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Constraints experienced by farmers in adoption of Climate Smart Agricultural (CSA) Technologies

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Abstract

Climate change has emerged as a critical challenge for global agriculture, affecting productivity, livelihoods, and food security. Climate Smart Agriculture (CSA) offers a viable solution by integrating adaptation, mitigation, and productivity-enhancing strategies. Despite its potential, the adoption of Climate Smart Agricultural Technologies (CSAT) remains limited among farmers, especially in developing regions. This study was conducted to identify and analyze the key constraints experienced by farmers in the adoption of CSAT across seven agro-climatic zones of Tamil Nadu, India. An ex-post facto research design was employed, and data were collected from 210 progressive farmers selected through multi-stage stratified sampling. The study utilized a structured interview schedule, and data were analyzed using frequency, percentage analysis, and Mean Perceived Score (MPS) ranking. Findings revealed that financial, infrastructural, and labour constraints were the most severe, with high input costs (MPS = 4.30), high labour charges (MPS = 4.23), and perceived delay in realizing benefits (MPS = 4.81) ranking among the top barriers. Technological challenges such as inaccessibility to quality inputs and lack of improved technologies also significantly impacted adoption. Additionally, slow information flow, weak institutional support, limited credit access, and socio-cultural barriers such as farmer conflicts further constrained effective implementation. The study emphasizes the need for targeted policy interventions, financial support, robust extension systems, and infrastructure development to facilitate the broader adoption of CSAT. Addressing these constraints through region-specific and farmer-centric strategies will play a crucial role in enhancing climate resilience and promoting sustainable agriculture in Tamil Nadu.

Keywords: Climate smart agriculture, constraints, adoption, farmers and Tamil Nadu

Introduction

Climate change poses a significant threat to global agricultural systems, particularly in regions already vulnerable to food insecurity and environmental degradation. The increasing frequency of extreme weather events, shifting rainfall patterns, rising temperatures, and unpredictable seasons are severely affecting agricultural productivity and farmers' livelihoods. According to the Intergovernmental Panel on Climate Change (IPCC, 2022) ^[8], global surface temperatures have risen by approximately 1.1 °C above pre-industrial levels, and this increase is projected to reach 1.5°C between 2030 and 2052 if current trends continue. These changes have resulted in declining yields for major crops, especially in tropical and subtropical regions, with yields of wheat and maize projected to decline by 6% and 7.4%, respectively, for every 1°C rise in global temperature (Lobell *et al.*, 2011; IPCC, 2022) ^[11, 8].

In response to these mounting challenges, Climate Smart Agriculture (CSA) has emerged as a comprehensive and transformative approach. CSA aims to sustainably increase agricultural productivity and incomes, build resilience and capacity to adapt to climate change, and reduce or remove greenhouse gas emissions wherever possible (FAO, 2013) ^[4]. It involves the adoption of innovative technologies and practices such as drought-tolerant crop varieties, efficient irrigation methods like drip and sprinkler systems, conservation tillage, agroforestry, integrated pest management (IPM), and improved livestock management practices.

Despite the evident benefits of CSA, the adoption rate among farmers remains relatively low, particularly in developing countries. For instance, a report by the Food and Agriculture Organization (FAO, 2021) ^[5] highlighted that only around 10-15% of smallholder farmers in sub-Saharan Africa and South Asia have adopted any form of CSA practices. In India, while

various government schemes promote climate-resilient farming, challenges such as limited awareness, lack of access to credit, poor infrastructure, and weak extension services continue to hinder widespread adoption (Aryal *et al.*, 2021; Khatri-Chhetri *et al.*, 2017) [2, 10].

Farmers often face numerous constraints that hinder their ability to implement these technologies effectively. These include limited access to financial resources, inadequate knowledge and training, lack of institutional support, socio-cultural barriers, and issues related to land tenure and infrastructure. Understanding these constraints is essential for designing targeted interventions and enabling wider adoption of CSA practices, especially among smallholder and marginal farmers.

The primary objective of this study is to examine the major constraints hindering the adoption of Climate Smart Agriculture technologies among farmers.

