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# Sowing sustainability: The rise of eco-centric farming practices

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**Abstract**
This review explores the dynamic research landscape surrounding eco-centric farming practices, including regenerative, sustainable, organic, and natural farming approaches. To understand this evolving field, a systematic literature review was conducted using the Scopus database. A rigorous search strategy identified relevant articles, which were then screened and selected based on predefined inclusion and exclusion criteria. Bibliometric analysis, employing tools like Bibliometric and VOS viewer, was used to analyse publication trends, identify key contributors, and map the research landscape. Key findings include the increasing importance of interdisciplinary research, drawing upon insights from agroecology, soil science, ecology, economics, sociology, and behavioural sciences. The emergence of innovative practices such as regenerative agriculture and agroecology is evident, emphasizing the importance of working in harmony with natural systems, enhancing biodiversity, and minimizing external inputs. Furthermore, the analysis underscores the growing recognition of the crucial role of farmers in shaping the future of agriculture. Research increasingly focuses on understanding farmers' knowledge, perceptions, and decision-making processes, and the role of social networks and community engagement in promoting the adoption of sustainable practices. The analysis reveals a global research landscape with significant contributions from diverse regions, emphasizing the need for international collaboration and knowledge sharing. Addressing the challenges of climate change, food security, and environmental degradation necessitates a global perspective and collaborative efforts to develop and implement sustainable agricultural practices that are context-specific and culturally appropriate. This review underscores the dynamic and evolving nature of eco-centric farming research and emphasizes the need for continued innovation, collaboration, and support for the adoption of sustainable practices to create a more resilient, equitable, and environmentally sustainable food system for future generations.

**Keywords:** Eco-farming, scopus, food security, environmental sustainability, soil health, agroecology

## 1. Introduction
Agriculture, the backbone of human development, is undergoing a significant transformation to address pressing environmental, social, and economic challenges. The escalating global population exerts increasing pressure on agricultural systems to produce food efficiently and sustainably (Ronald, 2011) [38]. Striking a balance between sustainability, which necessitates resource conservation and intergenerational equity, and profitability, which ensures the economic viability of agricultural activities, has become a central focus in contemporary discourse, research, and policy formulation (Cavallo *et al.*, 2019) [8]. Traditional farming methods, which often rely on extensive resource use and synthetic inputs, have been linked to soil depletion, biodiversity loss, and increased greenhouse gas emissions. Conventional farming practices, despite their high yields and efficiency, have drawn criticism for their environmental impact and long-term unsustainability (Herrero *et al.*, 2015) [17]. In contrast, ecological farming, which eschews the use of synthetic pesticides, herbicides, and genetically modified organisms, advocates for a holistic approach to agriculture (Behera *et al.*, 2012, Watson *et al.*, 2008) [6, 50]. While recognized for its environmental benefits, concerns persist regarding the economic feasibility of ecological farming on a large scale. While these practices have historically ensured short-term productivity, they are proving unsustainable as global populations rise and climate-related challenges intensify. In this context, regenerative, sustainable, organic, and natural farming have emerged as innovative approaches, redefining agriculture as an environmentally harmonious and resilient system.
Society faces the urgent challenge of feeding a growing and increasingly affluent global population while safeguarding the Earth's resources (Willett *et al.*, 2019) [51]. This is highlighted by international agreements such as the EU Circular Economy Action Plan and the Paris Climate Agreement, which emphasize the need for sustainable food production within planetary boundaries. Moreover, the detrimental impacts of land degradation and climate

change pose significant threats to both food security and the well-being of farmers.

To address these challenges, a shift towards more sustainable and regenerative agricultural practices is imperative. These eco-centric farming practices represent a shift toward agriculture that integrates ecological principles and prioritizes environmental regeneration. Regenerative agriculture, is an agricultural approach that prioritizes enhancing soil health, increasing biodiversity, and building the resilience of agricultural landscapes (Newton *et al.*, 2020; Schreefel *et al.*, 2020; Ikerd, 2021; Petcu *et al.*, 2023) [30, 41, 18, 32]. This approach aims to align agricultural practices with natural ecological processes, thereby supporting farmers in adapting to environmental changes while contributing to the achievement of global sustainability goals. Regenerative farming focuses on restoring ecosystem health through improved soil quality, biodiversity enhancement, and carbon sequestration, positioning it as a key strategy for addressing climate change. Regenerative agriculture practices, such as cover cropping and no-till farming, improve soil health by rebuilding organic matter and fostering microbial diversity (Kabenomuhangi, 2024) [20]. Sustainable farming balances agricultural productivity with long-term environmental, economic, and social goals, while organic farming emphasizes the exclusion of synthetic chemicals and the use of natural inputs to promote soil fertility and ecosystem health. Natural farming, on the other hand, seeks to mimic natural processes, creating self-sustaining systems with minimal external intervention. Together, these methods present a transformative approach to food production.

The growing prominence of these practices is driven by global priorities, such as the United Nations Sustainable Development Goals (SDGs), which emphasize sustainable food production, climate action, and biodiversity conservation. Policymakers, researchers, and farming communities are increasingly recognizing the potential of eco-centric farming to tackle challenges like food insecurity, rural poverty, and climate change. Simultaneously, consumers are advocating for ethically and sustainably produced food, further propelling the adoption of these innovative farming methods.

**The Role of Research in Supporting Eco-Centric Farming**

Research plays an essential role in driving the adoption and optimization of eco-centric farming practices. Over the past two decades, academic interest in this area has expanded significantly, encompassing a wide range of topics such as soil health, carbon sequestration, biodiversity, economic viability, and policy frameworks. Advances in fields such as precision agriculture, agroecology, and sustainable technologies have also enriched this domain, providing practical solutions and new opportunities for implementation.

In this complex context, interdisciplinary research emerges as a crucial tool, providing a more comprehensive understanding by integrating diverse perspectives from natural sciences, economics, and social sciences. As the global community seeks viable solutions, alternative cultivation systems are being investigated and proposed as potential pathways forward (Marcuta *et al.*, 2021) [24].

Despite the increasing body of research, the diversity of contributions and the interdisciplinary nature of the field make it challenging to synthesize and analyze trends effectively. Bibliometric analysis offers a systematic and quantitative method to evaluate research patterns, citation impacts, and thematic developments. By mapping the research landscape, bibliometric analysis can:

- Highlight the progression of research over time.
- Identify leading contributors, including authors, institutions, and regions.
- Map collaborative networks fostering innovation in the field.
- Pinpoint influential publications and their role in advancing the discourse.
- Detect emerging trends and gaps for future exploration.

**Research questions**

This study employs bibliometric analysis to examine the research landscape surrounding regenerative, sustainable, organic, and natural farming. It aims to:

1. What are the trends in the growth of research output on regenerative, sustainable, organic, and natural farming, and how is this research distributed geographically?
2. Who are the influential authors, journals, and institutions that have significantly contributed to the advancement of eco-centric farming practices, and how have their contributions shaped the field?
3. What are the key thematic clusters and emerging research topics within regenerative, sustainable, organic, and natural farming, and how are these topics evolving over time?
4. How have key publications in regenerative, sustainable, organic, and natural farming influenced agricultural policy and practical applications at local, national, and global levels?
5. What are the existing gaps in the knowledge base regarding regenerative, sustainable, organic, and natural farming, and what future research directions should be pursued to address these gaps?

The urgency of adopting eco-centric farming practices has never been greater. Reports from the Intergovernmental Panel on Climate Change (IPCC) emphasize the importance of sustainable land use in mitigating global warming, while global initiatives such as the European Union's Farm to Fork Strategy and climate-smart agriculture programs in the United States highlight the policy alignment with these approaches. By analyzing the academic contributions to this field, this study provides a comprehensive understanding of the role of eco-centric farming in addressing contemporary challenges in agriculture.

