of the investigations was on collaborative management of food systems and adaptation to climate change, particularly in response to food crises exacerbated by the COVID-19 pandemic (Clark & Jablonski, 2022). The theme of sustainability was particularly dominant in the studies of policy impacts in that year (Sánchez et al., 2001; Aubert & Enjolras, 2022; Bayram & Ozturkcan, 2022; Coderoni & Vanino, 2022; Chen, 2023). Along these lines, other studies discussed the effects of European Union subsidies on pesticide expenditures and the need for more effective environmental policies (Aubert & Enjolras, 2022); labor force mobility and the challenges of integrating new technologies in Chilean agriculture (Mancilla et al., 2022); and the pilot policy of water rights trading for the rural population in China (Mu et al., 2022), etc.

Identified themes

In searching for patterns related to themes of public agricultural policy evaluation, 10 bigrams recur frequently (Table 3). These bigrams transcend specific thematic boundaries and reflect issues that permeate different areas, being repeated in different study contexts and publication groups.

Table 3. Most frequent bigrams in the evaluation of public policy impacts.

Bigram	1960	1970	1980	1990	2000	2010	2020
Water resources / water issues	0	0	0	119	102	245	175
Climate change / climate issues	0	0	0	28	144	230	120
Environmental impact / environmental issues	0	0	0	33	114	201	167
Economic growth / economic issues	0	40	3	25	56	215	111
Food security / food safety	0	0	3	4	48	196	155
Rural development / rural issues	0	0	29	28	43	89	85
Sustainable development	0	0	0	5	16	95	119
Health issues	0	0	16	12	32	127	31
Decision making / decision makers	0	0	3	20	76	70	36
Social impact / social issues	0	0	6	5	13	98	74

[12] Random selection using the "sample_n" function from the dplyr package.

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Using topic modeling, it was possible to associate these bigrams with six created topics, which synthesized the trends and thematic concerns in the field. Therefore, topic modeling corroborates and confirms the frequent themes arising from the bigram tokenization technique. The classification is displayed together with the most prominent bigrams, the number of publications gathered, and the countries with the most significant representation[13] as follows (Table 4).

Table 4. Topic modeling of agricultural public policy evaluation.

Topic	Classification	Bigrams	Publications	Countries
1	Public health and socioeconomic development in rural areas	"social impact / social issues," "economic growth / economic issues," "rural development / rural issues," and "developing countries"	126	United States, United Kingdom, Canada, Brazil, and India.
2	Technology and agricultural production	"food security / food safety," and "small farmers"	181	United States, China, France, United Kingdom, and Indonesia.
3	Environmental conservation and ecosystem management	"environmental impact / environmental issues," and "natural resources"	155	Brazil, United States, United Kingdom, France, and Mexico.
4	Climate change and agricultural sustainability	"climate change / climate issues," and "ghg emissions"	169	China, United States, United Kingdom, Brazil, and Germany.
5	Research and development in sustainability policies	"sustainable development"	294	United States, United Kingdom, Australia, Canada, and France.
6	Water resources management and environmental impact	"water resources / water issues," "environmental impact / environmental issues," and "decision making / decision makers"	118	United States, United Kingdom, Italy, Netherlands, and Spain.

The "public health and socioeconomic development in rural areas" class, gathering 126 publications, focuses primarily on the interactions between public health, socioeconomic development, and demographic factors, especially in rural areas of developing countries like Brazil (Aliaga & Chaves-Dos-Santos, 2014), India (Ajay & Prabhakaran, 2010), and China (Tian et al., 2022). Bigrams such as "social impact / social issues" and "economic growth / economic issues" highlight the interconnection between these health-associated elements. Topics in this class emerge in the 1960s with a steady increase until the 2010s, when they begin to decline, which possibly indicates a shift in research priorities, or a maturation of the field with the integration of these topics into other areas (Figure 1). Countries like the United States, United Kingdom, Canada, Brazil, and India, in that order, lead discussions in this class.

Following the "technology and agricultural production" class, there is a concentration of studies on issues related to food production and agricultural technologies, emphasizing the role of farmers. This class covers both the animal and plant production, analyzing agricultural practices in different countries. It is essential for the understanding of issues such as food security and support for small farmers, reflected in bigrams like "food security / food safety." The United States, China, and France stand out among the countries with the highest number of studies. This class shows growth from the 1980s, with a peak in the 2010s and the following decade (Figure 2).