Research Methodology

An ex-post facto research design was employed for this study to assess the constraints experienced by farmers in the adoption of Climate Smart Agricultural (CSA) technologies. This design was deemed appropriate since the variables of interest had already occurred and could not be manipulated by the researcher. The study was conducted during the year 2022-23 across seven agro-climatic zones of Tamil Nadu. One representative district was selected purposively from each zone:

- Villupuram district from the North Eastern Zone

- Namakkal district from the North Western Zone
- Coimbatore district from the Western Zone
- Tiruvavur district from the Cauvery Delta Zone
- Ramanathapuram district from the Southern Zone
- Kanyakumari district from the High Rainfall Zone
- The Nilgiris district from the Hilly Zone

A multi-stage stratified sampling method was adopted. In the first stage, one district was chosen from each zone. In the second stage, suitable villages were identified within each district. In the final stage, 30 progressive farmers were selected from each district based on their adoption of CSA technologies or their participation in the NICRA (National Innovations in Climate Resilient Agriculture) program. These farmers were considered knowledgeable and experienced in CSA practices. In total, 210 farmers (30 from each of the 7 districts) constituted the primary respondents for the study.

A structured and pre-tested interview schedule was used to collect data through personal interviews, ensuring clarity, reliability, and relevance of the questions. Data Analysis were done using the statistical tools such as percentage analysis, frequency and Mean Percentage Score.

Results and Discussion

The constraints faced by the farmers in adopting climate smart agricultural technologies is given in the Table 1.

Table 1: Distribution of Constraints experienced by farmers in adoption of Climate Smart Agricultural Technologies (n=210)

S. No.	Constraints	Severity of constraints					Rank (MPS)
		Very severe constraint	Severe constraint	Moderate constraint	Somewhat of a constraint	Not at all a constraint	
I	Technological constraint						
1	Lack of availability of resources	7 (3.33)	16 (7.62)	54 (25.71)	128 (60.95)	5 (2.38)	III (2.49)
2	Lack of improved technology	3 (1.43)	24 (11.43)	118 (56.19)	65 (30.95)	0 (0.00)	II (2.83)
3	Inaccessibility of good quality inputs	14 (6.67)	51 (24.29)	83 (39.52)	51 (24.29)	11 (5.24)	I (3.03)
II	Information and knowledge management constraints						
1	Lack of credible information and knowledge	6 (2.86)	35 (16.67)	75 (35.71)	70 (33.33)	24 (11.43)	II (2.66)
2	Slow flow of information	18 (8.57)	46 (21.90)	63 (30.00)	54 (25.71)	29 (13.81)	I (2.86)
III	Policy and institutional barriers						
1	Lack of Government support	24 (11.43)	23 (10.95)	34 (16.19)	76 (36.19)	53 (25.24)	III (2.47)
2	Corruption	24 (11.43)	23 (10.95)	41 (19.52)	64 (30.48)	58 (27.62)	II (2.48)
3	Lack of institutional facilities like training, demonstration, provision of quality inputs	6 (2.86)	41 (19.52)	51 (24.29)	100 (47.62)	12 (5.71)	I (2.66)
4	Lack of political will	6 (2.86)	23 (10.95)	41 (19.52)	45 (21.43)	95 (45.24)	V (2.05)
5	Bureaucratic inertia	6 (2.86)	23 (10.95)	34 (16.19)	65 (30.95)	82 (39.05)	IV (2.08)
IV	Financial constraints						
1	Lack of access to credit facilities	12 (5.71)	59 (28.10)	69 (32.86)	58 (27.62)	12 (5.71)	III (3.00)
2	Lack of fund	6 (2.86)	12 (5.71)	41 (19.52)	98 (46.67)	53 (25.24)	IV (2.14)
3	High cost of inputs	104 (49.52)	76 (36.19)	18 (8.57)	12 (5.71)	0 (0.00)	I (4.30)
4	Low income	12 (5.71)	89 (42.38)	63 (30.00)	46 (21.90)	0 (0.00)	II (3.32)
V	Socio-cultural barriers						
1	Lack of interest	6 (2.86)	11 (5.24)	45 (21.43)	35 (16.67)	113 (53.81)	III (1.87)
2	Conflicts among farmers	5 (2.38)	45 (21.43)	23 (21.43)	47 (22.38)	90 (42.86)	II (2.18)
3	Benefits are perceived late	176 (83.81)	28 (13.33)	6 (2.86)	0 (0.00)	0 (0.00)	I (4.81)
VI	Infrastructure and Labour constraints						
1	Lack of space for installing water structure	0 (0.00)	6 (2.86)	59 (28.10)	133 (63.33)	12 (5.71)	IV (2.28)
2	Lack of labour availability	40 (19.05)	130 (61.90)	24 (11.43)	16 (7.62)	0 (0.00)	II (3.92)
3	High labour charges	70 (33.33)	124 (59.05)	10 (4.76)	6 (2.86)	0 (0.00)	I (4.23)
4	Unfavorable market	12 (5.71)	12 (5.71)	31 (14.76)	124 (59.05)	31 (14.76)	III (2.29)