Ultimately, this review not only sheds light on the evolution of research in regenerative, sustainable, organic, and natural farming but also offers guidance for researchers, practitioners, and policymakers to advance sustainable agricultural systems for future generations.

## 2. Materials and Methods

A Systematic Literature Review is a kind of literature review that systematically and comprehensively identifies, assesses, and synthesizes scientific research with a rigorous methodological process with the aim of addressing specific research questions (Struckell *et al.*, 2022) [44]. It is unbiased, reproducible, and reliable due to the clear and well-planned protocol adopted to consolidate the research field (Rathnayake *et al.*, 2020) [34].

### 2.1 Article search and identifications

In the present study articles used were retrieved from Scopus database. Scopus is a highly regarded article search engine recognized by experts for its extensive coverage, surpassing that of other search engines. The Scopus database encompasses records of 17 million researchers, 90 million curated documents, 80,000 institutional profiles, and 7,000 publishers. This highlights the database's broad scientific scope, making it a valuable resource for achieving the study's objectives. The process of identifying relevant research papers involves employing well-constructed search strings and precise phrases to locate articles pertinent to the current topic of interest.

A total of 825 articles were identified by using the first search equation with terms "Regenerative Agriculture" AND "Farmers", "Regenerative Agriculture" AND "Extension" and "Sustainable Agriculture" AND "Extension" (Table 1). The second search equation combined terms like "Regenerative Agriculture" AND "Impact" AND "Farmers", "Natural Farming" AND "Impact" AND "Farmers" and "Organic Farming" AND "Impact" AND "Farmers" resulting in 719 potential articles (Table 2). The third search equation combined terms like "Regenerative Agriculture" AND "Farmers" AND "Agricultural Extension", "Natural Farming" AND "Farmers" AND "Agricultural Extension", "Organic Farming" AND "Farmers" AND "Agricultural Extension", "Natural farming" AND "Farmers" AND "Extension Services" and "Organic farming" AND "Farmers" AND "Extension Services" with the help of Boolean operators, yielded 104 results from the Scopus database (Table 3). Another search equation combined terms like "Regenerative Agriculture" AND "Farmer" AND "Productivity" and "Natural Farming" AND "Farmer" AND "Productivity" yielded 36 articles (Table 4).

From the four search equations, a total of 1684 articles were identified in the initial search and a total of 1127 articles were excluded based on the inclusion and exclusion criteria. The inclusion criteria combine with the year from 2000 to 2024, subjects including Agricultural and Biological Sciences, Environmental Science, Social Sciences, Economics, Econometrics and Finance, Business, Management and Accounting, Multidisciplinary, Earth and Planetary Sciences. It includes only articles from journals in English. The articles with open access and fully published were only selected. From 1684 articles, with the above-mentioned inclusion criteria 557 articles were taken for the further step.

**Table 1:** First search equation

| Terms used | Initial results | Results after exclusion |
|---|---|---|
| "Regenerative Agriculture" AND "Farmers" | 138 | 69 |
| "Regenerative Agriculture" AND "Extension" | 09 | 06 |
| "Sustainable Agriculture" AND "Extension" | 678 | 184 |
| Total | 825 | 259 |

**Table 2:** Second search equation

| Terms used | Initial results | Results after exclusion |
|---|---|---|
| "Regenerative Agriculture" AND "Impact" AND "Farmers" | 34 | 16 |
| "Natural Farming" AND "Impact" AND "Farmers" | 17 | 06 |
| "Organic Farming" AND "Impact" AND "Farmers" | 668 | 223 |
| Total | 719 | 245 |

**Table 3:** Third search equation

| Terms used | Initial results | Results after exclusion |
|---|---|---|
| "Regenerative Agriculture" AND "Farmers" AND "Agricultural Extension" | 01 | 01 |
| "Natural Farming" AND "Farmers" AND "Agricultural Extension" | 02 | 02 |
| "Organic Farming" AND "Farmers" AND "Agricultural Extension" | 37 | 12 |
| "Natural farming" AND "Farmers" AND "Extension Services" | 03 | 03 |
| "Organic farming" AND "Farmers" AND "Extension Services" | 61 | 19 |
| Total | 104 | 37 |

**Table 4:** Fourth search equation

| Terms used | Initial results | Results after exclusion |
|---|---|---|
| "Regenerative Agriculture" AND "Farmer" AND "Productivity" | 21 | 09 |
| "Natural Farming" AND "Farmer" AND "Productivity" | 15 | 07 |
| Total | 36 | 16 |

From these 557 articles, they were further screened and 39 duplicates were excluded. Now from these 518 articles, 223 articles were excluded after going through the titles and abstract. Finally, 285 articles with relevant titles and abstract were included for the further analysis. This was diagrammatically shown in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram which is a visual representation of the stages of a systematic review or meta-analysis (Fig 1).

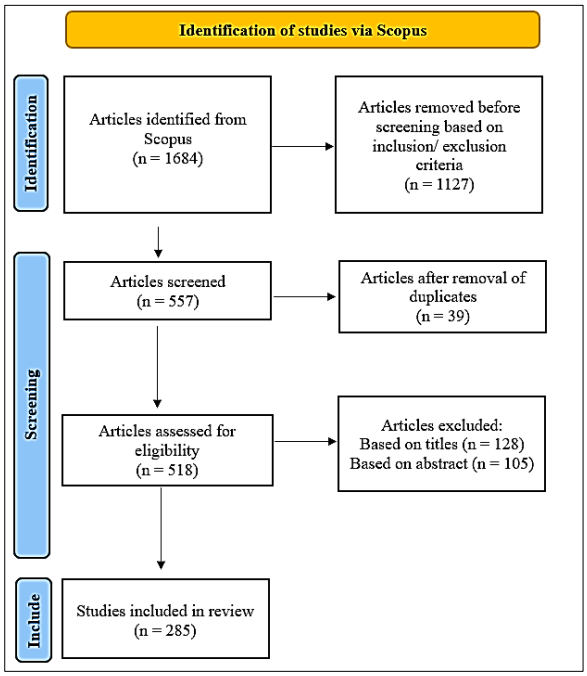


**Fig 1:** PRISMA flow diagram for the systematic review

### 2.2 Analysis of search results

The value of a systematic review in research largely relies on the application of rigorous methodologies, clear reporting, and scientific strategies to minimize potential errors and biases (Moher *et al.*, 2019; Linnenluecke *et al.*, 2019) [25, 23]. In this study, the systematic literature review process was

effectively supplemented with bibliometric analysis, descriptive statistics, and visual charts to derive meaningful insights on the topic under consideration. Scholars have long contended that a comprehensive review combined with bibliometric analysis can establish robust foundations for advancing a field in innovative and impactful ways (Donthu *et al.*, 2021) [12]. Such an approach enables researchers to (a) gain a comprehensive overview of the field, (b) identify knowledge gaps, (c) generate new research ideas, and (d) strategically position their contributions to the domain.

To address the research questions and test the hypotheses, we utilized a combination of R-Package Bibliometrix and VOSviewer software, both of which are widely recognized as powerful tools among scholars (Donthu *et al.*, 2021; Linnenluecke *et al*., 2019) [12, 23]. Bibliometrix provides interactive analysis through web applications and features a user-friendly interface built on Shiny under the R-package framework, which can be accessed via RStudio without requiring coding expertise (Aria and Cucurullo, 2017) [4]. Similarly, VOSviewer offers diverse functionalities for conducting performance analysis, science mapping, and network analysis (Donthu *et al.*, 2021; Van Eck and Waltman, 2010) [12, 48].

