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Major determinants of sustainable agriculture practices adoption: A systematic review

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ABSTRACT

Despite growing innovations and work in the field of sustainable agriculture practices, the adoption of such practices remains low. The increasing global population demands the agricultural systems to produce more food, enough to feed almost 10 billion mouths by 2050. However, despite their recognized benefits, SAP adoption remains limited due to various socio-economic, institutional, and governance-related barriers. This makes it imperative that we understand the determinants of low adoption rate of sustainable agricultural practices and perform necessary changes in current adoption approaches based on the desired requirements. This study conducts a global systematic review to identify the key determinants influencing SAP adoption. A total of 121 studies published between 2000 and 2024, focusing on one of the three determinants: Behavioural, Governance & Institutional, were identified, investigated and reviewed. Using hierarchical cluster analysis and word co-abundance techniques, we categorize these determinants into five clusters: governance support and incentives, household-level demographics, institutional incentivization, farmer perceptions and behaviour, and technological advancements. These clusters help us tackle the determinants in depth by performing a full-text analysis to understand the above-mentioned determinants and identify effective policy and adoption strategies. The findings highlight that financial constraints, lack of institutional support, and limited farmer awareness hinder widespread adoption, while education, market access, and policy interventions serve as enablers. We propose targeted policy recommendations, including financial incentives, farmer education programs, and infrastructure improvements, to promote SAP adoption. This study contributes to a deeper understanding of the multi-faceted drivers and barriers to sustainable agriculture, offering insights for policymakers and stakeholders aiming to enhance global agricultural sustainability.

1. Introduction

With the global population expected to reach approximately 9.8 billion by 2050, there is an increasing demand on agricultural systems to produce more food while relying on fewer natural resources, thereby safeguarding ecosystems and promoting socio-economic resilience (FAO, 2017). Currently, the global agricultural systems face unprecedented challenges due to increasing demands for food, climate change, environmental degradation, and the depletion of natural resources. Agriculture is thus both a driver as well as severely affected by these changes, leading to soil erosion, deforestation, increase in carbon footprint, and biodiversity loss (Maeda et al., 2021; Peplau et al., 2023). Many countries that primarily rely on agriculture as income sources create land deterioration and desertification due to chemical fertilizers use and poor irrigation practices (Olanipekun et al., 2019; Qadeer et al., 2024).

Global climate changes leads to rising temperatures, altered precipitation patterns, and extreme weather events—such as droughts, floods, and heatwaves—that diminish agricultural productivity,. The Intergovernmental Panel on Climate Change (IPCC) predicts global crop yields could decline by up to 30 % by 2050, with tropical and subtropical regions facing the greatest losses (Legg, 2021). Key crops like rice, maize, and wheat are particularly susceptible to temperature increases, which shortens the growing seasons negatively impacting the crop yields (Siebert et al., 2014; Agnolucci et al., 2020). Additionally, water scarcity, exacerbated by both droughts and competing demands, further threatens food production (Young et al., 2021). Another major climate-related risk to agriculture is the decreased suitability of land for different crops, affecting the microbial population and their enzymatic activities (Malhi et al., 2021). Understanding the determinants that

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influence the adoption of sustainable agricultural practices is therefore essential, and a systematic review provides the methodological rigor needed to synthesize the diverse evidence required to address this global challenge.

1.1. Sustainable agriculture- way out

Sustainable agriculture changes agricultural policy and practice to meet the growing need to address the dual challenges of ensuring global food security while simultaneously reducing agriculture's negative environmental impact (FAO, 2020). As a result, there has been a growing emphasis on the adoption of sustainable agricultural practices (SAPs) such as agroecology, drought-resistant crops, and improved water management, that can help reconcile food production with environmental preservation and social welfare (Giller et al., 2015; Pretty, 2023). Moreover, these practices tend to be more economically sustainable in the long run for smallholder farmers, who are vulnerable to food insecurity, by reducing dependency on expensive synthetic inputs and improving long-term profitability (Mugula et al., 2023). Sustainable agriculture's central goal is to enhance agricultural resilience in the face of climate change.

Despite literature extensively highlighting the advantages of SAPs (Tey et al., 2014; Coulibaly et al., 2021; Muhie, 2022) its adoption is still low, especially in developing countries. Their widespread adoption still needs to be improved by identifying the underlying determinants acting as barriers or enablers to their adoption, which vary across regions, farming systems, and socio-economic contexts (Ansari and Tabassum, 2018). Numerous studies investigate the determinants that impact the adoption of sustainable agriculture, including financial constraints, lack of access to knowledge, and insufficient government support. Transitioning to sustainable practices often requires upfront investment in education, technology, and infrastructure, which many small-scale farmers, particularly in developing countries, cannot afford (Diop et al., 2022; Reij and Winterbottom, 2015). Additionally, government policies often favour conventional farming systems, which hinder the adoption of sustainable alternatives (FAO, 2020). Despite these barriers, numerous case studies, such as the System of Rice Intensification (SRI) in Asia and agroforestry practices in Sub-Saharan Africa, demonstrate the potential for sustainable agriculture to both enhance food security and mitigate environmental degradation (Uphoff, 2007; Nair, 2014). Addressing these challenges through targeted policy interventions, financial incentives, and education programs can unlock the full potential of sustainable agriculture as a key strategy for combating food insecurity worldwide.

Studying the role of determinants in the adoption of sustainable agriculture is critical in the context of addressing global challenges such as climate change, food security, and environmental degradation (Saltiel, 2010; Zeweld et al., 2017; Foguesatto et al., 2020). Understanding the determinants that influence farmers' decisions to adopt SAPs can aid policymakers and allow for the development of more effective strategies to promote sustainability across agricultural sectors. Incentives for farmers can help to adopt these practices and improve their long-term productivity in shifting climate patterns. Knowledge about socio-economic determinants such as income and access to credit can lead to tailored financial support programs, ensuring that farmers have the resources needed to transition to sustainable practices. Lastly, studying the determinants also provides valuable insights into how technology, innovation, and knowledge transfer can facilitate the adoption of SAPs. With advances in agricultural technologies and practices, farmers may face challenges in accessing and utilizing new tools. Understanding the existing technological and informational barriers can help to make information on dissemination and technology transfer accessible, enabling farmers to adopt more efficient, sustainable methods.

By making a systematic review of the existing literature we synthesize evidence on the types of sustainable agricultural practices and the key determinants that either promote or hinder their uptake. We built on existing reviews that investigated aspects of what we focus on here. Piñeiro (2020) scoped the role of incentives in the adoption of various environmentally friendly practices. Begho (2022) focuses on the factors determining the adoption of sustainable agriculture but with a special focus on South Asian countries to provide an evidence based repository which tackles the relationshios between drivers and barriers of successful adoption of SAPs. Rosario (2020) conducts a systematic review with a special focus on sustainable innovation adoption. Most studies only tackle one specific type of sustainable practice or one type of determinant of adoption. So far, none of the studies integrate a focus on the determinants that can be manipulated or regulated by humans - Behavioural, Institutional, and Governance.