1. Technical Constraint

From Table 1, it is clear that the inaccessibility of good-quality inputs is the most pressing technological constraint, with a significant number of respondents identifying it as a severe to

moderate challenge (Rank I, MPS = 3.03). This indicates a critical gap in farmers access to essential, high-quality inputs required for CSAT. Lack of improved technology is identified as the second most pressing constraint (Rank II, MPS = 2.83), with

over half of the participants citing it as a moderate constraint. This highlights the disparity between available agricultural technologies and their accessibility to farmers. Lack of availability of resources ranks third (Rank III, MPS = 2.49), mainly perceived as a moderate to somewhat constraint. Many studies have highlighted that the inaccessibility to quality inputs and lack of improved technologies are among the leading barriers to CSA adoption, particularly in developing nations (Khatri-Chhetri *et al.*, 2017; Aryal *et al.*, 2021) ^[10, 21]. These findings address the technological barriers that hinder the adoption of CSAT. Therefore, there is a need to prioritize improving the accessibility of high-quality inputs, bridging the gap in technology dissemination, and ensuring that farmers have the necessary resources.

2. Information and knowledge management constraints

The data presented in Table 1, shows that the Slow flow of information has been ranked as the most significant barrier within the category (Rank I, MPS = 2.86). It is evident that a substantial number of respondents (21.90%) consider the slow dissemination of information to be a severe constraint, while (30.00%) view it as a moderate issue. Where the lack of credible information and knowledge is ranked as the second most pressing issue (Rank II, MPS = 2.66), this constraint underscores the challenge farmers face in accessing reliable and accurate information and (35.71%) of the farmers perceive this as a moderate constraint, while 33.33 per cent of respondents find it somewhat constraint, which points to a gap in the quality and credibility of agricultural information available to them. The slow flow and lack of credible information impede the effective dissemination of climate-smart practices, leading to reduced farmer engagement and trust (Arunrat *et al.*, 2017; Melesse *et al.*, 2021) ^[11, 12]. The findings reveal critical challenges in the dissemination and credibility of information related to CSAT among farmers. Addressing these constraints is crucial for empowering farmers with the knowledge and resources necessary to adopt climate-smart agricultural practices.

3. Policy and institutional barriers

From Table 1, it can be inferred that the lack of institutional facilities like training, demonstrations, and the provision of quality inputs is ranked as the most significant constraint within this category (Rank I, MPS = 2.66). A considerable portion of respondents consider the lack of institutional support, including training and demonstration programs and access to high-quality inputs, as a major obstacle. This highlights the critical need for stronger institutional frameworks that can offer the necessary resources and capacity-building opportunities to farmers. The second most pressing issue is identified as corruption (Rank II, MPS = 2.48), which affects the effectiveness of policies and institutional support mechanisms. Respondents indicated that corruption is a severe to moderate constraint. Lack of government support is ranked third (Rank III, MPS = 2.47). The perceived inadequacy of government support encompasses a wide range of issues that highlight a gap between the needs of farmers and the support provided by government entities. Bureaucratic inertia is identified as the fourth constraint (Rank IV, MPS = 2.08). Bureaucratic inertia refers to the sluggish processes within institutions that can hinder the implementation of effective CSAT policies and programs. Lack of political will is the least ranked constraint (Rank V, MPS = 2.05), indicating the challenges in securing commitment at the political level to prioritize and address the needs for CSAT adoption. Weak institutional infrastructure, corruption, and poor training

mechanisms often result in a lack of trust in governmental initiatives and hinder technology adoption (FAO, 2021; Hellin *et al.*, 2012) ^[5, 7]. These findings demonstrate the importance of addressing policy and institutional constraints to facilitate the adoption of CSAT. There is a clear need for increased government support, institutional reform, and initiatives to combat corruption in order to create a more favorable environment for farmers.

4. Financial constraints

It is evident from Table 1, that the high cost of inputs is identified as the most severe financial constraint (Rank I, MPS = 4.30), with a substantial majority of respondents (49.52%) considering it a very severe constraint. Low income is ranked as the second most significant financial constraint (Rank II, MPS = 3.32), which affects farmers' ability to invest in CSAT. A high percentage of respondents (42.38%) view low income as a major limitation, suggesting that their financial ability to adopt innovative and often expensive sustainable practices is restricted. Lack of access to credit facilities is ranked as the third constraint (Rank III, MPS = 3.00), highlighting the challenge farmers encounter in obtaining credit to invest in CSAT. Despite the potential of these technologies to enhance productivity and sustainability, the lack of financial services that meet farmers' needs hinders their adoption. Lack of funds is ranked fourth (Rank IV, MPS = 2.14). The general scarcity of funds encompasses broader financial challenges beyond credit access, reflecting the overall economic constraints that farmers encounter. The high cost of inputs, low income levels, and lack of access to tailored credit products severely limit farmers' ability to invest in CSA technologies (Saini *et al.*, 2021; Zilberman *et al.*, 2018) ^[14, 15]. These findings underscore the crucial role of financial support in facilitating the adoption of CSAT. Addressing the high cost of inputs and low income requires a multifaceted approach that includes subsidies, incentives, and financial products specifically designed for smallholder farmers.