## 3. Results and Discussion

The dataset shown in Table 5 spans from 2001 to 2024, with a total of 285 documents sourced from 147 different journals, books, and other publications. The annual growth rate of the research is impressive, at nearly 19 per cent, showing increasing interest in the topic. On average, the documents are quite recent, with an average age of 3.56 years, and are cited an average of 16.75 times each, reflecting a moderate impact in the academic community. The total number of references cited across all documents is 15,695, indicating the breadth and depth of the research.

There are 1,113 unique authors contributing to these documents, but only 19 of the articles are single-authored, emphasizing the collaborative nature of the research. On average, there are 4.44 co-authors per document, and around 33.70 per cent of the research involves international collaboration, showing the global nature of the research. All the documents in this dataset are articles, further indicating a focus on journal publications (Table 5). Overall, the data highlights a growing, collaborative, and internationally connected field with a substantial academic impact.

**Table 5**: Key bibliometric details about research

| Description | Results |
|---|---|
| **Main information about data** | |
| Timespan | 2001:2024 |
| Sources (Journals, Books, etc) | 147 |
| Documents | 285 |
| Annual Growth Rate per cent | 18.94 |
| Document Average Age | 3.56 |
| Average citations per doc | 16.75 |
| References | 15695 |
| Document contents | |
| Keywords Plus (ID) | 1033 |
| Author's Keywords (DE) | 1022 |
| AUTHORS | |
| Authors | 1113 |
| Authors of single-authored docs | 19 |
| **Authors collaboration** | |
| Single-authored docs | 19 |
| Co-Authors per Doc | 4.44 |
| International co-authorships per cent | 33.70 |
| **Document types** | |
| Article | 285 |

### 3.1 Most relevant sources

Figure 2 presents the data on most relevant sources of articles. The distribution of articles across journals highlights the diverse yet focused nature of research within the realm of sustainability and agriculture. Sustainability (Switzerland) emerges as the most influential source, with 34 articles, highlighting its central role in sharing research on diverse sustainability topics. Its prominence reflects its wide appeal to researchers and its broad thematic coverage. Frontiers in Sustainable Food Systems follows with 12 articles, and Agriculture (Switzerland) contributes 10, showcasing a strong emphasis on sustainable agricultural practices and food systems in these publications.

Journals like Agronomy (8 articles), Journal of Environmental Management (6 articles), and Land (6 articles) demonstrate the interdisciplinary approach of this field, blending research from agronomy, environmental sciences, and land-use studies. Contributions from the South African Journal of Agricultural Extension (6 articles) underscore the importance of regional insights and practical implementations in agricultural sustainability. Additionally, journals such as Agricultural Systems and the International Journal of Agricultural Sustainability, each with 5 articles, focus on systemic and targeted approaches to sustainability. Meanwhile, Agriculture, Ecosystems, and Environment (4 articles) emphasizes the critical relationship between agriculture and ecosystems.

This dataset highlights the diverse and interdisciplinary nature of sustainability research. Journals like Sustainability (Switzerland) play a crucial role in advancing global discussions, while other publications bring localized and specialized perspectives. This diversity ensures comprehensive coverage, fostering collaboration and innovation across various aspects of sustainable agriculture and food systems. The variety of contributions underscores the importance of combining global strategies with localized approaches to address the complex challenges of sustainability effectively (Rodríguez-Espíndola *et al.*, 2022) [37].

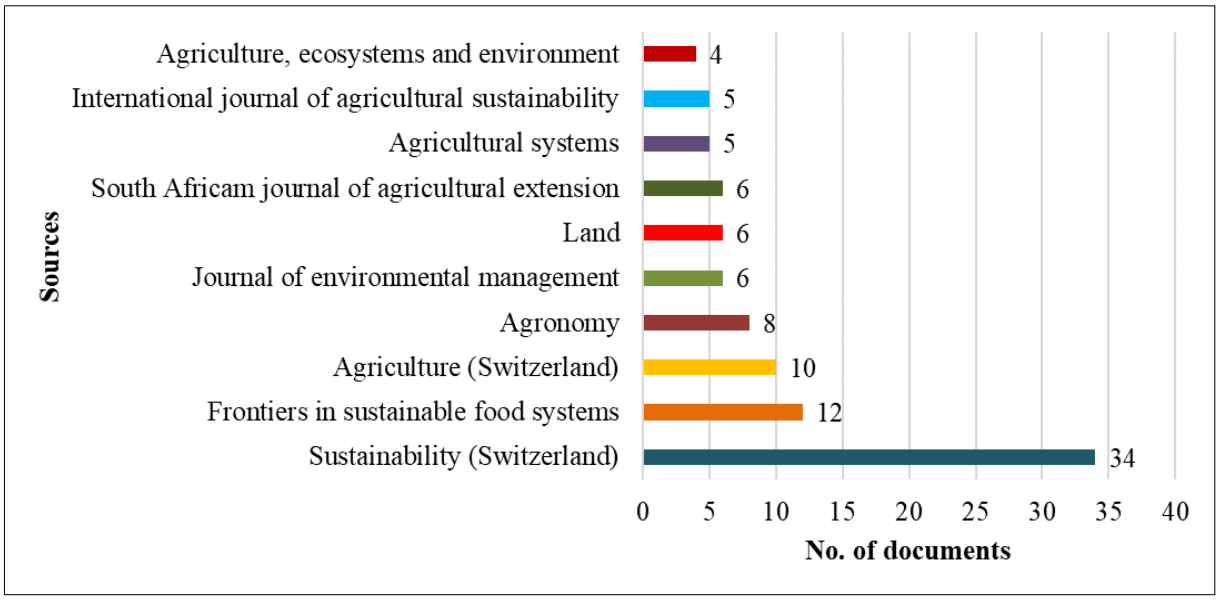


**Fig 2:** Most relevant sources

### 3.2 Annual scientific production

Figure 3 presents the data on annual scientific production of articles. The yearly distribution of articles from 2001 to 2024 shows a significant growth trajectory in research activity within this domain. During the initial phase (2001-2007), only five articles were published over seven years, indicating limited attention to the topic. However, a gradual increase begins in 2008, with three articles, and continues steadily through 2016, reflecting an emerging interest in the field.

A substantial increase in publication volume is observed after 2017, signalling a shift towards heightened scholarly focus. The number of articles rises from 8 in 2017 to 16 in 2018 and reaches 23 by 2020. The years 2021 and 2022 show remarkable growth, with 32 and 53 articles published, respectively. The peak is observed in 2024, with 54 articles, closely followed by 45 articles in 2023, underscoring the increasing relevance of this research area.

This pattern illustrates the field's evolution from a niche area to a dynamic and widely recognized subject of inquiry. The significant rise in publications post-2017 can be linked to the growing global focus on issues like climate change, food security, and sustainable development, which have spurred greater interest and funding in sustainability research (Filho *et al.*, 2023) [13]. The exponential growth in recent years points to an expanding community of researchers, enhanced international collaboration, and the increasing importance of sustainability practices.

Overall, the data highlights the rapid expansion and growing significance of this research area. The consistent rise in publication numbers, especially after 2020, signifies an active and evolving field. This trend emphasizes the necessity of continued support and investment in this research to address critical global challenges and contribute to the advancement of sustainable development goals (Sarpong *et al.*, 2023) [39].

