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Socio-economic determinants of smallholder farmers' adoption of sustainable agricultural practices: A global review

[1]Saiyadali Nadaf, [2]Sohail Indiakar and [3]Bebijan Nadaf

[1]Warder, Karnataka State Prisons and Correctional Services, Central Prison, Mysuru, Karnataka, India

[2]Project Co-ordinator, Shree Paramanand Rural Development Society (R), Harnal, Sindagi, Vijayapura, Karnataka, India

[3]Assistant Teacher, Govt. High School, Kagadal, Belgaum, Karnataka, India

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Corresponding Author: Saiyadali Nadaf

Abstract

The adoption of sustainable agricultural practices by smallholder farmers is essential for achieving food security, climate resilience, and environmental protection. Yet adoption rates remain uneven and often low, particularly in low- and middle-income countries. This review synthesises recent empirical evidence on socio-economic determinants of adoption, drawing on studies of conservation agriculture, climate-smart agriculture, organic and natural farming, integrated pest management, and integrated farming systems. It focuses on farmer and household characteristics, farm structure, financial and market conditions, information and extension, and psychological and behavioural factors. Systematic reviews indicate that education, access to extension, credit, and cooperative membership consistently increase the probability of adoption, while land tenure insecurity, liquidity constraints, and risk aversion remain major barriers. The review pays particular attention to the Indian context, including recent studies on sustainable input use in paddy cultivation, conservation agriculture in rainfed regions, and large-scale programmes such as climate-resilient agriculture initiatives and natural farming missions. The paper concludes that socio-economic determinants interact with institutional and biophysical factors. That tailored policy strategies are required to address context-specific barriers while leveraging education, collective action, and digital innovation to accelerate sustainable adoption.

Keywords: Smallholder farmers, sustainable agricultural practices, socio-economic determinants, climate-smart agriculture, India

1. Introduction

Sustainable agriculture has moved to the centre of global debates on food systems, climate change, and rural development. Practices such as conservation tillage, crop diversification, organic nutrient management, integrated pest management, agroforestry, and water-saving irrigation promise to maintain or increase yields while reducing environmental harm. Despite this, adoption among smallholder farmers remains partial and heterogeneous, even where technologies appear technically and economically sound [1, 2].

Understanding the socio-economic determinants of adoption is therefore critical. Smallholders operate under conditions of imperfect information, credit constraints, risk, and limited access to markets and public services [2, 3]. Their decisions are shaped not only by the agronomic performance of technologies but also by education, income, farm size, household labour, risk preferences, perceptions, and institutional context. Recent systematic reviews of conservation and climate-smart practices confirm that farmer and household characteristics, farm structure, financial conditions, and access to information and extension consistently influence adoption decisions [2, 3].

This paper provides a narrative review of socio-economic determinants of smallholder adoption of sustainable agricultural practices, combining global evidence with a specific focus on India. It integrates findings from quantitative econometric studies, meta-analyses, and qualitative case studies, and offers a structured interpretation of how different determinants interact. The review aims to contribute to more context-sensitive policy and programme design that can accelerate the transition to sustainable agriculture among small-scale producers [2, 3].

2. Conceptualizing Sustainable Practices and Smallholder Adoption

Sustainable agricultural practices, as discussed in the contemporary literature, cover a wide spectrum of technologies and management strategies. These include conservation agriculture, organic and natural farming, agroecological practices, integrated soil fertility management, integrated pest management, and climate-smart agriculture packages that combine productivity, adaptation, and mitigation goals. The common features of these practices are reduced dependency on synthetic inputs, improved soil and water management, diversification of production, and long-term resource conservation [3, 4].

Smallholder farmers are generally defined in terms of limited land size, labor-intensive production, and reliance on agriculture as a primary livelihood source. In South Asia and Sub-Saharan Africa, average smallholder farm sizes often fall below two hectares. The adoption of sustainable practices by such farmers is not a single, binary decision but a sequence of choices over intensity, combination, and duration of use. Empirical studies frequently distinguish between non-adoption, partial adoption, full adoption, and dis-adoption, and they show that determinants may differ at each stage [4, 5].