In the "environmental conservation and ecosystem management" class, the emphasis is on soil and land conservation and the sustainable management of natural and forest ecosystems. The studies concern about environmental impacts and the need to preserve natural resources, with bigrams like "environmental impact / environmental issues" and "natural resources" highlighting these issues. They begin to be produced from the 1980s, with a peak in the 2000s and 2010s, reflecting an awareness of

[13] Measure of expressiveness attributed by the number of countries present in the affiliations of each publication.

environmental issues and the need for sustainable ecosystem management practices. However, there was a decrease of publications in the 2020s. Brazil is the country with the highest number of studies in this class, followed by the United States and France.

Topic	Class	Decade						
		1960	1970	1980	1990	2000	2010	2020
1	Public Health and Socioeconomic Development in Rural Areas	1	4	14	26	22	39	20
2	Technology and Agricultural Production			2	8	15	72	84
3	Environmental Conservation and Ecosystem Management			4	9	29	72	41
4	Climate Change and Agricultural Sustainability			1	5	35	68	60
5	Research and Development in Sustainability Policies	1	3	7	19	60	131	73
6	Water Resources Management and Environmental Impact		2	2	19	45	33	17

Figure 2. Temporal distribution of publications within the identified classes.

"Climate change and agricultural sustainability" gathers 169 studies addressing the complex relationship between climate change, agriculture, and environmental impacts caused by greenhouse gas emissions. The studies explore how climate changes affect the agricultural production and seek solutions for more sustainable agriculture as for policies, with bigrams like "climate change / climate issues" and "ghg emissions." With a modest start in the 1980s, there was a sharp increase of research in this class in the following decades. China leads this class, followed by the United States and the United Kingdom. This class also highlights research associated with the SDGs. Research and development is explored in relationships with environmental degradation, agriculture, and trade, associated with the SDGs – 6 (*Clean Water and Sanitation*), 7 (*Affordable and Clean Energy*), 11 (*Sustainable Cities and Communities*), 12 (*Responsible Consumption and Production*), 14 (*Life below Water*), and 15 (*Life on Land*) (Alvarado et al., 2021).

The "research and development in sustainability policies" class includes 294 studies, focusing on the development and research of sustainability policies at national and international levels. This class explores the implementation of new strategies and technologies to promote sustainability, with "sustainable development" being a key bigram. It shows steady growth, with a significant jump in the 2010s. This can be interpreted as a reflection of the increase in policy formulation and strategies aimed at sustainability, a theme that has gained prominence in global discourse (FAO, 2022b). Studies like that by Choudhury and Behera discuss improving governance and land policies in India, regarding different SDGs – mainly the15 (*Life on Land*) and the 11 (*Sustainable Cities and Communities)* (Choudhury & Behera, 2017). The United States, the United Kingdom, and Australia stand out as the countries with the highest number of studies in this class.

"Water resource management and environmental impact" focuses on water-related issues, with 118 studies, including water resource management, water quality, pollution, and irrigation. This class is crucial because of the importance of water in all contexts and, specifically, for agricultural activities and the growing concerns about environmental sustainability, with bigrams like "water resources / water issues" and "environmental impact / environmental issues" highlighting these aspects. The research in this class shows continuous growth since the 1980s, with a peak in the 1990s. It also includes the discussion by Vanham and Mekonnen on SDG 6 (*Clean Water and Sanitation*), particularly on target "6.4" aiming to reduce water scarcity and improve water efficiency (Vanham & Mekonnen, 2021), whose article criticizes the scarcity-weighted water footprint indicator for not properly assessing the sustainability of water use. The decline in this class in recent decades may indicate an integration

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of these issues into broader sustainability studies or changes in research priorities, as noted in the studies by Vernier et al. (2017) and Wolters et al. (2022). Countries like the United States, the United Kingdom, Italy, and the Netherlands stand out as the most productive in the classes.

The observed decrease of publications across various thematic classes in the 2020s, comparison with the previous decades, reflects an incomplete time period and not the whole academic contributions that will yet emerge throughout the decade. The following section will present an analysis of trends related to these classes.