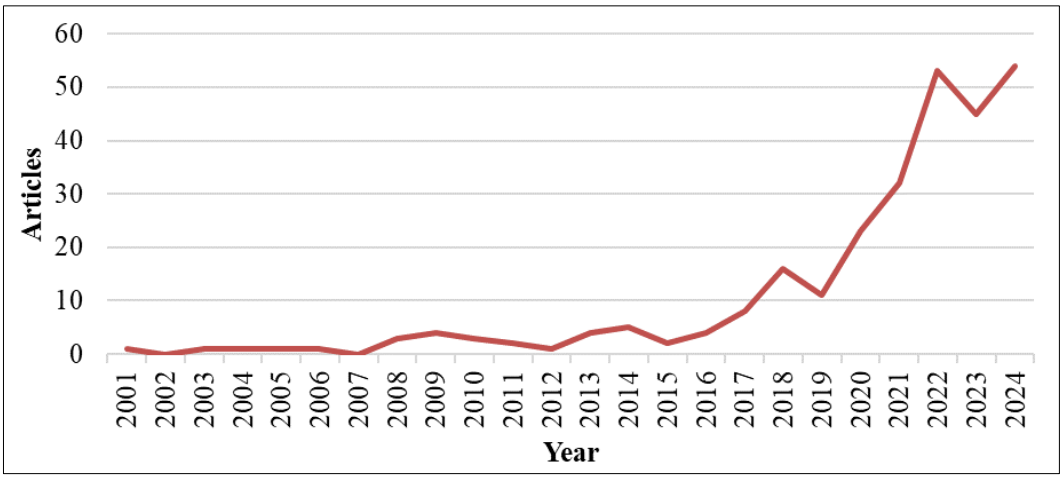


**Fig 3:** Annual scientific production

### 3.3 Most relevant words

Figure 4 represents the occurrence of most relevant words in the articles. The analysis of word occurrences highlights key thematic focuses within the research domain. The term “Organic farming” emerges as the most frequently mentioned, with 63 occurrences, underscoring its centrality in discussions about sustainable practices and eco-centric farming. This prominence indicates the widespread interest and significance of organic farming as a cornerstone of sustainable agricultural systems.

"Agriculture" ranks second with 48 occurrences, reflecting the broad scope of research that spans various farming methods, technologies, and practices. "Alternative agriculture", with 41 mentions, points to growing interest in innovative and non-conventional farming approaches, emphasizing diversity in agricultural strategies.

"Climate change", appearing 27 times, signifies the critical intersection of agricultural practices with environmental sustainability, highlighting the urgency of addressing climate-related challenges through adaptive farming practices. Similarly, "Sustainability" (25 occurrences) reinforces the overarching goal of achieving balance between agricultural productivity and environmental health.

The terms "Article" and "Sustainable agriculture", each mentioned 20 times, reflect the dual focus on scholarly output and the importance of sustainable practices in farming. "Agricultural worker" and "Farming system", both with 19 mentions, emphasize the human and systemic aspects of agriculture, suggesting a holistic approach to understanding agricultural ecosystems. Finally, "Soil", with 18 mentions, underscores the foundational role of soil health in sustainable farming practices.

This data reveals a cohesive narrative within the research domain, centered on sustainable agricultural practices, climate resilience, and the integration of innovative farming systems (Chao, 2024) [9]. The frequent mention of terms like "organic farming", "alternative agriculture", and "sustainable agriculture" suggests a strong emphasis on transitioning towards eco-centric and environmentally friendly farming practices.

Overall, the data reflects the evolving priorities within agriculture research, focusing on organic and alternative practices while addressing broader challenges like climate change and sustainability (Ortiz *et al.*, 2021) [31]. These themes collectively highlight the critical need for continued innovation and collaboration to ensure resilient and sustainable agricultural systems for the future.

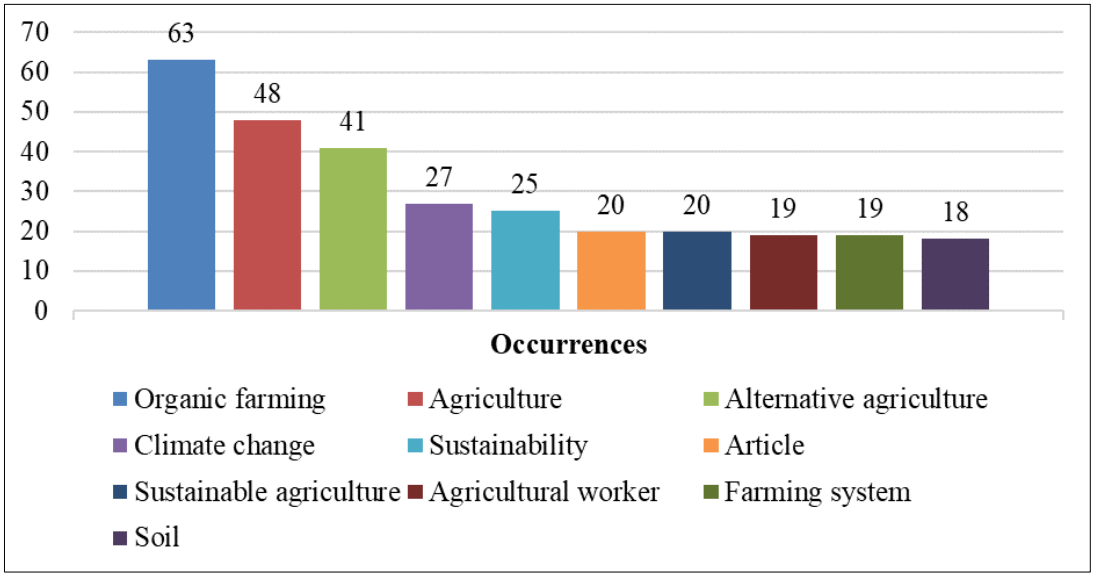


**Fig 4:** Most relevant words

### 3.4 Most global cited documents

Figure 5 shows the most global cited documents. The analysis of the most cited papers reveals significant insights into influential works within the field. Mondelaers *et al.* (2009) [26], published in the *British Food Journal*, leads in total citations with 299, averaging 18.69 citations annually and a normalized citation score of 2.76. This high citation count highlights its substantial influence on the field, reflecting its ongoing relevance and recognition.

The paper by DeLonge *et al.* (2016) [11] in *Environmental Science & Policy* ranks second with 218 total citations, an impressive average of 24.22 citations per year, and a normalized citation count of 3.21. Similarly, LaCanne and Lundgren (2018) [22], published in *PeerJ*, has 203 total citations, with the highest annual citation rate of 29.00 and a strong normalized score of 4.47, demonstrating significant scholarly impact in a short span.

Gosnell *et al.* (2019) [15], published in *Global Environmental Change*, has 163 citations with an annual citation rate of 27.17 and the highest normalized citation count of 4.76, indicating a considerable impact on current research in the field. Other important contributions include De Luca *et al.* (2018) [10] in *Journal of Cleaner Production* (116 citations, 16.57 per year) and Siebrecht (2020) [43] in *Sustainability* (97 citations, 19.40 per year, with the highest normalized citation count of 5.55), emphasizing the growing focus on sustainability and environmental issues.

Additional influential studies include Kaufmann *et al.* (2009) [21] in *Ecological Economics* (104 citations, 6.50 per year) and Ndambi *et al.* (2019) [29] in *Frontiers in Sustainable Food Systems* (96 citations, 16.00 per year). Murgai *et al.* (2001) [28] in *The World Bank Research Observer* with 99 total citations and an annual citation rate of 4.13, appears to have had a more lasting, rather than recent, impact. Similarly, Serra *et al.* (2008) [42] in *Agricultural Economics* has 84 citations, indicating steady relevance within agricultural economic studies.