1.2. Theoretical background

The available literature to date explores institutional, governance, and behavioural determinants, while emphasizing the complexity of agricultural systems and the importance of an integrated view. Governance determinants examine how a governing body polices itself, focusing on internal controls and practices to maintain compliance with regulations, implement best practices, and amend policies (Chibanda et al., 2009). The institutional determinants focus on policies, practices, or characteristics of the institutions that structure the society and human interaction (Kelly 1999; Kherallah and Kirsten, 2002), the behavioural determinants are attributed to the cultural values of a community and their attitudes towards the concerning issues, in this case, environmental issues; yet the collection of behaviours is specific to the population in consideration (Burton, 2004)

The above-mentioned determinants also address issues such as information asymmetries, opportunism, and conflicts of interest, but existing research often isolates these elements. There is a need to examine the extent of the interrelations of these determinants. Despite the growing interest in understanding adoption of SAPs, research synthesizing global evidence on this issue remains limited.

Existing studies tend to have primarily treated institutional, and governance as interlinked but separated from behavioural, with institutional and governance focusing on policy implementation and formulation while providing external support and behavioural addressing farmers attitude and perception (Clement, 2010; Feola and Binder, 2010; Bachev, 2010). To date, only a small number of reviews have attempted to examine the topic at a global scale, and those that exist often lack comprehensive coverage or consistent analytical frameworks. This gap highlights the need for a systematic, globally oriented review that consolidates available evidence and provides clearer insights into cross-regional similarities, differences, and emergent themes.

However, a gap remains in understanding the interdependencies between these determinants. Much of the existing literature also links SAPs to financial performance, such as share yield, productivity or profitability (Pretty, 2007). While valuable, this connection is often simplistic, and there is a lack of research on how the determinants mediate the relationship between SAP adoption and farmers. Considering these broader impacts and the trade-offs involved in adoption decisions, a more comprehensive understanding of determinants is required. By addressing this gap, our study offers a more holistic understanding of the global landscape and contributes essential context for researchers, practitioners, and policymakers working in this domain.

2. Methodology

To identify the most effective policy and other strategies to overcome barriers that hamper sustainable agriculture adoption and promote the scalability of sustainable practices in diverse agricultural systems, we conducted a systematic review of the above-mentioned determinants using a mixed methods design (Gough, 2015). A systematic review is a structured, transparent, and replicable method for synthesizing existing evidence to answer a clearly defined research question. This approach is especially appropriate when the literature on a topic is broad, multidisciplinary, and potentially inconsistent—as is the case with determinants of sustainable agriculture practice adoption. By enabling comprehensive identification, appraisal, and integration of findings across diverse studies, a systematic review reduces bias and uncovers overarching patterns that may not be evident in individual analyses (Hanley and Cutts, 2013). Guided by predefined inclusion criteria, systematic search strategies, critical quality assessment, and thematic or comparative synthesis, it ensures that the resulting conclusions are both rigorous and analytically grounded (Pollock and Berge, 2018). When applied to key determinants such as behavioral, institutional, and governance factors, this method facilitates a nuanced understanding of how farmer perceptions, organizational support structures, and broader policy environments interact to shape adoption outcomes.

The review utilizes multivariate statistics full-text articles combined with a full quantitaive analysis to explore and synthesize the academic literature, which helps us comprehend the heterogeneity within and among the articles, and nurture information among different clusters. Thereby, we try to reinforce the importance of 'holistic approach' in removing adoption obstacles and crafting customized policies resonating with realities of farmers. The bibliographic data were collected from two comprehensive scientific databases, Scopus and Web of Science (WoS) Core Collection, which are widely recognized for their extensive coverage and suitability for bibliometric research (Mongeon & Paul-Hus, 2016), on 12th March 2024 using the following search string:

[(TITLE-ABS-KEY ("sustainable agricult*") AND ("adopt*") AND ("factors") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT- TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "English AND PUBYEAR > 2000 AND PUBYEAR < 2024")) AND (LIMIT-TO (LANGUAGE, "English"))]

Only peer-reviewed journal articles written in English and published between 2000 and 2024 were included. Conference papers, book chapters, reviews, and grey literature were excluded to maintain the consistency and quality of the dataset. All retrieved records were exported from the databases in both BibTeX and CSV formats and were subsequently cleaned and standardized (Donthu et al., 2021). Duplicates and incomplete records were removed during this process. The final dataset represented a curated collection of publications forming the basis of both bibliometric and qualitative analyses. We obtained a raw sample of 2867 articles to which we applied to following inclusion criteria by screening only the articles' titles and abstracts:

1. The article is a peer-reviewed publication.
2. The article discusses SAP, specifically their adoption.

As a result, the sample was narrowed down to 659 articles. We then proceeded with a title and abstract screening of the sample and applied the following inclusion criteria:

1. The article discusses the behavioural, institutional and governance factors responsible for their adoption.
2. The article considers communities and their role in SAP adoption.

The sample was then reduced to 121 articles. Fig. 2 shows the geographical, temporal and categorical distribution of articles Tables 1–3.

For the analysis of the final sample (n = 121), we first conducted a textual abundance analysis, in which words were treated analogously as species and the respective articles as sites. The purpose of this analysis is to examine the relationship between research communities and the gradients between them based on the vocabulary composition they share (Abson et al., 2014; Rathgens et al., 2020; Engler et al., 2024). Conceptual vocabulary was extracted from the pdfs and stored into respective text files using pdf mining techniques and natural language processing filters in Python. The conceptual vocabulary was reduced to nouns as they carry more conceptual meaning, denoting entities, objects and categories (Gentner, 1982).

Table 1
Description of main steps involved in paper selection.

Steps	Approach	Criteria	Outcome (n =)
Step 1	‚Search Query' with keywords in scopus & web of science	[(TITLE-ABS-KEY ("sustainable agricult*") AND ("adopt*") AND ("factors") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT- TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "English AND PUBYEAR > 2000 AND PUBYEAR < 2024")) AND (LIMIT-TO (LANGUAGE, "English"))]	2867
Step 2	Title Screening	Peer-reviewed publications, Sustainable Agriculture practices, adoption, factors of adoption	659
Step 3	Abstract Screening	At least one of the three determinants: Behavioural, Institutional, Governance; Study focuses involves communities	130
Step 4	PDFs Found	PDFs available on various sources as open access	121

Table 2
The major variables categorized.

