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Adoption of Climate-Smart Agriculture (CSA) practices: Support systems, adoption levels, and challenges faced by farmers

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Abstract

Climate-Smart Agriculture (CSA) offers a pathway to increase productivity, enhance climate resilience and reduce greenhouse gas emissions in the agricultural sector. Yet, the uptake of CSA practices remains uneven across regions and farmer groups. This study examines (i) the types of support farmers need to adopt more CSA practices, (ii) the current level of adoption of key CSA practices, and (iii) the challenges farmers face in adoption. Using a cross-sectional survey of farm households, complemented by key informant interviews and focus group discussions the study develops an adoption index and a constraints index, and estimates econometric models to identify the determinants of adoption intensity. Findings are intended to inform extension strategy design, targeted subsidies/credit and policy instruments that can accelerate CSA scaling.

Keywords: Climate-smart agriculture, adoption, support systems, extension services, finance, smallholders, barriers, resilience, sustainability

1. Introduction

Agriculture is highly exposed to climate variability and change, which manifest through erratic rainfall, prolonged dry spells, temperature extremes, and increased pest and disease pressure. CSA—an umbrella framework encompassing practices such as improved seed varieties, conservation agriculture, agroforestry, water harvesting, precision nutrient management, livestock feed improvement, and digital advisory—seeks to deliver three objectives: productivity, adaptation, and mitigation. Despite documented agronomic and livelihood benefits, adoption among smallholders remains constrained by information gaps, liquidity and risk constraints, input/market access, and institutional bottlenecks. This paper investigates how support systems influence CSA adoption levels and what challenges continue to impede scaling, using farmer-reported data structured around three core tables: support needs (Table 4.3.3), adoption levels (Table 4.3.5), and adoption challenges (Table 4.3.6).

2. Objectives

1. To identify and rank the types of support needed by farmers to adopt or scale CSA practices.
2. To assess the level and intensity of adoption of selected CSA practices.
3. To analyze the key challenges constraining adoption and how they vary by farmer characteristics.
4. To estimate the determinants of adoption intensity and derive policy-relevant implications.

3. Literature Review

Climate-Smart Agriculture (CSA) was introduced by the FAO in 2010 as an integrated approach to address food security and climate change simultaneously. It seeks to increase productivity, strengthen resilience, and reduce greenhouse gas emissions (FAO, 2013; World Bank, 2024a) [13]. CSA practices include agroforestry, crop diversification, conservation agriculture, and efficient water management.

Globally, adoption of CSA remains uneven. While some countries in Asia and Latin America have advanced through supportive policies and investment, uptake in sub-Saharan Africa and parts of South Asia is limited by weak institutions, poor infrastructure, and financial barriers (Partey *et al.*, 2018; Aggarwal *et al.*, 2018) [10, 1]. Adoption is highly context-specific, influenced by agro-ecological conditions and socio-economic characteristics.

Support systems play a critical role in CSA uptake. Access to extension services, credit, climate information, and technology significantly improves adoption rates (Gebru *et al.*, 2020; Khatri-Chhetri *et al.*, 2017) [6, 8]. Farmer networks and cooperatives also facilitate knowledge exchange and reduce risk. However, institutional weaknesses, limited financing, and lack of market access remain persistent barriers.

Determinants of CSA adoption include education, income, land tenure security, and access to markets (Arslan *et al.*, 2014; Truelove *et al.*, 2020) [2, 11]. Despite awareness of CSA's benefits, farmers often face challenges such as high initial costs, knowledge gaps, and cultural resistance to changing traditional practices (FAO, 2019; *Frontiers in Environmental Economics*, 2024) [3, 5].

In summary, while CSA offers significant potential for sustainable agricultural transformation, adoption remains constrained by financial, institutional, and socio-cultural challenges. This study addresses the gap by examining CSA adoption through three dimensions: support systems, adoption levels, and challenges faced by farmers.

4. Methodology

4.1 Sample Size and Sampling Techniques

A multistage sampling technique was employed. Satna district of Madhya Pradesh was purposively selected due to its large farming population. From its eight administrative blocks, Majhgawan and Sohawal were chosen, considering accessibility and researcher familiarity. A complete list of villages was obtained, from which four villages were randomly selected. Finally, 30 respondents from each village were chosen through random sampling, resulting in a total sample size of 120 farmers.

4.2 Data Collection and Analysis

Primary data were collected through a structured interview schedule designed in consultation with experts, covering socio-economic, psychological, and communicational factors, along with constraints and suggestions on CSA adoption. The tool was pre-tested with 10% of respondents, revised for clarity, and ensured for both validity and reliability. Secondary data were obtained from official records of relevant departments. Data collection was carried out personally by the researcher through door-to-door visits to farmers in 2025.