These results highlight a mix of long-established and recent studies that have shaped the field. The works with high annual and normalized citations, such as those by LaCanne, Gosnell, and Siebrecht, reflect growing areas of research interest. In contrast, influential studies like those by Mondelaers and Kaufmann demonstrate enduring contributions to the academic discourse over time.

Overall, this analysis emphasizes the value of both groundbreaking and foundational research in advancing sustainability and agricultural practices. The combination of ongoing contributions and emerging studies is key to the continued progress and development of the field.

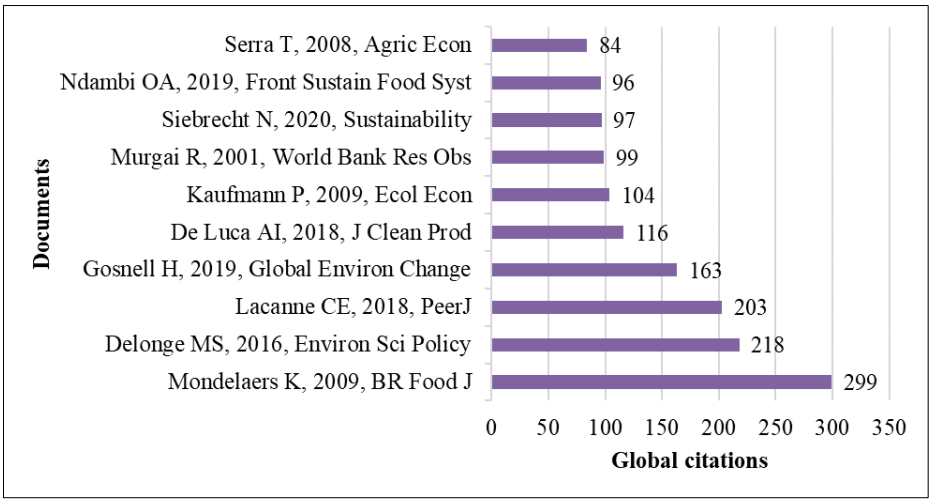


**Fig 5:** Most global cited documents

### 3.5 Most relevant authors

The analysis of author contributions reveals important patterns regarding their publication output and fractionalized contributions. De Vente J leads with five articles, holding the highest fractionalized score of 1.42, which suggests that this author has contributed significantly to multiple papers and possibly collaborated on various research topics within the field.

Following closely, Alotaibi BA, Azadi H, Hamzah A, Khwidzhili RH, and Tiraieyari N each have four articles, but their fractionalized scores differ. Khwidzhili RH stands out with a fractionalized score of 2.00, the highest among the authors, indicating substantial contributions to highly collaborative research projects or possibly involvement in multi-author studies where the individual's contribution is split among various papers. On the other hand, Alotaibi BA and Tiraieyari N both have fractionalized scores of 0.98 and 1.08 respectively, indicating moderate but consistent contributions to their published work.

Allahyari MS, Chen X, Cuéllar Padilla M, and Kassem HS all have three articles, with fractionalized scores ranging from 0.56 to 1.40. These authors show varied contributions, with Chen X having the lowest fractionalized score of 0.56, which could suggest a more singular role in the studies they participated in, compared to others like Allahyari MS with a score of 1.40, suggesting a broader involvement in multiple collaborative research efforts.

The data highlights that authors with higher fractionalized scores likely played more diverse or integral roles in several papers, indicating a higher level of collaboration or multi-disciplinary contributions. Authors with lower fractionalized scores may have had more focused contributions, either as single authors or within a smaller scope of collaboration.

Overall, the analysis reflects the varied degrees of collaboration and contribution among authors in this field, showing how involvement in multi-author studies influences the fractionalized impact of individual contributions (Razzaq *et al.*, 2022) [35]. This emphasizes the dynamic nature of academic research, where some authors contribute to multiple papers, while others focus their efforts on specific, impactful works.

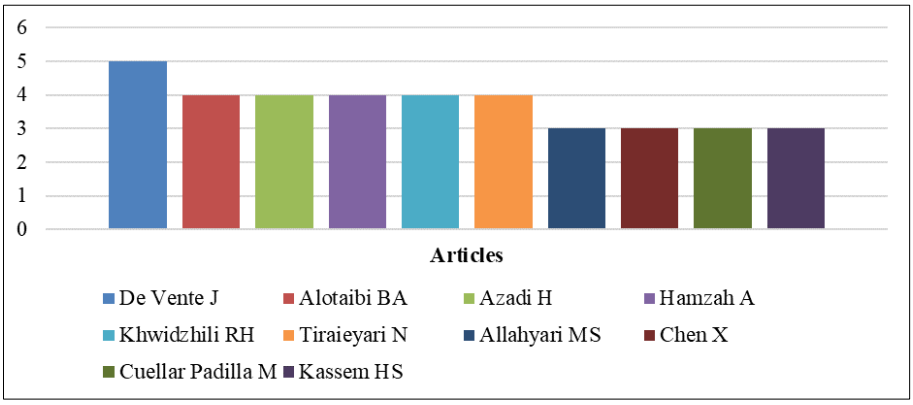


**Fig 6:** Most relevant authors

### 3.6 Country scientific production

Figure 7 highlights the countries with the greatest number of publications. The data on the number of publications by country reveals a global distribution of research activity in the field, with the USA leading the way with 163 publications. This substantial output indicates the USA's dominant role in

driving research and scholarly activity related to the topic, reflecting its advanced infrastructure for academic research and its significant investment in environmental and agricultural studies.

India follows closely with 117 publications, showcasing its growing contribution to global research, particularly in the context of sustainability, agriculture, and eco-centric farming practices. India's strong research output is indicative of the increasing focus on these areas, supported by government and institutional initiatives to enhance agricultural sustainability.

China comes next with 65 publications, demonstrating a solid presence in research related to environmental sustainability and agricultural systems. Despite having a large population and considerable agricultural influence, China's research output in this specific domain is less than that of India or the USA, which may point to different priorities or the evolving nature of its academic contributions in this area.

The UK, with 60 publications, reflects a consistent output, underpinned by its rich tradition of research in environmental sciences and agriculture. Indonesia, contributing 49 publications, shows regional engagement, particularly in the context of Southeast Asia's agricultural practices and sustainability challenges.

The Netherlands (44 publications) and Germany (41 publications) indicate strong research communities in Europe, with a particular focus on sustainable agricultural practices and environmental management. These countries often lead in agricultural innovation and are actively involved in international collaborations that address global sustainability challenges.

Australia (34 publications), Pakistan (33 publications), and Switzerland (33 publications) demonstrate notable contributions, though at a slightly lower level. Australia's research reflects its significant agricultural sector, which faces unique challenges such as climate change, while Pakistan's output is indicative of its ongoing development in sustainable farming practices. Switzerland, known for its environmental policy leadership, contributes valuable research in this field, particularly on topics like sustainable development and ecological conservation.

The distribution of publications by country illustrates the global nature of research on sustainability and agriculture, with strong contributions from North America, Asia, and Europe. Countries like the USA and India play a pivotal role in advancing research, while others like China, the UK, and Indonesia are contributing to the discourse in significant ways. This diverse global output highlights the international collaboration needed to address the shared challenges in sustainability, climate change, and agricultural practices. The varying publication volumes reflect the unique research priorities and capacities of each country, with developed nations leading the research agenda and emerging economies making increasing contributions to the global knowledge base (Velenturf and Purnell, 2021) [49].