Category	Representative Variables
Farm/Land Characteristics	Farm size, fertility, plot size, plot quality, farm ownership, irrigation, farm management, weed control, tillage, land tenure, land titling, desertification, slope, following, land degradation, erosion,
Household Characteristics	Family size, age, gender, livestock, education, finances, household head
Organizational Characteristics	Market access, cooperatives, social networks, social capital, credit availability,
Crop Characters & Yield	Productivity, cover crops, intercropping, crop health, crop type, seed quality, crop rotation,
Climatic Characteristics	Drought, flooding, slope, temperature, rainfall

The text files were imported in R to build an abundance table (conceptual vocabulary as rows and articles as columns, and frequencies in the cells) to continue with the textual abundance analysis:

1. Using the abundance table as the input, a detrended correspondence analysis (DCA) (Hill and Gouch, 1980) was used to generate coordinates for each noun and axes that serve as gradients explaining the nouns composition across articles, with the first axis the one with more explanatory power. Words close together appear in similar articles while words more far apart appear in different ones. The DCA plot generated has only two axes for readability reasons.
2. An agglomerative hierarchical clustering (using Ward's method) was applied to the abundance table to group all those articles with similar word composition. The number of clusters were decided based on the distribution of the number of articles in each cluster.
3. Once the gradients and groups were done, an indicator species analysis (Dufrêne & Legendre 1997) was carried out to find the words that are more characteristic in each cluster of articles, that is, the words that occur mainly in each cluster and the words that appears in most of the articles from each cluster.

Finally, a word cloud was produced to visualize how the words appear grouped in the ordination space. The clusters of articles were utilized as the entry point to explore and analyse qualitatively the full-text of the sample. For each of the cluster, articles were coded

Table 3
The five clusters of determinants of sustainable agriculture practices, with number of contributions, few examples and ten most significant conceptual words.

Cluster	Words	Number of articles	Examples
Governance Support	smallholder, head, maize, household, probability, poverty, rainfall, manure, fertility, access	38	Mazhar et al., 2021; Rodriguez et al., 2009
Household heads	agriculture, education, information, level, use, management, university, interest, production, sample	24	Kudama et al., 2021; Abera et al., 2020
Institutional Incentives	construct, intention, alpha, belief, modeling, reliability, theory, innovation, path, phenomenon	20	Marques et al., 2015; Boz, 1018
Farmers Behaviour	implementation, lack, forestry, system, society, agriculture, barrier, management, movement, cycle	30	Bottazzi et al., 2023; Coulibaly et al., (2021); Foguesatto & Machado, 2021
Technological Advancements	cognition, dummy, village, treatment, robustness, county, estimation, acquisition, roster, column	7	Zhao et al., (2022);

inductively and then analysed for common themes regarding aspects of sustainability agricultural practices.

We finally explored the clusters using a qualitative full-text analysis of the respective articles to identify the clusters ́common denominator. A qualitative content review of the included articles was conducted using MAXQDA (Version 24.7.0). Each article was reviewed in full to identify key themes, theoretical perspectives, methodologies, and findings relevant to the research focus. Coding was performed inductively to allow themes to emerge from the data, and the coding scheme was refined iteratively to ensure consistency and depth of interpretation. This qualitative synthesis complemented the bibliometric findings by providing contextual and interpretive insights into how the field has developed conceptually over time.

Data integrity and reliability were ensured through repeated validation steps. All analyses were conducted independently by two authors, and coding discrepancies in MAXQDA were discussed until consensus was achieved. Cross-validation between textual abundance analysis and qualitative themes enhanced the robustness of the overall interpretation.

3. Results/findings

Since the 1987 Brundtland report (Keeble, 1988) research on sustainable agriculture and the practices being associated with sustainable agriculture has gradually increased. The millennium Declaration report (2000) marks an explicit focus on sustainable development and the necessity to increase food security, thereby the literature increased with most articles published in 2021 & 2023 (36 %). The articles discuss a variety of sustainable agricultural practices being practiced (Fig. 1 and 2. Conservation agriculture is the most widely talked about and discussed (12 %), followed by organic farming and a mixture of climate-smart agriculture and integrated pest management. 32 % of the studies focus on several practices, ranging from sustainable land management, and precision agriculture to green control technology. However, only 4 articles talk about sustainable agricultural practices explicitly.

Based on the literature, we identified 117 different variables considered in the studies included in the review (See Supplementary). We identified the most frequently discussed variables in the papers to

	Determinant		
Sustainable Agriculture Practice	Behavioural	Institutional	Governance
Climate Smart Agriculture		3	
Conservation Agriculture	5	5	4
Good Agricultural Practices		2	
Green Fertilizers Technique	2		
Integrated Pest Management		1	1
Multiple	7	10	19
Natural Resource Management			2
Not Applicable			2
Organic Farming	1	4	5
Other	1	6	9
Smart Farming	2	2	1
Sustainable Agriculture Intensification	3	3	
Sustainable Land Management		2	2
Technology Adoption	1	1	4
Total	22	39	49

Fig. 1. Distribution of the articles discussing various SAPs across type of determinants. 9 papers discussed multiple determinants in their study. 1- Behavioural Determinants, 2-Institutional Determinant, 3-Governance Determinant 102 studies are empirical and investigated various aspects of farming communities in terms of practicing SAPs. 46 % of the studies are conducted at a regional scale, followed by local (32 %). A mere 4 studies were conducted at an international or multinational level. 73 % have smallholder and subsistence farming communities as their main concern, whereas only 5 % are interested in large-scale commercial farmers. Maize is the most investigated crop (17 %), among other cereals (rice, wheat, rye & barley). Fruits are another commodity discussed concerning crops being grown by farming communities using SAPs. Natural components of the agriculture (soil, water, trees, etc.) (35 %) is the most investigated component of agriculture, followed by human/social (29 %) and then artificial (14 %) (such as machinery, technology, etc). Many papers also focussed on multiple components.