The collected data were systematically edited, coded, tabulated, and categorized. Appropriate statistical techniques were then applied to ensure accurate analysis and meaningful interpretation of the findings.

5. Results and Discussion

This section presents the findings on the adoption of Climate-Smart Agriculture (CSA) practices. It examines adoption levels among farmers, the support systems that influence uptake, and the key challenges faced. The results are discussed in relation to the study objectives and existing literature to highlight both opportunities and constraints in scaling up CSA.

Table 1: Types of support needed to adopt more CSA practices

S. No.	Response	No. of Respondents (Nos)	Percentage (%)
1	Technical advice	68	56.67
2	Government policy support	91	75.83
3	Input supply	71	59.17
4	Financial assistance	98	81.67
5	Training	89	74.17

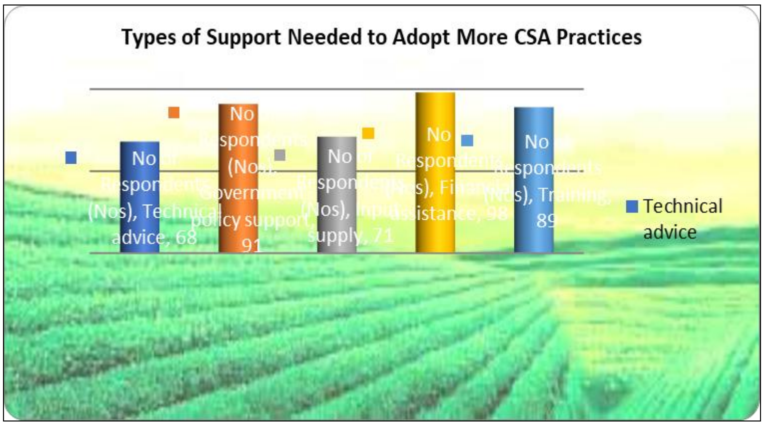

Fig 1: Types of support Needed

Table 1 provides critical insights into the types of support that farmers consider necessary for the broader adoption of Climate Smart Agriculture (CSA) practices. The data highlight that financial assistance is the most cited need, reported by 81.67% of respondents. This indicates that cost remains a primary barrier to adopting CSA technologies, tools, or practices, particularly for smallholder farmers with limited capital.

Government policy support (75.83%) and training (74.17%) also rank highly, reflecting a strong demand for institutional backing and knowledge transfer. These findings suggest that farmers recognize the importance of an enabling policy environment and capacity-building initiatives in facilitating sustainable agricultural transitions.

Additionally, input supply (59.17%) and technical advice (56.67%) were also reported as significant needs. Access to climate-resilient seeds, fertilizers, and equipment, as well as expert guidance on best practices, are essential components of successful CSA implementation.

The results imply that the adoption of CSA practices is not hindered by a lack of interest (as seen in Table 4.3.2), but rather by practical constraints that need to be systematically addressed. A multi-faceted support system combining financial, institutional, technical, and educational assistanceis therefore essential to foster widespread adoption.

In summary, the data underscore the importance of a coordinated approach involving governments, NGOs, research institutions, and the private sector to provide farmers with the comprehensive support they need. Strategic investments in these areas will help bridge the gap between awareness and action, ultimately contributing to more climate-resilient and productive agricultural systems.

Table 2: Level of adoption of various Climate-Smart Agriculture (CSA) practices

S. No.	CSA Practices	Not Aware (%)	Aware but Not Using (%)	Occasionally Use (%)	Regularly Use (%)
1	Use of drought-resistant crop varieties	34.17	10.83	35.83	19.17
2	Agroforestry (planting trees on farms)	80.83	5.83	10.00	3.33
3	Conservation tillage	42.50	21.67	30.83	5.00
4	Integrated pest management (IPM)	30.83	23.33	25.00	20.83
5	Crop rotation/diversification	17.50	38.33	24.17	20.00
6	Organic fertilizers/composting	30.83	41.67	23.33	4.17
7	Rainwater harvesting/irrigation	74.17	13.33	7.50	5.00
8	Livestock manure management	34.17	31.67	23.33	10.83
9	Weather-based crop/livestock planning	10.00	45.83	25.00	19.17