5. Socio-cultural barriers

In Table 1, the data shows that Benefits are Perceived Late as the most significant socio-cultural constraint (Rank I, MPS = 4.81), with an overwhelming majority of respondents (83.81%) considering it a very severe constraint. Conflicts among farmers are ranked as the second most critical socio-cultural constraint (Rank II, MPS = 2.18), which reflect the complexities of community dynamics and differing opinions on farming practices, and 21.43 per cent of respondents perceived this constraint as a significant issue. Lack of interest is the third-ranked constraint (Rank III, MPS = 1.87), with a major portion of respondents (53.81%) considering it not a constraint at all. Socio-cultural perceptions and delayed realization of benefits from CSAT often lead to hesitation and resistance among traditional farming communities (Gbetibouo, 2009; Moser & Ekstrom, 2010) ^[6, 13]. However, the existence of this limitation, even if considered less severe, highlights the difficulty of involving farmers who may resist changing traditional practices or be skeptical of new technologies. Addressing socio-cultural constraints is crucial for creating a supportive environment for CSAT adoption.

6. Infrastructure and Labour constraints

Table 1 illustrates that high labour charges are identified as the major constraint in this category (Rank I, MPS = 4.23), and they are viewed as a very severe barrier by a large proportion of

respondents (33.33%). Now a day, it was getting labor at low costs is very difficult. Lack of labour availability is the second-ranked constraint (Rank II, MPS = 3.92), with a majority of respondents (61.90%) citing it as a severe issue. The scarcity of available labor affects the feasibility of adopting labor-intensive practices. The unfavourable market is ranked third (Rank III, MPS = 2.29), this constraint points to the market-related challenges that affect the adoption of CSAT. An unfavorable market can include factors such as poor access to markets, low prices for climate-smart produce, or a lack of demand for sustainable products. This affects the economic viability of adopting CSAT for many farmers. Lack of space for installing water structures is seen as the least severe constraint (Rank IV, MPS = 2.28), with a significant number of respondents (63.33%) considering it somewhat of a constraint. Labour scarcity and rising wage rates are critical constraints in Indian agriculture, which directly impact the adoption of labour-intensive climate-smart practices (Birthal *et al.*, 2015; Jat *et al.*, 2016)^[3, 9]. While not as critical as the other factors, based on the findings, addressing these infrastructure and labor constraints is crucial for enabling the wider adoption of CSAT markets. Overcoming the challenge of limited space for water structures may involve innovative approaches to water management and conservation that are adaptable to small and constrained spaces. Together, tackling these constraints necessitates a coordinated approach.

Conclusion

The study comprehensively examined the multifaceted constraints hindering the adoption of Climate Smart Agricultural Technologies (CSAT) among progressive farmers across seven agro-climatic zones of Tamil Nadu. The findings reveal that despite a growing awareness of the importance of CSA in combating the adverse effects of climate change, farmers face several technological, informational, financial, institutional, socio-cultural, infrastructural, and labor-related challenges that limit effective adoption. Among the most severe constraints identified were high input costs, lack of labor availability, high labor charges, and the perception that benefits from CSA are realized only after a long time. Technological barriers such as the inaccessibility of quality inputs and lack of improved technologies also significantly affected adoption. Additionally, delays in the flow of information, weak institutional support, and limited access to credit further exacerbated these issues. Socio-cultural factors, including inter-farmer conflicts and traditional beliefs, while less severe overall, still presented localized barriers.

The study emphasizes that a one-size-fits-all approach is inadequate to address these diverse constraints. Instead, a region-specific, need-based, and integrated strategy involving government agencies, research institutions, extension systems, and community-based organizations is essential. Strengthening access to quality inputs, improving credit and subsidy mechanisms, enhancing farmer training and demonstration programs, promoting market linkages, and encouraging community participation can collectively help overcome the current adoption barriers. Ultimately, enabling the wider and more effective adoption of CSAT among farmers will not only improve productivity and resilience but also contribute significantly to sustainable agricultural development and climate change mitigation in Tamil Nadu and beyond.

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