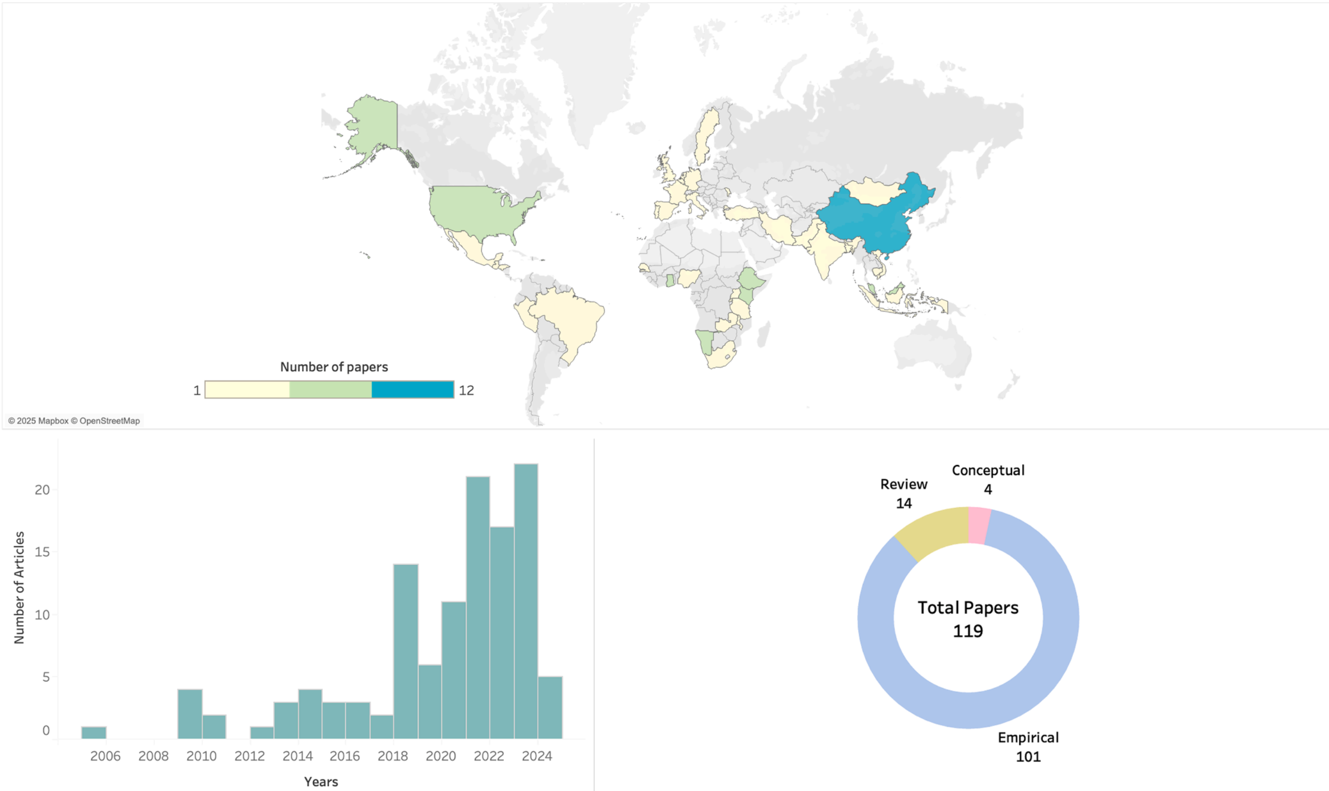

Fig. 2. Distribution of all 121 publications globally a) article share per country b) number of articles published over the years c). article distribution as empirical, conceptual and review.Out of 102 empirical studies, 26 papers performed descriptive analysis, and the rest implemented regression models with multivariate probit regression being the lion's share. The conceptual papers all comprise 'framework papers' proposing the various policy and institutional reforms in making SAP adoption widespread. The reviews either were scoping reviews or systematic reviews. The systematic reviews conducted the review using the PRISMA framework.

analyse the factors impacting SAP adoption (as shown in the table below) and categorized them following Knowler and Bradshaw (2007). It is evident that 'farmland characteristics' are the most commonly and widely used variables, followed by 'household characteristics'. Many studies also considered the organizations and their role as an important variable while studying adoption of SAP. Multiple studies mention land tenure or land ownership, market access, knowledge and information, labour access as some of the major barriers when considering SAP adoption among farmers. Whereas, income, education, experience, farm size, government support, and soil quality, are some of the facilitators in SAP adoption.

3.1. Bibliometric full text analysis

The focus of this study is to analyse the major determinants functioning either as a barrier or as enablers of SAPs adoption. While screening, articles comprising at least one of the three determinants: Behavioural, Institutional & Governance were considered. The clusters through co-abundancy were built. Fig. 3 shows the distribution of underlying determinants across clusters, highlighting the determinant overlap among studies. The top 10 most abundant words in each cluster are shown below.

3.2. Full-text analysis: types of clusters

3.2.1. Cluster 1: governance support (n = 33/121)

This cluster focusses predominantly on the support the government can and should provide to improve the adoption of SAPs, along with recommending policy reforms. The studies in this cluster focus on various governmental or institutional incentives while trying to grasp the impacts of various projects/schemes/policies on farmers' adoption behaviours. Existing incentive mechanisms primarily emphasize marketing enhancement, policy and informational outreach, and the provision of advisory services (Mazhar et al., 2021; Feliciano D, 2022; Ferreira et al., 2020), with fewer initiatives explicitly targeting governance-related dimensions critical to the widespread adoption of sustainable agricultural practices (Pineiro et al., 2020; Coulibaly et al., 2021; Priya & Singh, 2024).This cluster differs from the third cluster in that it approaches SAPs by trying to help or motivate farmers to adopt such practices, thus making this cluster essentially about 'implementation' while documenting the barriers.

Most studies (19) review 'agroforestry' or 'reforestation' or 'tree planting' as the potential form of a sustainable solution to increasing pest growth, land degradation, or erosion. The studies also identify awareness and information dissemination as the limiting factor in the adoption of SAPs by the farmers. The studies also highlight the lack of attention given to certain socio-economic factors of the targeted regions while formulating policies. Many studies (Tiraieyari et al., 2014; Adjei et al., 2017; Akenroye et al., 2021) find that lack of information dissemination (on the government's part), high application cost, and poor technical know-how of farmers are the major reasons holding back the adoption of SAPs. Ndah (2018) conducted a study trying to understand the reasons behind the success of conservation agriculture (CA) in Zambia. The study finds that the systematic promotion of CA by the government, along with providing ample knowledge and support led to the success of CA.

This cluster does engage with practices, but the government policies or role in enhancing the sustainability of agriculture by promoting such practices. Multiple studies conclude that 'numerous barriers form a self-reinforcing system in which farmers perceive to have little leeway to implement sustainable practices'.