Thematic Trends

When analyzing the trends, three possible situations for the six classes are observed, as follows: those with a growth trend; those with fluctuating trends, and those with future trends. In this sense, for the growth trend situation, four classes stood out: "technology and agricultural production"; "climate change and agricultural sustainability," and "research and development in sustainability policies" (Figure 3).

In the condition of a fluctuating trend, the class "environmental conservation and ecosystem management" is presented. Although there seems to be a growth trend in this class from 2000 on, there is fluctuation, indicating there may be periods of increase and decrease. The classes with reduced trends are "public health and socioeconomic development in rural areas (reduced trend)" and "water resources management and environmental impact (reduced trend)." These classes are integrated, in a way, with other themes present in the other classes.

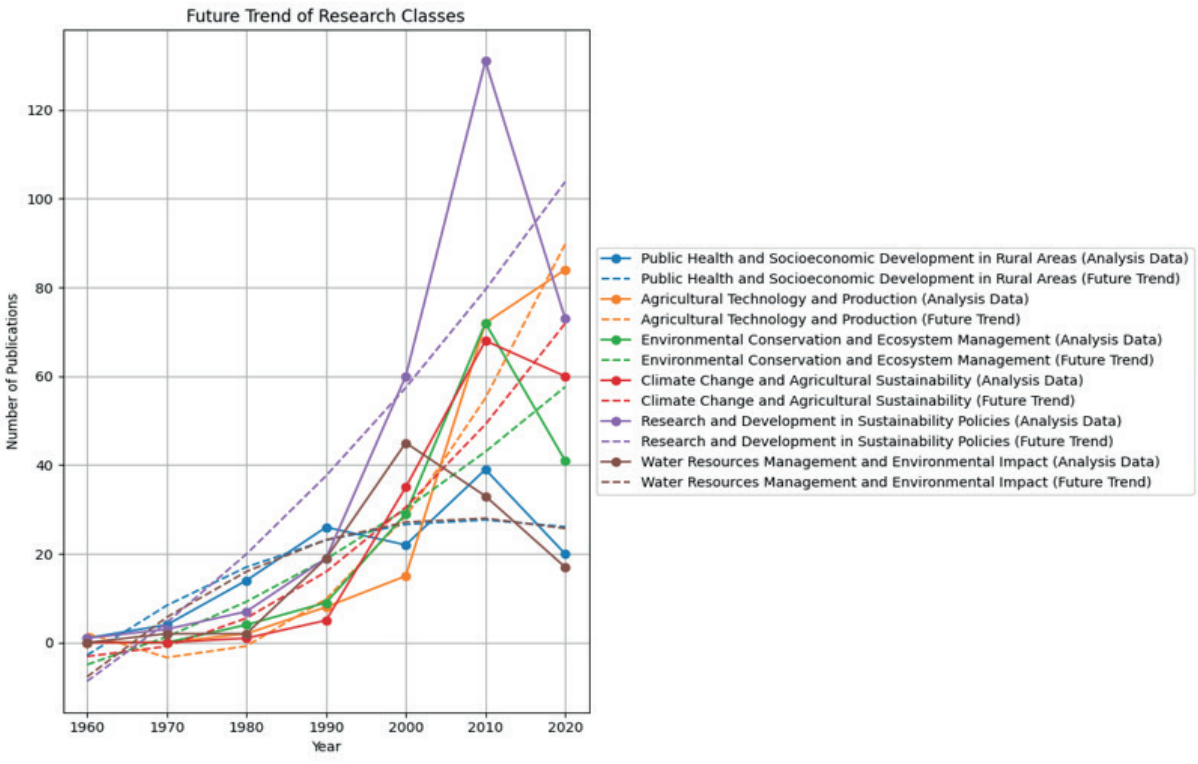

Figure 3. Trends for agricultural policy evaluation.

It can be observed that themes related to agricultural technology, climate change, and sustainability policies, which align with a mission-oriented approach (Mazzucato, 2018a), are gaining more attention. In contrast, others, such as public health in rural areas and water resources management, may be receiving relatively less focus in recent years, or, as already mentioned, are being integrated in a cross-sectional manner in policies.