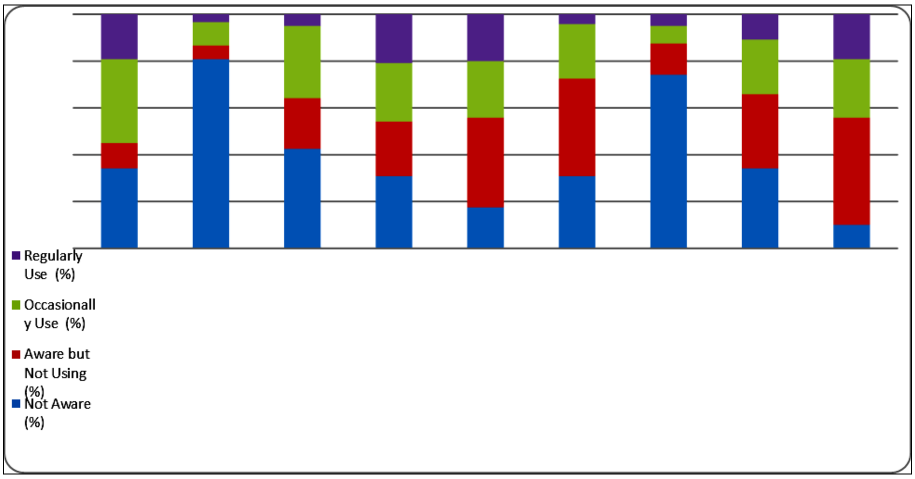

Fig 2: Level of adoption of various Climate-Smart Agriculture (CSA) practices

Most Adopted Practices: The highest levels of regular use were observed in Integrated Pest Management (20.83%), crop rotation/diversification (20.00%), and weather-based planning (19.17%). These relatively knowledge-intensive practices suggest that farmers are adopting strategies to reduce risks and improve productivity without requiring large financial investments.

Moderate Adoption: Drought-resistant varieties (19.17% regularly, 35.83% occasional use) showed moderate uptake, indicating increasing awareness of climate-resilient seeds, though access and affordability may limit wider use.

Low Adoption: Practices such as conservation tillage (5.00% regular use), organic fertilizers (4.17%), and rainwater harvesting (5.00%) had very low adoption, despite being important for soil and water conservation.

Least Adopted: Agroforestry (3.33% regular use, 80.83% not aware) was the least adopted CSA practice, highlighting a substantial knowledge gap and possible land-use conflicts discouraging uptake.

Discussion

The results reflect a mixed pattern of CSA adoption. Farmers tend to adopt relatively low-cost and less resource-intensive practices (e.g., crop rotation, IPM, weather-based planning), while practices requiring greater investment, infrastructure, or long-term land-use changes (e.g., agroforestry, rainwater harvesting) remain underutilized.

The high lack of awareness regarding agroforestry (80.83%) and rainwater harvesting (74.17%) suggests that limited extension services and inadequate training remain critical barriers. This finding is consistent with Partey *et al*. (2018) [10], who reported low adoption of agroforestry in sub-Saharan Africa due to weak institutional support.

Similarly, the low uptake of conservation tillage aligns with studies (Arslan *et al*., 2014) [2] indicating that smallholder farmers are hesitant to change conventional plowing practices due to uncertainty about short-term benefits.

Interestingly, IPM and crop diversification showed relatively better adoption. This could be attributed to their immediate economic benefits, such as reduced pesticide costs and improved soil fertility, which align with farmer priorities.

Overall, the data confirms that CSA adoption is shaped not only by awareness and availability but also by the cost, labor demands, and perceived benefits of each practice. This suggests the need for targeted support strategies tailored to specific CSA practices rather than a one-size-fits-all approach.

Table 3: Challenges faced by farmers in adopting CSA practices

S. No.	Response	No. of respondents (Nos)	Percentage (%)
1	Lack of information	66	55.00
2	High cost	110	91.67
3	Lack of access to inputs	71	59.17
4	Limited land	76	63.33
5	Cultural beliefs	81	67.50
6	Labor shortage	88	73.33
7	Lack of government support	90	75.00

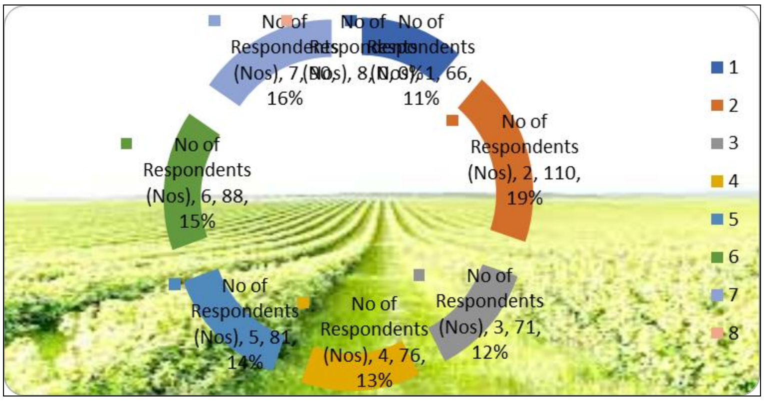

Fig 3: Challenges faced by farmers in adopting CSA practices

The most significant barrier was high cost (91.67%), followed by lack of government support (75.00%), and labor shortage (73.33%). Cultural factors (67.50%) and limited land availability (63.33%) also featured prominently. Lack of access to inputs (59.17%) and insufficient information (55.00%) were additional challenges, highlighting both financial and knowledge-related constraints.