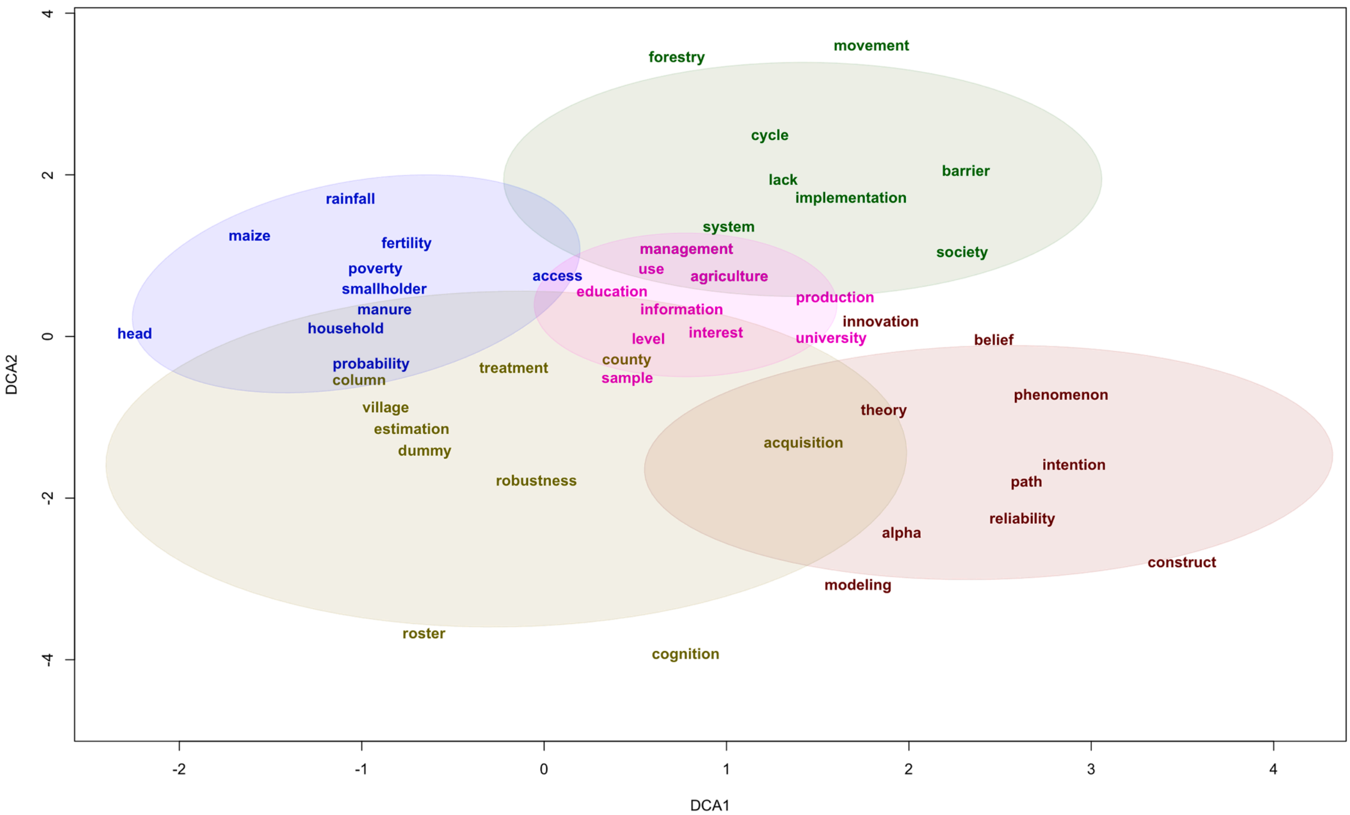

Fig. 3. Figure showing the overlap of clusters and the word cloud showing gradient between 'social and natural context' and 'individual behaviour', in the first axis (DCA 1) while the second axis (DCA2) is about 'implementation of SAP' & their 'modelling'.

3.2.2. Cluster 2: demography & households (n = 38/121)

This cluster was deductively formed after we realized that many papers focus on demographic determinants of SAP adoption. The papers also focus on other determinants, namely institutional and governance, but their main investigative points are households and their demographic qualities and how that plays a role in households' decisions regarding any SAP, consequently leading to the separation of this cluster.

This cluster aims at household income, livelihood options, remittances, and any other form of secondary income and tries to underline the role played by individual finances in SAP adoption decisions. Questionnaire surveys were conducted with household (HH) heads (22) as respondents, as HH heads are considered the decision-making authority in study areas, responsible for resource distribution and other decisions. A substantial proportion of studies investigated how variations in plot or farm size and the biophysical condition of the land affect household heads' decision-making processes concerning the adoption of sustainable agricultural practices (Kassie et al., 2009; Pilarvo et al., 2018; Morgan et al., 2019; Pham et al., 2021) Gender, education, knowledge, and training of the household head and other members are determined to be some of the major influential factors (Myeni et al.,2019; Marfo et al., 2021; Onoja, 2023; Mdoda et al., 2023). Financial, natural, and manual resource use and distribution are also considered and explored as major driving factors while adopting certain practices (Zondo and Baiyegunhi, 2021; Aguilar et al., 2024). Fertilizer management and distribution is the most widely discussed factor, followed by labour, and farm training and experience. Many studies also tried to quantify the yield differences, soil quality, and impact of seed quality by analysing plots.

Many studies concluded that households with lower access to diversified income, financial support, and training were less likely to adopt sustainable agriculture practices. Khataza (2018) stresses that farmers who have survived drastic events adversely impacting the crops are more likely to take chances with 'risky' practices. Innovative solutions, land monitoring and management, and land tenure alongside economic mechanisms proved to be beneficial in boosting SAP adoption. Kudama (2021) mentions the role of literacy and organizational support, as they help farmers become aware of the innumerable available sources.

3.2.3. Cluster 3: Institutional Incentivisation (n = 23/121)

This cluster is the first and only cluster among all others that has active discourse surrounding 'sustainability' in the studies (Savari et al., 2013; Aydogdu et al., 2020; Bourne et al., 2021;Topp et al., 2023). The studies talk about 'alternative farming systems and methods' that can ensure farmers' profitability and tackle the decreasing global food security. This cluster predominantly talks about bringing institutional-level changes to make the adoption of SAPs successful at a wider level. Boz (2018) mentions the importance of environmental programs and the role of financial security in establishing a wider network of SAP adoptions. This cluster also recognizes the significance of maintaining soil quality to continuously produce quality produce without much environmental exploitation.

Policy formulation and amendments are a major theme in this cluster. The farmers were surveyed about their awareness regarding incentivization to tackle the degradation of various environmental components, owed to agricultural malpractices, especially soil and land degradation (15 out of 23 studies). Most studies examined how capacity-building initiatives, economic incentives, social capital, education levels, and policy support collectively shape farmers' decisions to adopt sustainable agricultural practices (Jussaume and Glenna, 2009; Boz, 2018; Sheng et al., 2018; Caffaro and Cavallo, 2019). Consequently, many studies focus on considering the role of 'chemical fertilizers', and 'erosion' in degrading land and soil quality. Marques (2015) is analyzing what measures do the vine growers in Central Spain take and how their awareness of governmental initiatives regarding the excessive erosion problem shapes their adoption rate of sustainable land management. The studies in this cluster investigate the contribution of local actors and their interaction with institutional actors in decision-making leading to SAP adoption. The studies also explore alternative agrifood developmental practices with farmers' involvement. The idea is to have a revised vision of modernity that has equity and sustainability at its core.

3.2.4. Cluster 4: farmers' behaviour and perception (n = 20/121)

This cluster deals prominently with the farmers' behavior and their perception of different SAPs being implemented. The studies in this cluster (13) work on at least one of the following theories: Theory of Planned Behaviour, Social Attribution Theory, and Norm Activation Theory. Farmers' attitudes, perceptions, perceived usefulness, and ease of use are the major factors studied (Rosario et al., 2022; Bottazzi et al., 2023; Bhujel and Joshi, 2023; Kirungi et al., 2023). Coulibaly and others (2021) proposed a framework to fill 'the intention behaviour gap' in SAP research. The framework is based on the 'Theory of planned behaviour' and 'Norm Activation Theory'. The key objective of this cluster is to understand multiple behavioural factors determining the adoption of SAP.