Identified methodologies

Regarding the techniques employed, it was possible to automatically classify 712 publications, corresponding to 68.2% of the selected data. Among the set of 103 techniques and methodologies identified from the dictionary, 84 were effectively used in the publications. Of these, 19 are qualitative, representing 90.4% of the qualitative techniques listed in the dictionary, and 65 are quantitative, which corresponds to 79.2% of the total quantitative techniques identified. These techniques were classified into three main categories: analysis, data collection, and design. Out of the total mapped techniques, 71 were used for "analysis," eight associated with "data collection," and five with the "design" of studies or approaches (Table 5).

Table 5. Category of classified methods.

Category	Qualitative	Quantitative	Total
Analysis	12	59	71
Data Collection	6	2	8
Design	1	4	5
Total	19	65	84

In general and absolute terms, quantitative studies, environmental impact assessment (EIA), econometric analyses, risk analyses, and regressions, in a descending order, stood out in the "analysis" category. The survey was the most adopted method for "data collection," followed by case studies and interviews, respectively. For the "design," scenarios stood out, followed by the framework proposed, the design methodology approach, the sustainable livelihoods framework, and the theory of change.

Over time, the number of methodologies has expanded from 1 to 72 different methods (Table 6). Thus, it is noticeable that every 10 years there was 98% increase, on average, in the number of methods employed in the studies. Despite that, studies used up to two different methods on average. The "growth (%) (methods)" column shows the percentage increase in the number of methodologies adopted over the previous decade (Table 6).

Table 6. Amount of publications and methods by decade.

Decade	Publication	Method average	Method amount	Growth (%) (methods)
1960	2	1	2	0
1970	9	2	10	400
1980	30	1.6	11	10
1990	86	1.9	30	173
2000	206	2.1	46	53
2010	415	1.9	68	48
2020	295	2	72	6

The overall scenario that emerges (Figure 4) is of a research field that is expanding for the number of articles published (light blue), but not in the same order as the number of distinct methods used (dark blue). Therefore, the growth trend in the number of publications is not directly proportional to the growth of the number of methodologies. While the number of publications increased more than 200 times from 1960 to 2010, the number of methodologies increased about 98 times, in the same period. This may indicate that more studies are being conducted with a relatively stable set of well-established methodologies.

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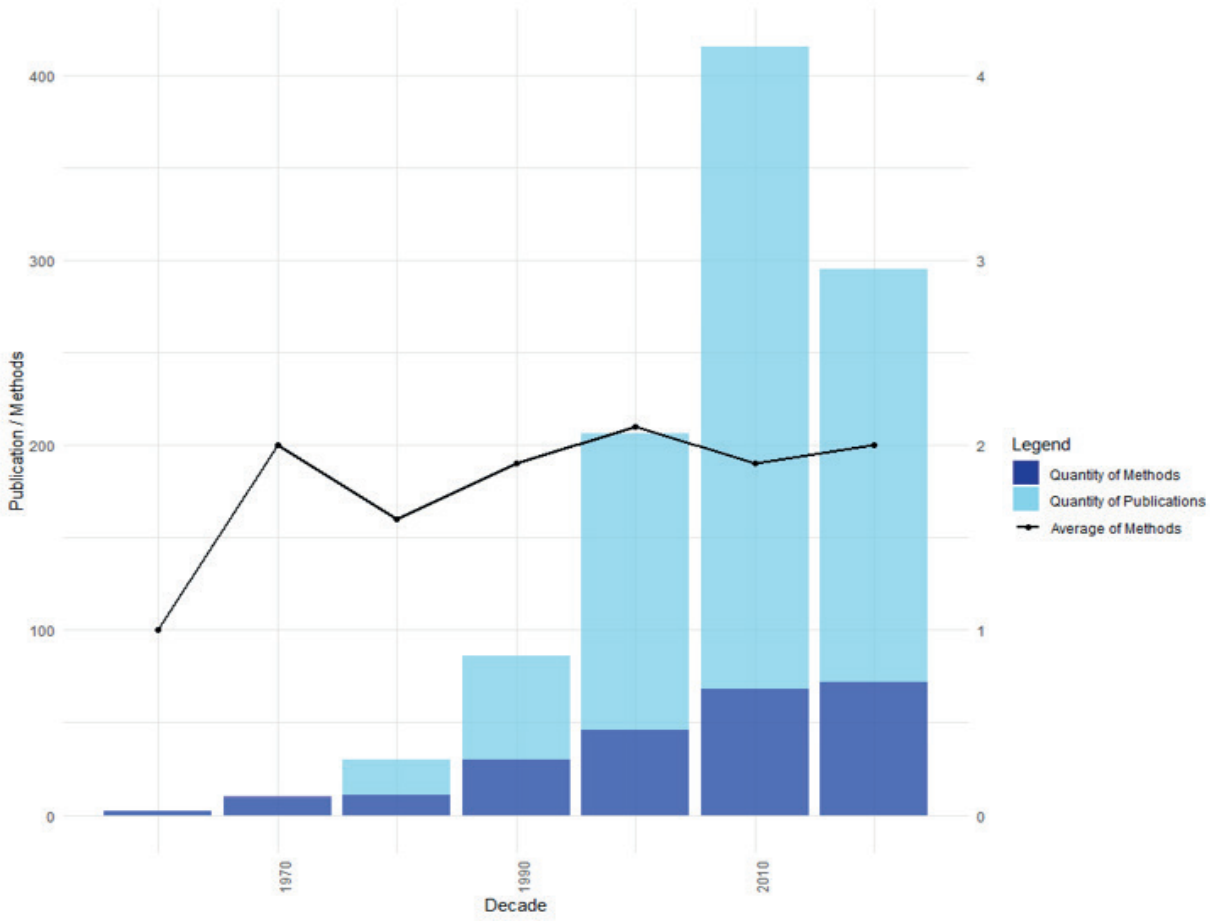