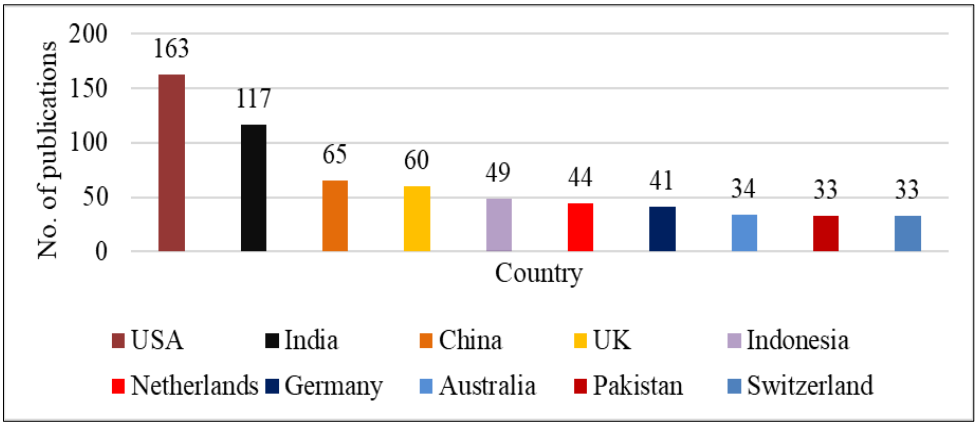


**Fig 7:** Country scientific production

### 3.7 Thematic map

The thematic map offers a comprehensive view of the research landscape by categorizing topics based on their level of development (density) and relevance (centrality). Divided into four quadrants: Motor Themes, Basic Themes, Niche Themes, and Emerging or Declining Themes (Figure 8). The map provides a clear depiction of the interconnectedness and maturity of various research areas.

1. **Motor Themes (Upper-right Quadrant, strong centrality and high density):** Motor Themes, such as "agriculture", "article", and "sustainable agriculture" are the most advanced and influential topics in the research landscape. These themes drive agricultural sustainability forward, reflecting well-established studies with practical applications. Their high density demonstrates significant advancements, while their centrality highlights their pivotal role in addressing critical issues like food security and climate change. As mature research domains, these themes shape the field and serve as essential focal points for future innovation, offering opportunities to develop groundbreaking solutions rooted in robust theoretical and practical foundations.
2. **Basic Themes (Lower-right Quadrant, low centrality, high density):** Basic Themes, including "organic farming", "alternative agriculture", and "sustainability" are highly relevant yet less developed. These topics lay the groundwork for eco-centric and sustainable farming methods, emphasizing environmentally conscious and resource-efficient approaches. Although their lower density suggests room for further investigation, they provide a strong base for advancing sustainable agriculture. By refining these themes and integrating them into broader research efforts, scholars can enhance their theoretical foundations and contribute significantly to sustainable farming practices (Alonso-Martínez *et al.*, 2024) [2].
3. **Niche Themes (Upper-left Quadrant, high centrality, low density):** Niche Themes, such as "agricultural

management", "carbon sequestration" and "maize" represent specialized areas of research that are highly developed but less central to the broader sustainability discourse. These themes focus on specific aspects of agriculture, such as reducing carbon emissions and improving crop-specific strategies. Their advanced development showcases notable achievements; however, their lower centrality indicates limited connection to the broader research landscape. Strengthening the integration of these specialized topics into more central themes could boost their relevance and impact, such as by linking carbon sequestration strategies to sustainable agricultural practices for a more comprehensive approach to climate challenges (Jat *et al.*, 2022) [19].

4. **Emerging or Declining Themes (Lower-left Quadrant, low density and low centrality):** Emerging or Declining Themes, such as "risk assessment", "Thailand" and "environmental impact assessment" exhibit low levels of development and relevance. These topics may represent either nascent research areas or fields that are losing prominence. Despite their lower metrics, they hold potential for growth, particularly "environmental impact assessment" which is critical for evaluating the sustainability of agricultural practices. Regional studies, like those focusing on "Thailand" also offer valuable insights into localized agricultural systems. Researchers should assess whether these themes warrant renewed attention or whether focus should shift to more promising areas, as they could still address important future challenges.

This analysis highlights the varying roles and development stages of the themes, providing a roadmap for targeted research efforts to drive progress in eco-centric and sustainable farming practices (Xu *et al.*, 2024) [53].

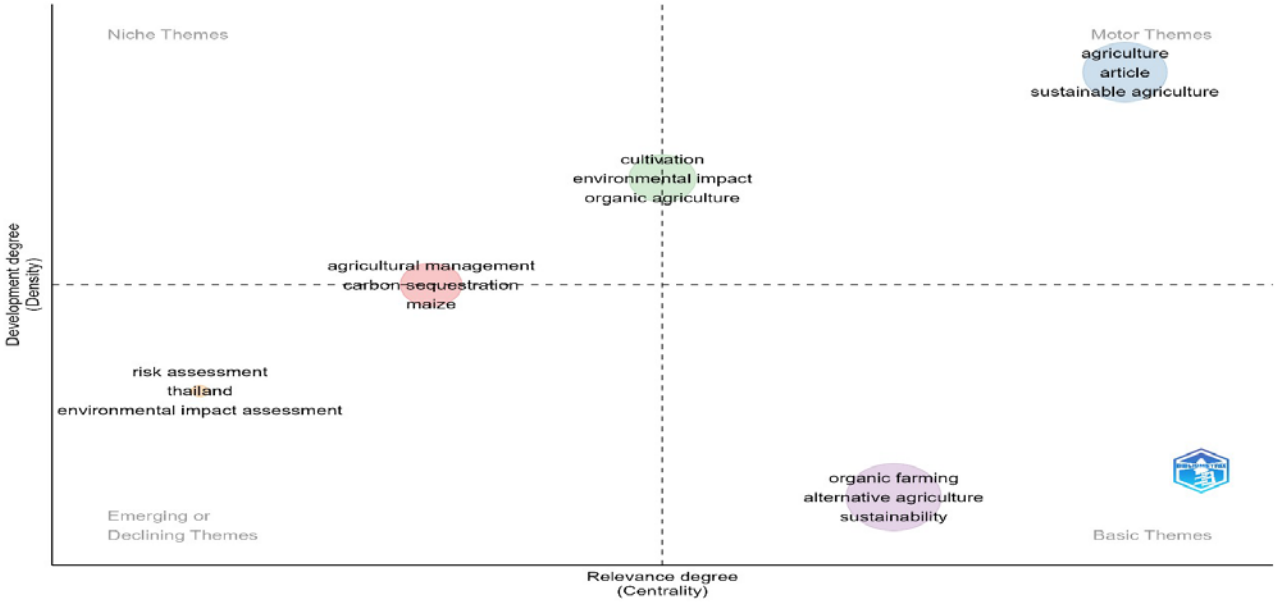


**Fig 8:** Thematic map

### 3.8 Trend topics

Figure 9 illustrates the evolving trends in topics related to eco-centric farming practices and sustainability in agriculture over the years. Larger node sizes indicate a higher concentration of publications on specific topics (Arthur *et al.*, 2024) [5]. Prominent themes such as "carbon sequestration," "climate change," "sustainable agriculture," and "organic farming" have shown significant growth in frequency, highlighting their increasing importance in addressing global environmental issues. This trend reflects a growing focus on integrating sustainability and environmental priorities into agricultural practices, influenced by international efforts such as the Paris Agreement and the Sustainable Development Goals.

The consistent rise of topics like "soil carbon," "agroforestry," and "sustainability" emphasizes their foundational role in advancing sustainable agricultural systems. Similarly, emerging themes such as "ecosystem services," "food security," and "biodiversity" point to a heightened awareness of the interconnectedness between agriculture, ecological balance, and human well-being. These trends signify a broader perspective in agricultural research that encompasses not only productivity but also ecological and social sustainability.