This cluster focuses on how intent and interaction with farmers implementing certain practices influence farmers' decision-making process. Mutyasira et al., 2018 tries to understand farmers conservation behaviours by studying how personal norms link to SAP adoption. Their findings highlight a positive relationship between the two. This highlights how social norms and networks can be used to motivate farmers to adopt newer sustainable practices. The cluster concludes that adoption models based entirely on economics fail to capture the deeper complexity of farmers' decision-making and behaviour. Bottazzi and others (2023) emphasize the drawbacks of viewing farmers as 'rational agents whose main objective is to improve yields and profits'. They called this approach 'reductive' as it limits the scope of understanding the influence of cultural and social barriers in decision-making.

3.2.5. Cluster 5: technological advancements (n = 7/121)

This cluster largely focuses on agriculture's impact on environmental pollution and the possible cure for the same. Another common theme running through the cluster is the role of land tenure or land consolidation in the adoption of SAPs. Some authors are also trying to understand the role of digital finance in helping farmers obtain credit support and 'alleviate their credit constraints' (Zhao et al., 2022). The studies consider SAPs which are rather technical. All the studies were conducted in China, except for one which was conducted in Vietnam.

Another aspect within this cluster is that it focuses (6) on the importance of social credit/capital and subsidy/financial credit in enhancing farmer's green technologies adoption. Empirical evidence across studies indicates that digital financial services, land endowment structures, and targeted subsidy schemes constitute key institutional and economic drivers influencing the adoption of sustainable agricultural practices. The impacts are often enhanced if the land is tenured in farmers' names for a longer period or if they own it. A few authors also try to quantify the impact of subsidy support on adoption rates experimentally (Thu et al., 2020; Zhang and Fu, 2022).

4. Discussion

The results of this review highlight the increasing scholarly attention toward sustainable agriculture practices (SAPs) over the past two decades, with a significant surge in 2021 and 2023 (Fig. 2). This growing research interest aligns with the global policy shift following the Millennium Declaration (2000), which emphasized sustainable development and food security. The observed focus on conservation agriculture, organic farming, and climate-smart agriculture (Fig. 1) reinforces the notion that the academic discourse has matured from conceptual debates on sustainability toward empirically grounded examinations of practical interventions. The distribution of studies across determinants and scales (Figs. 2–4) underscores that SAP adoption remains a multifaceted process shaped by interactions among behavioural, institutional, and governance factors. The predominance of smallholder- and subsistence-based studies (73 %) suggests a strong geographical and socio-economic concentration, with limited research on commercial or large-scale farming systems. This imbalance may limit the generalizability of the findings to global agricultural systems, despite the increasing number of multinational studies.

The negative impacts of conventional, input-intensive farming practices on the environment and human health have increased globally with the increasing demand for food supply (Hazel & Wood, 2008; Gomiero et al., 2011). The emphasis on natural components (soil, water, trees) over artificial or technological inputs (machinery, irrigation systems) further demonstrates that sustainability is still primarily framed through an ecological rather than a techno-economic perspective (35 % studies focused on natural component as compared to 14 % on machinery or technology in agriculture). These growing concerns have enhanced the interest of researchers worldwide in sustainable agriculture and associated practices. Such practices are vital for preserving the environment by minimizing less efficient agricultural practices and resource wastage. These practices also enhance soil, water, and air quality and support food security by improving the nutritional value of produce (Njeru, 2016). They reduce cultivation costs, boost farmer incomes, and contribute to rural development through diversified farming methods like crop rotation and intercropping, which create employment opportunities.

Despite government efforts worldwide to promote SAPs, adoption rates remain limited. Experiences from countries like the USA, Belgium, Thailand, Nepal, and China highlight several factors influencing SAP adoption, including socio-economic, biophysical, institutional, financial, technical, and psychological considerations (Barnes et al., 2019). Farmers' decisions to adopt sustainable agricultural practices in response to these efforts are complex and multifaceted (Adhikari et al., 2017, Foguesatto et al., 2020). Rather than being a binary choice, adoption occurs along a continuum influenced by numerous factors. These include the government's efforts' design, stakeholders' responsibilities, the type and level of incentives provided, and individual attributes such as environmental preferences, personal perspectives, education, and farming experience (Mdoda et al., 2023; Setiawan et al., 2024).

Farmers' choices are deeply rooted in personal views—such as their attitudes toward conservation, perceptions of program benefits, and risk tolerance. Economic circumstances, including income levels, asset ownership, age, and access to alternative livelihoods, also play a key role in determining their capacity to engage with such initiatives (Bhujel and Joshi, 2023). Adjei (2016) argues that the adoption of innovative agricultural practices is rooted in their awareness of the cost-benefits and ease of adoption of such practices. Educational levels play a significant role in sustainable agriculture practices adoption, with educated farmers more likely to adopt sustainable methods (Mogaka et al., 2022). This trend is more evident in developing countries like Nigeria and Thailand, and to some extent in India, and China where educated farmers are more environmentally conscious (Lee, 2005; Akinyi et al., 2022). Governments should focus on grassroots educational campaigns to increase awareness.

Beyond individual and economic factors, the decision-making process is further impacted by the physical features of the land, ownership of the land, the regulatory and institutional environment, and even shifts in agricultural market dynamics (Emerton and Snyder, 2018; Singh et al., 2016). The distribution of determinants across all clusters also supports the argument that determinants are composed of multiple factors and cannot be treated as a 'case isolate' (Munguia et al., 2020). These interconnected variables underscore the need for context-specific policies and diverse, adaptable strategies to encourage the adoption of sustainable practices effectively. The determinants can be considered as the guiding focus, but evidence shows that several other factors are impacting their adoption (Anibaldi et al., 2021; Baumgart-Getz et al., 2012; Knowler and Bradshaw, 2007; Pannell et al., 2006). Henceforth, targeting one determinant often is not enough to tackle the underlying problem of low adoption of SAPs.

The clustering analysis also provides deeper insights into how these determinants interact to shape SAP adoption. The *Governance Support* cluster (Fig. 4 and 5demonstrates that policy interventions and institutional incentives can substantially improve adoption rates when coupled with knowledge dissemination and capacity-building mechanisms (e.g., Ndah, 2018). In contrast, the *Demography & Household* cluster (Fig. 4) emphasizes the socio-economic heterogeneity among farmers—education, gender, household income, and resource access are key enabling or constraining variables, confirming earlier findings by Knowler and Bradshaw (2007) that adoption decisions are rarely homogeneous within farming communities. Similarly, the *Institutional Incentivisation* cluster (Fig. 4 and 5) reveals that well-designed environmental and financial programs are instrumental in mainstreaming SAPs, especially when institutional and local actors collaborate to align sustainability goals with farmers' economic interests.