Figure 4. Comparative analysis of number of publications versus methodological diversity over decades, highlighting the average number of methods employed per decade.

The expansion of the number of published articles contrasted with the more moderate growth in the use of different methodologies, which led us to perform a more detailed analysis of the use of predominant methods in the identified thematic classes (Figure 2). Therefore, an effort was made to better understand how methodologies were applied to each topic over time (Figure 5).

This made it possible not only to observe changes in methodological preferences over time, but also to understand how these changes align with the predominant investigation topics in each period. This also helped to capture the evolution of the field of impact evaluation of agricultural public policies, reflecting both methodological innovations and changes in thematic focuses. It is essential to note that there is a distinction in the classification of topics by decade compared to topics by methods and decade. This discrepancy probably occurred because 32% of the dataset could not be classified.

Generally, the 1960s is a period with few studies and, consequently, fewer methods employed. The period is marked by a quantitative and theoretical approach, with econometric analysis and literature review appearing once each. The following decade (1970s) presents a greater diversification, with 10 methods mapped, whereas case studies lead in frequency. Econometric analysis and descriptive statistics also stand out, suggesting an orientation towards quantitative methods. In the 1980s, with 11 techniques identified, spatial analysis emerges as the most frequent methodology in analysis. As in the previous decade, case studies continued to be outstanding in the context of data collection. In the 1990s, there was a predominance of studies with mathematical and theoretical models together with environmental impact evaluations. Compared to the previous decade, there is a leap in the growth of the amount of methods used (172%).

In the 2000s, with 46 techniques mapped and a growth of 53%, in comparison with the 1990s, environmental impact evaluation and scenarios took the lead, potentially indicating an increase of

environmental consciousness and the need for planning for sustainable futures. Risk analysis also became a common methodology, suggesting a concern with the management of uncertainties in the context of agricultural activity. In the 2010s, with 68 techniques mapped, scenarios became the most frequently reported methodology. Case studies and surveys were also used, showing the valuation of empirical data collection. In the current decade (2020s), surveys emerge as the most used methodology, indicating the importance of direct data collection and feedback from participants (Delphi methodology). Regression analyses and Markov´s decision processes also appear as key methodologies, reflecting the continued emphasis on quantitative analysis and decision modeling.