Conceptually, adoption decisions can be seen as the outcome of a utility-maximizing process under constraints. Farmers compare expected benefits and costs of new practices relative to existing ones, subject to liquidity, information, labor, land, and risk constraints. Socio-economic determinants influence both the perceived net benefits and the binding nature of constraints. Education affects information processing and openness to innovation; income and farm size shape the ability to bear short-term losses; social networks and organizations influence information flows and risk sharing. The following sections unpack these determinants in detail [5, 6].

3. A Framework for Socio-Economic Determinants

Recent review work has classified adoption factors into several broad thematic groups. Feliciano and colleagues categorize them into farmer and household characteristics, farm structure and financial state, policy and institutional settings, information and cognitive factors, and environmental and biophysical conditions. Manono and co-authors similarly group determinants into socio-economic, institutional, and biophysical factors, and argue that adoption decisions are shaped by interactions among these groups rather than by isolated variables. Climate-smart agriculture reviews for Africa and Asia distinguish personal, farm-related, financial, environmental, and informational drivers [7, 8].

For the purposes of this review, socio-economic determinants are understood to include the following dimensions. Farmer and household characteristics cover age, gender, education, farming experience, risk attitudes, and intra-household decision-making. Farm structure and resources refer to land size, tenure security, livestock holdings, asset ownership, and diversification [8, 9]. Financial and market conditions include agricultural and non-agricultural income, access to credit, savings, market distance, and price environments. Social and institutional factors involve membership in cooperatives or farmer groups, access to extension and training, participation in projects, and local leadership. Cognitive and behavioral determinants include perceptions of risk, attitudes to sustainability, subjective norms, and perceived control or self-efficacy [10, 11].

This framework helps organize empirical findings and highlights that socio-economic determinants are not only individual attributes but are embedded in broader institutional contexts and social relations [11, 12].

Table 1: Conceptual Framework of Socio-Economic Determinants

Determinant Category	Key Variables & Dimensions	Impact Mechanism
Farmer & Household Characteristics	Age, gender, education, farming experience, risk attitudes, intra-household decision-making	Influences information processing, openness to innovation, and risk management
Farm Structure & Resources	Land size, land tenure security, livestock holdings, asset ownership, and diversification.	Determines capacity to experiment, investment horizons, and ability to absorb shocks
Financial & Market Conditions	Agricultural/non-agricultural income, credit access, savings, market distance, price environments.	Affects liquidity for upfront investments and profitability expectations
Social & Institutional Factors	Cooperative membership, extension access, project participation, and local leadership.	Facilitates information flow, collective experimentation, and risk sharing
Cognitive & Behavioural Factors	Risk perception, sustainability attitudes, subjective norms, perceived control/self-efficacy	Shapes how objective information is interpreted and acted upon

4. Global Evidence on Key Determinants

4.1 Education, Knowledge, and Human Capital

Education is among the most consistently significant determinants of adoption in empirical studies. A systematic review of farmers' adoption of sustainable practices across multiple countries finds that education, extension and training, and access to information are strong positive drivers [3, 6]. Educated farmers are more likely to understand complex agronomic recommendations, interpret risk-reward trade-offs, and engage with new institutions and markets [7, 8].

In Kenya, Mozambique, and Zambia, studies on conservation agriculture show that higher levels of formal education and participation in training increase the likelihood and intensity of adoption of practices such as minimum tillage, residue retention, and crop rotation. In Uganda, analysis of climate-smart agriculture adoption demonstrates that education and extension contact significantly raise the probability of using improved varieties, mulching, soil conservation, and agroforestry [10, 11].

Beyond formal schooling, human capital includes farming experience and specific technical skills. Studies that incorporate measures of experience often find a non-linear effect: some experience enhances adoption by improving managerial ability, but very long experience may correlate with attachment to traditional practices and lower willingness to experiment [12, 13].

4.2 Farm Size, Assets, and Tenure

Farm size and asset endowments influence adoption in multiple ways. Larger farms may find it easier to allocate experimental plots, absorb risk, and exploit economies of scale in machinery use or labor organization. A number of econometric analyses in Africa and Eastern Europe report positive associations between farm size and adoption of conservation tillage, cover crops, and nutrient management practices. However, in settings with very large land inequality, sustainable practices are sometimes adopted by smallholders precisely because they are labor-intensive rather than capital-intensive [14, 15].