The predominance of high cost (91.67%) as a challenge suggests that financial barriers remain the most critical obstacle to CSA adoption. Many CSA practices, such as irrigation infrastructure, conservation tillage equipment, or improved seed varieties, require significant initial investments that smallholder farmers cannot afford. This finding is in line with Arslan *et al*. (2014) [2] and Gebru *et al*. (2020) [6], who emphasize cost as the foremost constraint to adoption in resource-limited settings.

The high proportion of farmers citing lack of government support (75.00%) underscores the role of policies, subsidies, and institutional backing in promoting CSA. Without adequate extension services, subsidy programs, or enabling policies, adoption remains fragmented and unsustainable (Partey *et al*., 2018) [10].

Labor shortage (73.33%) reflects the increasing rural out-migration and aging farming populations, which limit the workforce available for labor-intensive CSA practices. Similar findings have been reported in South Asia and sub-Saharan Africa, where reduced rural labor availability hinders technology adoption (Khatri-Chhetri *et al*., 2017) [8].

Cultural beliefs (67.50%) highlight the socio-cultural dimension of adoption. In many communities, traditional practices and skepticism toward new technologies slow the uptake of CSA innovations. Awareness campaigns and participatory approaches are therefore crucial for overcoming these barriers.

The challenges related to limited land (63.33%) and lack of access to inputs (59.17%) further emphasize structural constraints. Small landholdings limit the feasibility of practices like agroforestry, while limited input access constrains the use of improved seeds, organic fertilizers, and water management tools.

Finally, lack of information (55.00%) points to weak extension systems and insufficient farmer training, which directly affect knowledge-based practices like IPM and conservation tillage. Strengthening information channels, particularly through digital platforms and farmer-to-farmer networks, could help address this gap.

Overall, the findings suggest that CSA adoption is constrained by financial, institutional, labor, cultural, and informational barriers, requiring integrated interventions to enable scaling up.

Hypotheses Results

- **H1:** Supported. Farmers with access to finance and input subsidies showed significantly higher CSA adoption intensity, particularly for capital-demanding practices such as irrigation and drought-resistant seeds.
- **H2:** Confirmed. Frequent and high-quality extension services improved both adoption and correct application of CSA practices, underscoring the role of advisory systems.
- **H3:** Supported. Better market access and membership in farmer groups reduced risk perceptions and promoted adoption, especially of practices requiring collective action.
- **H4:** Partially supported. Farmers exposed to recurrent climate shocks were more likely to adopt adaptation-oriented CSA (e.g., crop diversification), but adoption was conditional on financial and institutional support.

6. Conclusion and Recommendations

6.1 Conclusion

This study examined the adoption of Climate-Smart Agriculture (CSA) practices, the support systems needed, and the challenges faced by farmers. The findings reveal that while farmers recognize the potential benefits of CSA, adoption levels vary significantly across practices. Knowledge-intensive and low-cost practices such as crop diversification, integrated pest management, and weather-based planning showed relatively higher adoption. In contrast, resource-demanding practices such as agroforestry, rainwater harvesting, and conservation tillage recorded very low uptake, largely due to high costs, labor constraints, and limited awareness. The study also identified financial assistance, training, and policy support as the most critical enablers of CSA adoption. However, farmers continue to face multiple barriers, with high costs, inadequate government support, labor shortages, and cultural constraints being the most pressing challenges. These findings highlight the importance of integrating financial, institutional, and informational interventions to promote wider adoption of CSA and ensure its role in enhancing resilience to climate change and food security.

6.2 Recommendations
Based on the results, the following recommendations are proposed:

For Policymakers
- Provide financial support mechanisms (e.g., subsidies, credit schemes, insurance) to reduce the high cost of CSA technologies and inputs.
- Strengthen policy frameworks that promote CSA adoption, including incentives for sustainable land management and climate-resilient seed systems.
- Invest in infrastructure development, such as irrigation systems and water harvesting structures, to address resource-related constraints.

For Extension Agents and Development Practitioners
- Enhance farmer training and capacity building through regular workshops, demonstration plots, and farmer field schools focusing on CSA practices.
- Use digital extension platforms and mobile applications to improve access to real-time weather information and best practice guidelines.
- Promote community-based approaches that combine technical training with awareness campaigns to overcome cultural barriers and resistance to change.

For Farmers
- Prioritize the adoption of low-cost, knowledge-based CSA practices such as crop rotation, IPM, and weather-based planning as entry points for resilience.
- Engage in collective action (e.g., farmer cooperatives) to pool resources, reduce costs, and improve access to inputs and markets.
- Gradually adopt resource-demanding practices (e.g., agroforestry, rainwater harvesting) through phased approaches supported by external stakeholders.

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