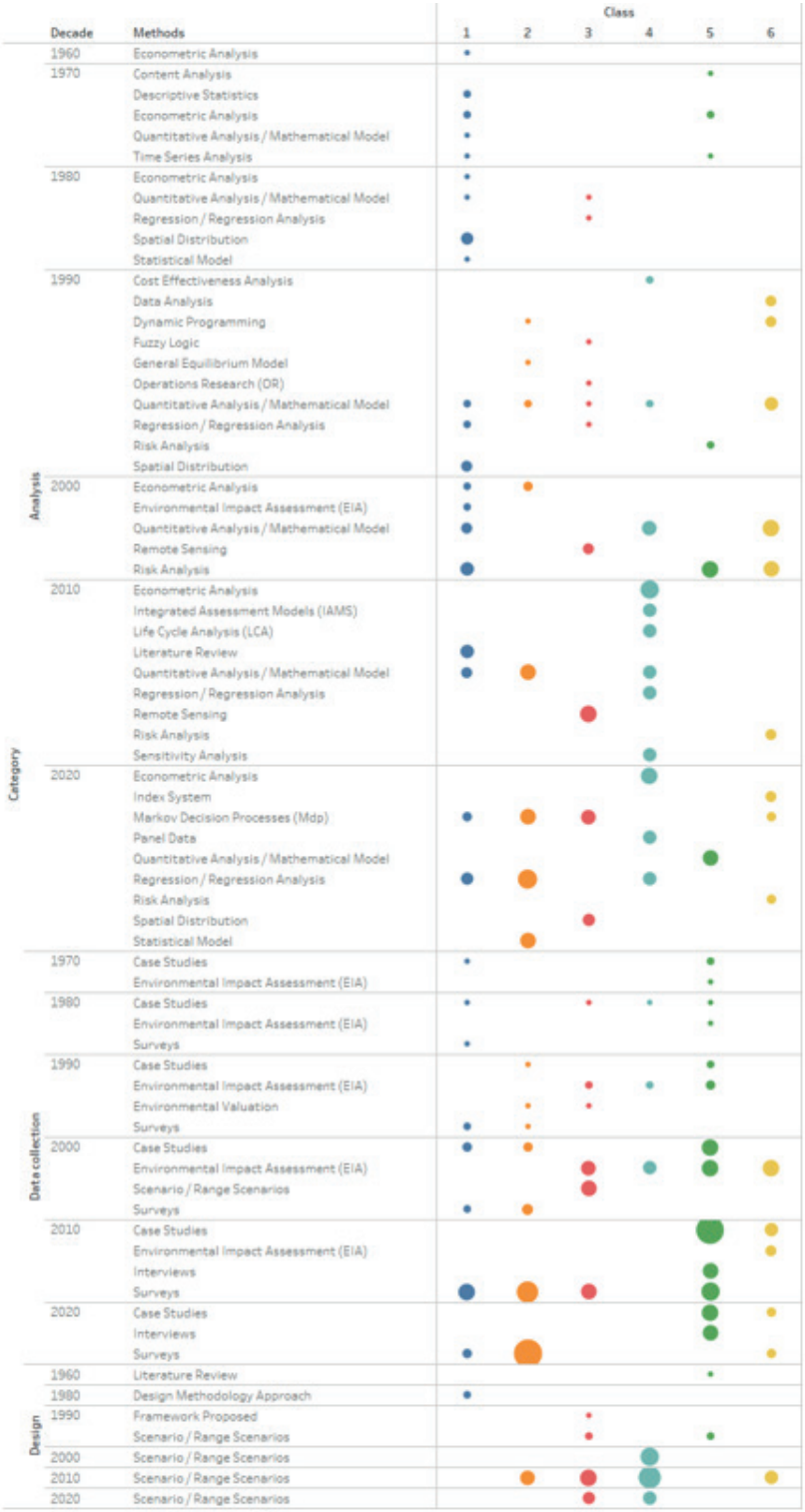

Figure 5. List of methods by thematic classes and decades.

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DISCUSSION

Sustainability themes were outstanding, intertwining with challenges such as health, rural socioeconomic development, water resource management, food security, and climate change mitigation. These interconnections suggest a holistic approach aiming to harmonize economic development with environmental preservation and social well-being, highlighting the importance of sustainability in agriculture and the need for an integrated strategy to overcome current challenges (Hunter et al., 2017; Pretty, 2018; FAO, 2022a).