Asset holdings such as livestock, irrigation equipment, and communication devices often act as enabling factors. In Mozambique, ownership of livestock and communication assets such as radios or mobile phones is associated with higher conservation agriculture adoption, as these assets provide buffer stocks and improve access to information. Multiple studies find that tenure security, whether through formal title or long-term customary rights, encourages investment in practices with long payback periods, including agroforestry and soil conservation [16, 17].

4.3 Income, Credit, and Financial Constraints
Financial factors are central to adoption decisions, especially for practices requiring upfront investment with delayed returns. Diaz and co-authors show that education level, agricultural income, cooperative membership, and access to credit are important determinants of adoption of various agricultural practices in Mexico, and that these factors are more relevant than non-agricultural income for household welfare. Studies from South Africa and Mozambique similarly document the positive influence of credit access and savings on adoption of conservation and water-saving technologies [18, 19].

Meta-analyses of the impact of human capital and risk preferences on adoption decisions suggest that liquidity constraints and risk aversion significantly limit adoption of innovative practices, especially where yield outcomes are uncertain in the short term. This is particularly relevant for sustainable practices whose benefits are long term and whose performance depends on correct implementation [20, 21].

4.4 Markets, Distance, and Price Environments
Market access conditions shape the profitability of sustainable practices and the feasibility of input use. Distance to markets and input suppliers often has mixed effects, depending on the practice. For integrated pest management and biological control, greater distance from input markets may encourage adoption, because farmers have less access to chemical pesticides and seek alternatives. For practices that require specialized equipment or outputs marketed through niche channels, greater distance can become a barrier [22, 23].

Price environments, including output price variability and input costs, influence adoption through expectations of relative profitability. In some cases, sustainable practices are adopted when they reduce input costs even if they do not significantly raise yields. In others, farmers require price premiums (for example for organic produce) or subsidies to offset short-term yield reductions. Market uncertainty interacts with risk preferences and access to insurance or safety nets; where farmers lack such mechanisms, they tend to prefer familiar practices even when more sustainable alternatives offer higher expected returns [24, 25].

4.5 Social Capital, Cooperatives, and Extension
Farmer organisations, cooperatives, and informal networks play a critical role as conduits of information, collective experimentation, and risk sharing. Studies of conservation agriculture and climate-smart practices emphasise that membership in farmer groups and cooperatives significantly increases the likelihood of adoption, partly through peer learning and partly through better access to training and credit [26, 27].

Extension services, when regular and responsive, have strong positive effects. Nkonki-Mandleni and co-authors report that extension visits and training frequency show significant positive influence on conservation agriculture adoption in South Africa. Reviews of African climate-smart agriculture similarly highlight information and advisory services as key drivers, although constraints in public extension capacity limit coverage [28, 29].

4.6 Attitudes, Perceptions, and Behavioural Factors
Beyond observable socio-economic variables, adoption decisions are shaped by attitudes, subjective norms, and perceived control. A recent study in Nepal finds that smallholders' adoption of sustainable practices is significantly influenced by their attitudes towards sustainability, perceived utility, normative concerns, and sense of control over implementation. Earlier behavioural literature emphasises the importance of risk perception, time preferences, and trust in information sources [30, 31].

These findings suggest that socio-economic determinants interact with cognitive processes. For instance, education and extension affect not only knowledge but also perceptions of risk and expected benefits. Social networks shape normative expectations and create social pressure for or against adoption [32, 33].