Behavioural determinants (Fig. 4) add further complexity by showing that adoption is not solely a rational economic choice but also a socially and psychologically mediated process. The application of behavioural theories—such as the Theory of Planned Behaviour and Norm Activation Theory—highlights that farmers' perceptions, attitudes, and social networks significantly influence their willingness to adopt sustainable practices (Coulibaly et al., 2021; Bottazzi et al., 2023). Finally, the *Technological Advancement* cluster (Fig. 3 and 4) suggests that digital finance, credit access, and land tenure security are emerging as pivotal enablers of SAP adoption, especially in rapidly developing agricultural economies such as China and Vietnam. Together, these findings underscore that promoting SAPs requires a multidimensional approach—one that simultaneously strengthens institutional structures, addresses socio-economic inequalities, and leverages behavioural and technological innovations to achieve broad-based agricultural sustainability.

Sustainable agriculture implementation frameworks should employ an integrated approach that addresses immediate priorities, such as growing food insecurity, degrading natural resources, poor soil quality, and economic profitability, while concurrently working toward long-term environmental objectives (Clune, 2021; Alaoui et al., 2022; Wieliczko & Florianczyk, 2021). Formulating such policies often necessitates navigating trade-offs among long-term outcomes, diverse environmental goals, and equity and efficiency considerations. In the context of sustainable agriculture, policymakers often must balance between the negative and positive outcomes of SAPs being implemented (Kanter et al., 2018). For instance, productivity-based SAPs often compete with SAPs focusing on soil quality, and there is an obvious productivity trade-off with the first few years of organic farming. These outcome measures also need to account for trade-offs among various types of incentives and explore how SAP choices might complement the farmers' household conditions to achieve desired objectives.

Focusing on wealthier landowners often results in greater environmental benefits (Adolph et al., 2021). These farmers typically face lower opportunity costs for adopting sustainable practices compared to poorer farmers, whose primary focus may be subsistence production. In such cases, achieving environmental goals may exacerbate socioeconomic disparities. SAPs targeting wealthier regions with significant environmental degradation may yield higher environmental returns but risk excluding poorer farmers. Additionally, this may further increase the income gap, intensify inequality and decrease the chances of SAP adoption (Makate et al., 2017). Therefore, reconciling environmental objectives with equity and development goals often requires differentiated policy tools. However, the alignment of equity and efficiency is typically heightened for policies directed toward SAP adoption among impoverished farming communities (Sunny et al., 2022). Multiple studies advocate for a systems-based approach in evaluating trade-offs and synergies across scales (Bernues et al., 2011; Rosa-Schleich et al., 2019; Allouche, 2024). They recommend promoting self-sufficient, low-input systems with more focus on informed decision-making and practices suited to local conditions. This methodology enables the design of adaptive strategies tailored to specific contexts, ultimately fostering sustainable agricultural development.

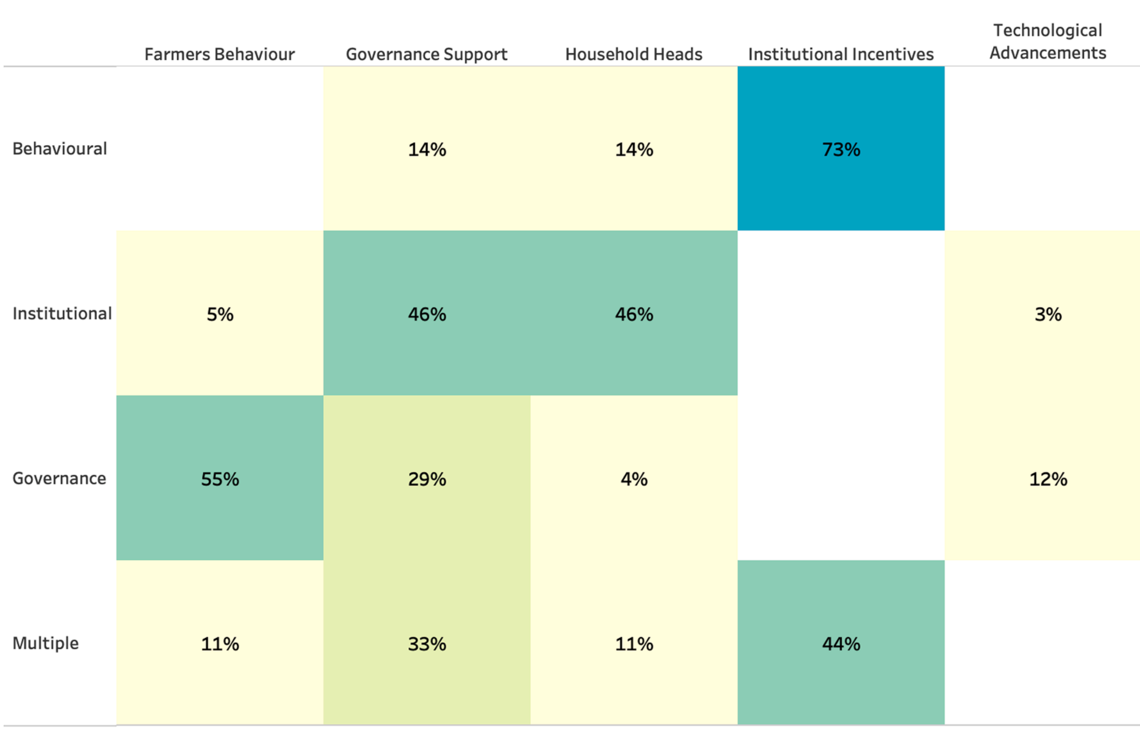

Fig. 4. Chart shows the distribution of papers with different determinants across the five clusters. 1- Behavioural Determinants, 2-Institutional Determinant, 3-Governance Determinant and, 4- Multiple Determinants.

Sustainable Agriculture Practice	Cluster: Farmers Behaviour	Governance Support	Household Heads	Institutional Incentives	Technological Advancements
Climate Smart Agriculture	1	2			
Conservation Agriculture	2	3	6	2	1
Good Agricultural Practices			2		
Green Fertilizers Technique				2	
Integrated Pest Management	1	1			
Multiple	7	21	5	7	2
Natural Resource Management	2				
Not Applicable	2				
Organic Farming	4	2	2	1	1
Other	7	2	3	1	3
Smart Farming	1		2	2	
Sustainable Agriculture Intensification		3	1	3	
Sustainable Land Management		3	2		
Technology Adoption	3	1	1	2	
Total	30	38	24	20	7

Fig. 5. Distribution of percentage of articles discussing various SAPs across five clusters.

An alternative strategy is to direct efforts in SAP adoption towards areas most vulnerable to changing climate or farmers with the least resources and accessibility (Weltin & Zasada, 2018). Thus, bundled or multipronged practices that integrate social, economic, and productivity components are particularly effective in developing countries. This raises the critical question of when and where extra efforts are necessary to stimulate adoption. Farmers likely to adopt sustainable practices often reside in regions with lower deforestation risks, prefer conservation initiatives, face lower opportunity costs, or perceive high net benefits from adopting sustainable methods (Zabala et al., 2015; Rahman et al., 2017). These benefits are enhanced together with economic incentives. Thus, incentivization can be regarded as a secondary driver of sustainable practice adoption, and considered while formulating a trade-off (Wunder et al., 2008; Bremer et al., 2014). Targeting incentive programs toward regions or populations where adoption is less probable ensures higher adoption and enhances environmental efficiency.