Conversely, earlier topics such as "conservation of natural resources" and "Europe" have shown relatively limited growth in recent years. This could indicate a shift in research focus or terminology, or a decreased emphasis on these areas as they become integrated into broader sustainability frameworks.

Overall, the trend topics demonstrate a dynamic and interdisciplinary research landscape. While established themes continue to drive advancements, emerging topics present fresh opportunities for exploration. The growing focus on carbon management, ecological health, and food security highlights a forward-thinking approach to addressing critical challenges related to climate change and sustainability (Anandita *et al.*, 2024) [3]. These insights provide valuable guidance for shaping future research, policies, and practical strategies in sustainable agriculture.

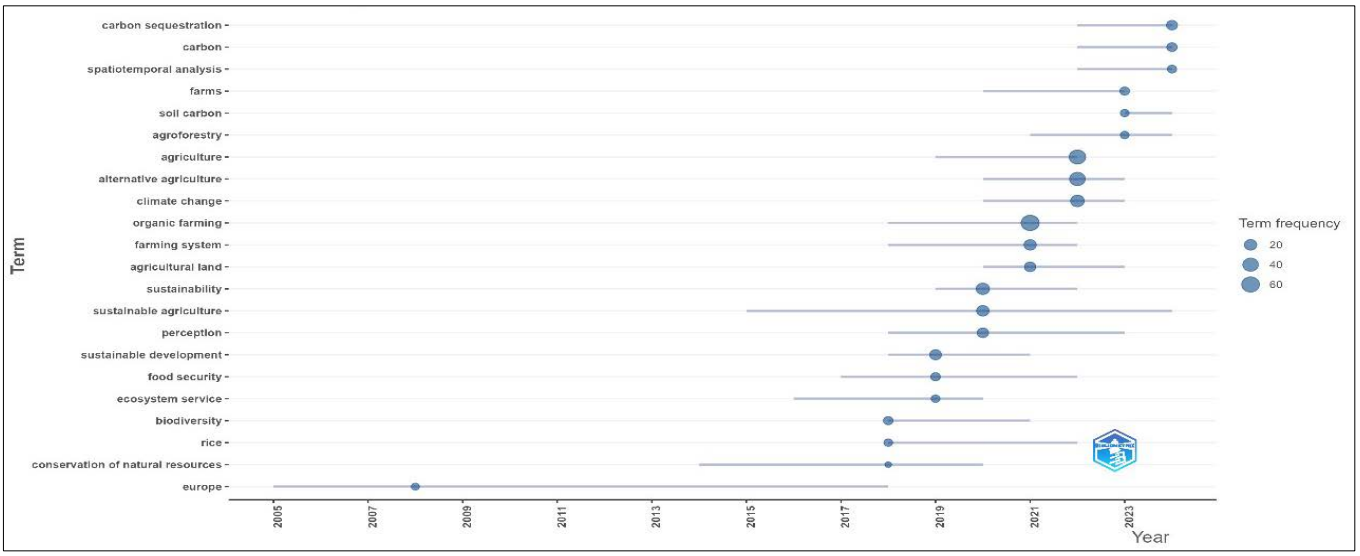


**Fig 9:** Trend topics

### 3.9 Co-occurrences of keywords

#### 3.9.1 Word clouding

The word clouding provides a clearer understanding of the subject based on the available articles (Arthur *et al.*, 2024) [5]. Fig. 10 offers insight into the development of articles on this topic. The size of the keywords indicates their frequency in the curated documents analyzed. This world cloud gives a comprehensive view of key themes in agricultural sustainability and eco-centric farming practices. Prominent terms like “organic farming”, “alternative agriculture”, “sustainability”, and “agriculture” highlight their central role in sustainable agricultural research. These concepts reflect the shift from conventional to environmentally-friendly farming practices that aim to balance productivity, ecological health, and economic viability.

The terms “climate change” and “carbon sequestration” emphasize agriculture’s critical role in addressing climate-related issues. These terms underscore the sector's dual impact: contributing to and mitigating greenhouse gas emissions, thus forming a key focus for sustainable strategies. Similarly, “soil carbon” and “agroforestry” stress the importance of soil health and agroecological practices, which are essential for long-term sustainability.

Additional terms such as “farming system”, “agricultural land”, “sustainable agriculture” and “sustainable development” represent the integration of sustainability into both policy and practice. These terms point to a comprehensive approach to land use, resource efficiency, and agricultural planning. “Food security” and “ecosystem service” further reflect the interconnected goals of meeting human needs while preserving ecological integrity (Richardson, 2010) [36].

Socially-oriented terms like “perception”, “agricultural worker”, “farmers' attitudes” and “decision-making” highlight the growing focus on the role of farmers and stakeholders in shaping sustainable agriculture. These terms suggest that effective implementation of sustainable practices depends on understanding the perspectives and behaviours of those directly involved in farming (Muhie, 2022) [27].

Emerging themes like “biodiversity”, “crop production”, “fertilizer application”, “smallholder” and “agricultural management” point to evolving areas of research. Biodiversity and crop production emphasize the need for resilient farming systems that sustain both human and environmental health (Gamage *et al.*, 2023) [14]. At the same time, terms like “nitrogen” and “fertilizer application” highlight ongoing concerns about optimizing nutrient use and reducing environmental harm.

Regional and thematic terms such as “China”, “India”, “United States”, “spatiotemporal analysis” and “policy-making” reflect global and localized efforts to understand and promote sustainability. These terms stress the need for region-specific strategies, backed by advanced analytical methods, to address diverse agricultural and environmental challenges.

In summary, the word clouding reveals the broad range of topics in agricultural sustainability research. Established themes like organic farming and climate change continue to dominate, while emerging topics like biodiversity and smallholder practices present new opportunities for further study. Addressing these themes together will foster the development of innovative, sustainable, and inclusive agricultural systems that address global challenges and contribute to the achievement of the Sustainable Development Goals (Çakmakçı *et al.*, 2023) [7].


**Fig 10:** Word clouding

#### 3.9.2 Keyword mapping

The keyword map generated using VOSviewer offers an insightful visualization of the research landscape surrounding sustainable agriculture (Figure 11). The network connection within the keywords is imperative as it also supports the generation of novel ideas and identifies gaps within a specific domain (Donthu *et al.*, 2021) [12]. Fig. 11 indicates the evolution of articles on the current subject. The curve lines

joining the nodes indicate the connectivity and relationship of the key terms. The central theme of sustainable agriculture dominates the map, indicating its prevalence across the literature. The size of the node highlights that most studies focus on sustainable farming practices, emphasizing the importance of balancing productivity with environmental sustainability.

**Clustered Themes and Subfields:**

The map reveals several distinct clusters that represent subfields or closely related research areas:

**1. Green Cluster (Sustainability, Knowledge and Farmers)**

Terms like sustainability, knowledge, farmers, agricultural extension, and perception are tightly connected. This cluster underscores the importance of farmers' knowledge and perceptions in adopting sustainable practices. The frequent co-occurrence of these terms suggests that knowledge transfer, through extension services and advisory programs, plays a crucial role in promoting sustainability in agriculture (Tayang *et al.,* 2023) [47]. This highlights the need for education and effective communication with farmers to enhance the adoption of sustainable practices (Han and Niles, 2023) [16].