Table 2: Summary of Global Empirical Evidence on Adoption Determinants

Region/Country	Sustainable Practice Focus	Key Significant Determinants Identified
Kenya, Mozambique, Zambia	Conservation Agriculture (min. tillage, crop rotation)	Formal education and participation in training increase adoption intensity
Uganda	Climate-Smart Agriculture (mulching, agroforestry)	Education and contact with extension services significantly raise adoption probability
Mozambique	Conservation Agriculture	Ownership of livestock and communication assets (radio/mobile) acts as enabling factors
Mexico	Various Agricultural Practices	Education, agricultural income, cooperative membership, and credit access
South Africa	Conservation Agriculture & Water-saving	Frequency of extension visits, training, credit access, and savings
Nepal	Sustainable Practices (General)	Attitudes toward sustainability, perceived utility, and sense of control

5. Evidence from India
India offers a rich empirical context for examining socio-economic determinants of sustainable practice adoption due to its diverse agro-ecologies, large smallholder population, and multiple sustainability initiatives [34, 35].

A recent study on paddy farmers in India analyzes the adoption of multiple sustainable inputs, including organic manures, biofertilizers, and biopesticides. The results show that education, farm size, access to extension, membership in farmer organizations, and perception of environmental problems significantly increase the probability of adopting these inputs. The study also finds that adoption has positive effects on net returns when combined with appropriate management, which reinforces continued use [36, 37].

Research in the rainfed Nimar region of central India examines determinants of adoption of organic conservation agriculture among smallholder farmers. The study reports that while many farmers recognize ecological and economic benefits, adoption is constrained by small landholdings, short-term yield concerns, limited credit, and labor availability. Households with higher education, diversified income, and better access to markets and extension services are more likely to adopt and maintain organic conservation practices [38, 39].

Integrated farming systems have attracted growing interest as a pathway to resilience. A 2024 study on integrated farming systems in India shows that adoption is associated with higher income diversification and improved risk management, but requires higher management capacity, labor coordination, and initial investment. Socio-economic determinants such as education, family labor, livestock ownership, and access to technical support are key predictors [40 41].

Large-scale public programmes provide additional insight. Bihar Agricultural University's climate-resilient agriculture programme has promoted minimal tillage, organic inputs, and water conservation among more than forty-five thousand farmers across eighteen districts. The programme's success is linked to targeted training, demonstration plots, and integration with existing cooperatives and dairy federations, which helped overcome information and risk barriers for smallholders. In Maharashtra, outreach under the state's organic and natural farming mission has encouraged farmers in Bhandara district to adopt natural farming techniques that reduce chemical input costs. The initiative relied on farmer field schools, progressive farmer champions, and support from farmer producer organizations, illustrating the importance of social learning and institutional facilitation [42, 43].

These Indian cases underline that education, organized extension, cooperative and producer organization membership, and targeted public support are critical socio-economic enablers of sustainable practice adoption. At the same time, land fragmentation, credit constraints, and short-term yield considerations continue to limit adoption among more vulnerable smallholders [44, 45].

6. Case Studies

Several case studies from different regions help clarify how socio-economic determinants interact [43, 44].

In Mozambique, research on conservation agriculture shows that about forty to forty-five percent of farmers adopted at least one conservation practice when supported by projects. Adoption was higher among households with larger family size, livestock ownership, access to information via radio or mobile phone, and membership in farmer groups. These determinants capture both resource availability and social embeddedness [44, 45].

In South Africa, studies of conservation agriculture and water-saving irrigation technologies indicate that access to credit, extension visits, training attendance, and farm size significantly influence adoption. These findings highlight the role of formal institutions in complementing farmer characteristics [46, 47].

In East Africa, climate-smart agriculture adoption studies show that household head education, farming experience, access to climate information, and membership in farmer groups strongly affect adoption probabilities. Social networks and local project participation were critical in reducing perceived risk [48, 49].

In India, the integrated farming system case and the sustainable input adoption in paddy farming show that diversified income sources and membership in farmer organizations increase farmers' capacity to experiment with and sustain new practices. Local leadership, including progressive farmers and village-level resource persons, often acts as a catalyst by demonstrating success and sharing practical knowledge [49, 50].

These examples underscore that socio-economic determinants rarely act in isolation. They form clusters and interact with institutional arrangements, policies, and biophysical conditions, leading to context-specific adoption patterns [51, 52].

7. Methodological Considerations and Research Gaps

The literature on socio-economic determinants of sustainable practice adoption relies heavily on cross-sectional household surveys analyzed with discrete choice models such as probit, logit, and multinomial logit, and more recently with double-hurdle and multivariate probit models to account for multiple practices. While these approaches identify correlates of adoption, they face challenges in establishing causality due to unobserved heterogeneity and selection biases [53, 54].