The analysis showed an evolution of themes and methods over decades, reflecting shifts in research priorities and methodological advances. The frequency of analyzed bigrams suggests a gradual shift in research priorities. Initially, themes like "economic growth" and "food security" prevailed, reflecting concerns with economic development and food security. Over time, issues such as "climate change," "environmental impact," and "water resources" gained prominence, indicating environmental awareness and the need for more sustainable policies, as observed in the literature (Pingali, 2012). This evolution is corroborated and confirmed by topic modeling, synthesizing trends into six main thematic classes. Each class represents a key focus area in the evaluation of public agricultural policies, from public health issues in rural areas to water resource management and environmental impact. The growth in publications within these classes indicates an increasing interest and importance of those topics in the field.

Besides identified trends, it is important to highlight the presence, albeit limited, of studies focused on the SDGs and responses to the COVID-19 pandemic. These studies reflect the contemporary dynamics and relevance of agricultural policies in addressing global challenges. Some works explicitly addressed the SDGs (Ramirez-Rubio et al., 2019), linking the evaluation of public agricultural policies to global sustainability goals. In the context of the COVID-19 pandemic, some studies explored how governments and other initiatives supported agricultural production (Mardones et al., 2020; Dixon et al., 2021; Ojokoh et al., 2022). These investigations are crucial for understanding how global health crises impact food security and agricultural policies.

The investigation indicates a preference for well-established data analysis and collection methodologies, despite an increase of the number of techniques available over time, which suggests stability in technique application, while new methods have been gradually integrated. Interestingly, the methodological diversification does not match the magnitude of growth in the number of publications, which may reflect a consolidation of research practices in the field. Similarly, quantitative approaches overlapped qualitative ones, evidencing a trend towards methods that provide more objective and measurable analyses, facilitating comparison and generalization of results in studies of public agricultural policies. However, it is noted that qualitative approaches have been gaining ground, gradually increasing over the decades (Mertens & Wilson, 2018).

The trend of growth in themes like "climate change" and "agricultural technology and production" highlights the need for policies more focused on sustainability and technological innovation in the agricultural sector. Moreover, the integration of quantitative methods, such as regression analyses and Markov´s decision processes, with direct data collection methods like surveys, reflects a balance between quantitative and qualitative approaches that are essential for a holistic understanding of public agricultural policies.

Regarding gaps, no studies were identified that assess the impact of agricultural policies on specific crops across different socioeconomic and geographical contexts. As mentioned in the introduction of this work, there is an absence of systematic review studies specifically focused on agricultural policies. Similarly, studies evaluating and comparing various policies across different contexts were not identified, showing a gap in the application of meta-analysis methods, for instance. This subject presents opportunities for future research, such as developing new research methods, particularly in the context of data science. Advances in the field of artificial intelligence and machine learning (Ullah et al., 2020) could provide tools for large-scale data analysis, as well as deeper

insights on specific topics. The lack of global comparative analyses of agricultural policies suggests opportunity for research comparing the performance of different policies across various geographical, economic, and social contexts.

FINAL CONSIDERATIONS

The use of NLP techniques, such as tokenization and topic modeling, innovates in the analysis of published texts, enabling an automatic and efficient thematic categorization. This method showed the main themes addressed, contributing to the identification of trends in agricultural research and providing a basis for policy evaluators to anticipate future directions. The combination of bigrams and topic modeling enriched the understanding of emerging themes, while the creation of a dictionary of techniques and methods marked an advancement in impact evaluation methodologies.

However, the analysis was limited to data from Scopus and Web of Science databases, with potential limitations of the NLP techniques used, such as accuracy in identifying themes. The research was based on titles, abstracts, and keywords, suggesting that analyses of full texts could deepen the findings. Additionally, selection bias and the influence of funders on research are limitations to consider, indicating that policy evaluations may not cover all relevant or accessible studies.

In conclusion, this study highlights the evolution and importance of impact evaluations in agricultural policies, underlining the need for more comprehensive and updated evaluation methods, given the complexity of current challenges that include issues related to sustainability, agricultural technology, and climate change, from a mission-oriented perspective. Thus, it points to the necessity of adopting more integrated and holistic methodologies, capable of capturing the complexity and multiple impacts of agricultural policies, in economic, environmental, and social terms. This study is useful to researchers, evaluators, public managers, and policy makers in the field of agriculture, offering a practical toolkit for analysis and support in the planning and execution of impact evaluations of agricultural policies.

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