**2. Red Cluster (Regenerative Agriculture and Ecosystem restoration)**

Keywords such as regenerative agriculture, agroforestry, and soil fertility form a distinct grouping. This cluster focuses on ecological restoration and regeneration within farming systems, emphasizing approaches that restore soil health and integrate agroforestry practices. Regenerative agriculture, aimed at rebuilding ecosystems and enhancing biodiversity, emerges as a key component of sustainable agriculture. This highlights a growing recognition of the need to move beyond sustaining ecosystems towards actively regenerating them.

**3. Purple Cluster (Agroecology and Natural farming)**

The agroecology cluster is linked to concepts such as integrated pest management and natural farming. This suggests a strong emphasis on ecological principles in farming systems that minimize chemical inputs while enhancing biodiversity and ecological balance. Agroecology, as a systems-based approach, is gaining attention for its holistic nature, integrating sustainable practices across various farming activities (Akanmu *et al.,* 2023) [1]. The association with natural farming also shows the shift towards minimal intervention techniques that work with nature.

**4. Yellow Cluster (Sustainability, Agriculture and Extension)**

The presence of terms like extension and agriculture in the sustainability cluster reflects the critical role that advisory services play in spreading sustainable agricultural knowledge. Extension programs bridge the gap between research and practice, ensuring that farmers have the tools and understanding needed to implement sustainability-focused strategies (Raji *et al.,* 2024) [33]. This highlights the ongoing importance of extension systems in the dissemination of sustainable technologies and practices.

**Interconnections and Cross-Disciplinary Themes**

The strong interconnections between sustainable agriculture and other major themes such as regenerative agriculture, agroecology, and organic agriculture suggest that these are complementary approaches within the broader pursuit of sustainable farming. The overlapping connections point to an interdisciplinary approach where sustainable agriculture integrates ecological principles, soil management, biodiversity conservation, and farmer education (Schoonhoven and Runhaar, 2018) [40].

Moreover, the integration of terms like smallholder farmers and theory of planned behavior indicates an emerging interest in understanding the socio-economic and psychological factors influencing sustainable farming practices (Swart *et al.,* 2023) [45]. The focus on smallholder farmers highlights the challenges faced by these producers in adopting sustainable methods, particularly in developing regions where resources may be limited.

**Emerging Themes and Future Directions**

The keyword map points to several emerging research areas. The inclusion of behavioral science concepts, such as theory of planned behavior, suggests that there is growing interest in the behavioral and attitudinal factors influencing the adoption of sustainable practices. Understanding farmers' perceptions, motivations, and decision-making processes is critical for the successful implementation of sustainable agriculture (Wittstock *et al.,* 2022) [52]. This will likely drive future research aimed at understanding how to encourage more widespread adoption of sustainable techniques, particularly among smallholder farmers who face unique challenges.

In summary, this keyword map illustrates that sustainable agriculture is a multidisciplinary field, with strong interconnections between ecological, social, and economic dimensions (Taoumi and Lahrech, 2023) [46]. The clusters reveal the central role of farmers' knowledge and perceptions, the increasing focus on ecosystem restoration through regenerative practices, and the importance of advisory services in disseminating sustainable farming techniques. Emerging research on behavioral factors and smallholder farmers suggests that future studies will continue to explore how social and psychological elements impact the adoption of sustainable agricultural practices.

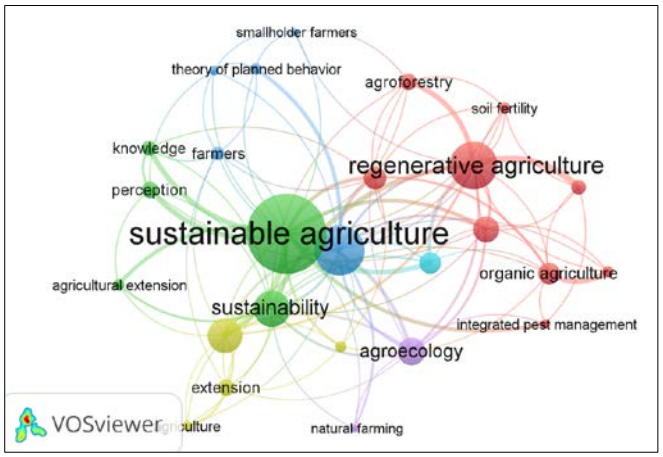


**Fig 11:** Keyword mapping

**4. Conclusion**

This review investigates the dynamic research landscape surrounding eco-centric farming practices, including regenerative, sustainable, organic, and natural farming approaches. The analysis, based on a thorough examination of scholarly literature, reveals a field characterized by rapid growth, increasing complexity, and a growing awareness of the urgent need for transformative change within agricultural

systems.

The analysis highlights the multifaceted nature of eco-centric farming, emphasizing its interdisciplinary character. Research increasingly draws upon insights from diverse fields, including agroecology, soil science, ecology, economics, sociology, and behavioral sciences. This interdisciplinary perspective is crucial for understanding the intricate interplay of ecological, social, and economic factors that shape agricultural systems.

Several key themes have emerged as central to the discourse on eco-centric farming. Climate change mitigation has become a paramount concern, with research focusing on strategies such as carbon sequestration, agroforestry, and climate-smart agriculture. Soil health is recognized as a foundational element of sustainable agriculture, with a growing emphasis on practices that enhance soil fertility, biodiversity, and resilience. Furthermore, the social dimensions of sustainable agriculture are increasingly recognized, with research focusing on farmers' knowledge, perceptions, and decision-making processes, along with the role of social networks and community engagement in promoting the adoption of sustainable practices.

The review underscores the rise of innovative farming approaches, such as regenerative agriculture and agroecology. These approaches emphasize the importance of working in harmony with natural systems, enhancing biodiversity, and minimizing external inputs. Organic farming, while a well-established practice, continues to evolve, with research focusing on improving yields, enhancing soil health, and developing new organic inputs. Natural farming, with its emphasis on minimal intervention and working with natural processes, provides a unique perspective on sustainable agriculture.

A key finding of this review is the growing recognition of the crucial role of farmers in shaping the future of agriculture. Research increasingly focuses on understanding farmers' perceptions, knowledge, and decision-making processes, and the role of social networks and community engagement in promoting the adoption of sustainable practices. Effective knowledge transfer, through extension services and participatory approaches, is crucial for bridging the gap between research and practice and empowering farmers to adopt sustainable farming methods.

The analysis reveals a global research landscape with significant contributions from diverse regions, highlighting the need for international collaboration and knowledge sharing. Addressing the challenges of climate change, food security, and environmental degradation necessitates a global perspective and collaborative efforts to develop and implement sustainable agricultural practices that are context-specific and culturally appropriate.

## Future directions

Building upon these findings, future research should focus on several key areas:

- **Scaling up successful practices:** Research should focus on scaling up successful eco-centric farming practices, evaluating their long-term impacts, and identifying best practices for their implementation at the farm, regional, and national levels.
- **Addressing challenges faced by smallholder farmers:** Research should specifically address the challenges faced by smallholder farmers in adopting sustainable methods, including access to resources, technology, and markets.
- **Developing robust policy frameworks:** Research findings should be effectively translated into policy recommendations to support the transition towards more sustainable agricultural systems, including incentives for sustainable practices, market development for eco-friendly products, and support for farmer training and education.
- **Strengthening interdisciplinary collaboration:** Continued interdisciplinary collaboration among researchers, policymakers, farmers, and other stakeholders is essential for advancing the field and ensuring the successful implementation of sustainable agricultural practices.

In conclusion, this review underscores the dynamic and evolving nature of eco-centric farming research. By fostering innovation, promoting collaboration, and supporting the adoption of sustainable practices, we can create a more resilient, equitable, and environmentally sustainable food system that meets the needs of present and future generations.

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