Several gaps emerge. First, many studies capture adoption at a single point in time and do not examine persistence, dis-adoption, or intensity of use. Second, socio-economic determinants such as risk preferences, time preferences, and intra-household bargaining power are rarely measured directly, even though recent studies show they can significantly affect adoption decisions [55, 56]. Third, interactions between socio-economic and biophysical factors are often underexplored; for example, the benefits of conservation practices depend on soil type and rainfall patterns, which may alter the role of farm size or credit access. Fourth, evidence from India and other South Asian countries on integrated and agroecological systems is growing but still limited in terms of panel data and rigorous impact assessment [55, 56].

Future work can benefit from longitudinal designs, mixed methods that integrate qualitative insights on perceptions and norms, and experimental or quasi-experimental approaches that improve causal inference about socio-economic determinants [59, 60].

8. Policy Implications

The evidence reviewed in this paper suggests that policies to promote sustainable agricultural practices must address multiple socio-economic determinants simultaneously. Strengthening education and farmer training is fundamental

[57, 58]. Investments in rural schooling, adult literacy, and targeted technical training programmes enhance farmers' ability to understand complex recommendations and adapt them to local conditions. Extension systems require adequate staffing, continuous capacity development, and integration with digital tools to provide timely, context-specific advice [7, 8].

Policies should improve smallholders' access to credit and risk management instruments. Credit lines tailored to sustainable investments, combined with crop insurance or safety nets, can relax liquidity and risk constraints that currently discourage adoption. Support for farmer organizations, cooperatives, and producer companies can amplify these efforts by providing platforms for collective bargaining, joint investment, and shared learning [8, 9].

In India, ongoing initiatives such as natural farming missions, climate-resilient agriculture programmes, and support for farmer producer organizations demonstrate how coordinated interventions can work through state agencies, universities, and local organizations to shift practices at scale. Attention should also be given to land tenure arrangements and land consolidation or cooperative models that allow smallholders to adopt practices requiring plot-level coordination, such as contour bunding, communal irrigation, or landscape-based soil conservation [10, 11].

Behavioral aspects call for interventions that reshape perceptions and norms. Demonstration plots, farmer field schools, peer learning networks, and the use of trusted local leaders can alter subjective expectations about risk and benefits. Communication strategies that present evidence on yield stability, cost savings, and long-term soil health can strengthen positive attitudes toward sustainable practices [12, 19].

9. Conclusion

This review has examined socio-economic determinants of smallholder farmers' adoption of sustainable agricultural practices, drawing on global literature and focusing on recent Indian evidence. The main conclusion is that adoption is shaped by an interlocking set of socio-economic factors rather than by any single variable. Education, knowledge, and human capital consistently emerge as strong positive determinants. Farm size, assets, and tenure security matter because they affect both the capacity to invest and the horizon over which benefits are evaluated. Income and credit access determine whether farmers can bear short-term costs and risk. Market conditions and distance influence the profitability and feasibility of adopting alternative technologies. Social capital, cooperative membership, and extension services provide information, reduce uncertainty, and facilitate experimentation. Attitudes, perceptions, and behavioral traits mediate how farmers interpret information and evaluate innovations.

The Indian experience confirms these patterns. Studies on sustainable input use in paddy, organic conservation agriculture in rainfed areas, integrated farming systems, and large-scale climate-resilient and natural farming programmes show that adoption is highest where education, extension, organized farmer groups, and credit support come together. Smallholders who lack land security, liquidity, and access to knowledge remain least able to adopt and sustain new practices, even when they recognize environmental benefits. The evidence reviewed here implies that policies to promote sustainable agriculture must move beyond the simple dissemination of technologies. They need to address underlying socio-economic conditions by expanding education and extension, improving access to credit and risk management, strengthening farmer organizations, and tailoring interventions to local contexts. Future research that uses longitudinal data, richer behavioral measures, and experimental designs can deepen understanding of how socio-economic determinants operate over time.

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