4.1. Policy recommendations

There is a diverse range of determinants at play in the adoption of SAPs. Some of these determinants are directly linked to governmental policies, while others are related to individual-level choices made by farmers, with the potential to be influenced by policies. Consequently, the way policymakers respond to the underlying variables of these determinants has a significant impact on the adoption of SAPs (Peshin et al., 2019; Tey et al., 2012). It is imperative to identify the variables that require higher priority to address and formulate policies accordingly. Economic challenges, such as high upfront costs, can be mitigated by providing subsidies, low-interest loans, and facilitating farmer participation in carbon markets (Wreford, 2017). Policies must also invest in farmer education through extension services, technical training, and farmer field schools to improve knowledge about sustainable practices (Coulibaly et al., 2021). Additionally, infrastructure enhancements like efficient irrigation systems and digital platforms can support farmers in adopting eco-friendly techniques (World Bank, 2020). To stabilize markets, governments should offer premium pricing for sustainably grown produce, guaranteed procurement, and cooperative marketing opportunities, ensuring fair value for farmers' efforts (Bland et al., 2023). These measures, combined with regulations promoting reduced chemical use and soil conservation, align agricultural practices with the Sustainable Development Goals, especially No Poverty (SDG1), ZERO Hunger (SDG2), and Climate Action (SDG 13)

Moreover, addressing climate change through incentives for agroforestry, disaster insurance schemes, and the promotion of climate-resilient crops is vital for sustainable farming's long-term viability (IPCC, 2022). Engaging communities through participatory policy development and awareness campaigns can overcome social and cultural resistance, while inclusive policies ensure gender equity in farming (Laborde Debucquet et al., 2024). Investments in research and development (R&D) can deliver localized solutions for soil fertility, water conservation, and pest management (FAO, 2021). International collaboration on knowledge-sharing and sustainable trade agreements can further accelerate adoption, especially in developing nations (World Economic Forum, 2023). Investing in research to develop region-specific sustainable practices that consider local environmental conditions and crop varieties, while tailoring solutions to the specific needs of farmers is more likely to be effective and adopted (Barbosa Junior et al., 2022). By consolidating these strategies, governments can address barriers holistically, fostering a global transition toward sustainable agriculture.

5. Conclusion

The adoption of sustainable agricultural practices is essential for addressing the growing challenges of food security, climate change, and environmental degradation. Despite their numerous benefits, sustainable agriculture practices adoption remains limited due to a complex interplay of behavioural, institutional, governance, and demographic factors. The review achieved two main objectives: highlighting and identifying key determinants influencing farmers' adoption of sustainable agriculture practices and policy strategies for their enhanced adoption and emphasizing methodological gaps in existing studies to guide future research. It confirmed that sustainable agriculture adoption is driven by multiple interconnected factors rather than isolated influences.

From a policy perspective, several actions can be taken to promote sustainable agricultural practices. Policymakers must adopt a multifaceted approach to overcoming these barriers, integrating financial support, education, infrastructure development, and regulatory frameworks to encourage sustainable farming. International collaboration, market-based incentives, and localized research tailored to specific agricultural systems can further accelerate sustainable agriculture practices adoption. Governance and institutional support play a crucial role in facilitating adoption through targeted policies, incentives, and awareness campaigns. Investments in education and training can improve farmers' skills and awareness, while technical support from consultants and industry experts can facilitate adoption.

Financial incentives such as grants, and tax benefits can lower costs and barriers. Encouraging knowledge sharing among farmers and implementing awareness campaigns can further drive adoption. Additionally, household characteristics, particularly income, education, and access to resources, significantly impact farmers' willingness to adopt sustainable practices. Behavioural factors, including perceptions of risk, social norms, and cultural values, further shape adoption decisions, underscoring the need for context-specific strategies. Technological advancements, financial accessibility, and land tenure security are also instrumental in scaling up sustainable agriculture practices implementation. By addressing these determinants holistically, governments and stakeholders can drive a global transition toward resilient, sustainable, and climate-smart agricultural systems, ensuring long-term food security and environmental conservation.

These insights contribute to policy discussions on promoting sustainable agriculture innovations, especially in parts demanding it most. Understanding farmers' needs and local requirements more thoroughly can lead to more effective policies, avoiding unrealistic assumptions in policy design. For instance, the European Common Agricultural Policy (CAP) has had mixed success due to its reliance on traditional policy tools without fully accounting for farmers' motivations. The study's findings could help policymakers tailor interventions to farmers' specific needs, ultimately supporting the achievement of the United Nations Sustainable Development Goals (SDGs) by 2030.

However, the review has certain limitations. First, its systematic approach still involves subjective decisions, meaning different researchers might emphasize different aspects. Second, it exclusively analyzed scientific articles, excluding books, newspaper articles, commentaries and other gray literature, and only considered studies indexed in Scopus and Web of Science, potentially overlooking relevant research. Third, the review focused solely on three determinants, namely Behavioural, Institutional, and Governance missing insights from articles focusing on other factors. The studies reviewed did not allow for a deep examination of how other factors interact with the considered determinants. Despite these limitations, the study has theoretical, methodological and practical implications. Theoretically, it aims to fill gaps in the fragmented literature, especially regarding the three determinants which fall under human control, directly or indirectly. It also supports the idea that socio-demographic, behavioural, and governance factors consistently interact and should be considered together. Methodologically, it provides guidance for conducting systematic reviews with stronger validity and more rigour. This leaves future research with a lot of possibilities to explore within agricultural sector.

CRediT authorship contribution statement

Jorge Gustavo Rodriguez Aboytes: Writing – review & editing, Visualization, Methodology, Formal analysis. **Henrik von Wehrden:** Writing – review & editing, Supervision, Resources, Conceptualization. **Neha Chauhan:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kretschmer Max Friedemann:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis.

Ethics statement and informed consent

Not Applicable

Author contributions

Neha Chauhan conceptualized and designed the study. Material preparation, data collection and analysis were performed by Neha Chauhan, Max Kretschmer and Jorge Gustavo Rodriguez Aboytes. The first draft of the manuscript was written by Neha Chauhan, except for methods section which was written by Max Kretschmer and Jorge Gustavo Rodriguez Aboytes. The manuscript was revised/reviewed by Max Kretschmer, Jorge Gustavo Rodriguez Aboytes and Henrik von Wehrden. The study was supervised by Henrik von Wehrden. The final manuscript was read and approved by all the authors.

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The authors declare that

- the work described has not been published previously in any form.
- the article is not under consideration for publication elsewhere.
- all authors approve the article's publication.
- if accepted, the article will not be published elsewhere in the same form, in English, or any other language, including electronically, without the copyright holder's written consent.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2026.107941.

Data availability

The data (research articles) are available on open source government websites.

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