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IMPLEMENTATION FEASIBILITY AND SUPPORT MECHANISMS FOR SCALING CLIMATE SMART AGRICULTURE INTERVENTIONS ACROSS DIFFERENT AGRO-ECOLOGICAL REGIONS IN INDIA

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ABSTRACT

Climate change poses a serious threat to agricultural sustainability, particularly in climate-vulnerable and rainfed regions where farmers have limited adaptive capacity. In this context, Climate Smart Agriculture (CSA) technologies offer viable solutions to enhance productivity, resilience, and sustainability of farming systems. However, the successful adoption and scaling of CSA interventions largely depend on their implementation feasibility, perceived barriers, and the effectiveness of incentive mechanisms and institutional support. The present study assesses the implementation feasibility of CSA technologies and examines adoption barriers, incentives, and institutional mechanisms under the National Innovations in Climate Resilient Agriculture (NICRA) project.

The study was conducted using an ex post facto research design in selected NICRA project villages, covering 540 stakeholders comprising farmers, Krishi Vigyan Kendra (KVK) staff, and line department officials. Implementation feasibility was analyzed across four dimensions-technical feasibilities, cost feasibility, gender inclusivity, and synergy with government schemes-using a Likert scale-based index. Adoption barriers, incentive mechanisms, and key institutions supporting CSA adoption were also assessed through stakeholder perceptions.

Results revealed that crop production technologies were perceived as the most feasible, followed by livestock and fisheries technologies, while institutional interventions and in-situ moisture conservation technologies showed lower feasibility. Acceptability of technology and lack of awareness emerged as the most critical barriers across most CSA domains, though their relative importance varied by intervention type. Capacity building and extension support were identified as stronger drivers of adoption than financial incentives. Public and community-based institutions, particularly Custom Hiring Centres and farmer groups, played a significant role in promoting CSA adoption. The study underscores the need for targeted extension strategies, enhanced institutional convergence, and context-specific support mechanisms to effectively scale CSA technologies in climate-vulnerable regions.

Keywords **:** Climate-Smart Agriculture, Implementation Feasibility, Incentive Mechanisms and Institutional Support.

Introduction

Climate change has emerged as one of the most critical challenges confronting global agriculture, particularly in developing countries like India where farming systems are highly sensitive to climate variability (FAO, 2013 and 2017). Increasing frequency and intensity of droughts, floods, heat stress, and erratic rainfall patterns have significantly affected agricultural productivity, water availability, soil health, and livestock performance (Birthal *et al.*, 2014). These impacts are more pronounced in rainfed and resource-constrained regions, where farmers possess limited adaptive capacity and coping mechanisms. In this context, enhancing the resilience of agricultural systems has become a key priority for ensuring food security, livelihoods, and sustainable development (Aggarwal *et al.,* 2004).

Implementation feasibility is a multidimensional concept that goes beyond technical soundness to include cost considerations, gender inclusivity, and alignment with existing government schemes and institutional frameworks. Even when farmers recognize the need for climate-resilient practices, adoption is often constrained by factors such as low acceptability of technologies, inadequate awareness, limited access to extension services, labour shortages, insufficient government support, and financial constraints (Chand *et al*., 2017). These barriers vary across technology domains and stakeholder groups, necessitating a differentiated and context-specific approach to promote CSA adoption (Lipper *et al*., 2014).

Recognizing these challenges, the Indian Council of Agricultural Research (ICAR) initiated the National Innovations in Climate Resilient Agriculture (NICRA) project to enhance the resilience of agricultural systems through participatory demonstrations, capacity building, and institutional strengthening in vulnerable regions (ICAR, 2011). While NICRA has facilitated the introduction of several climate-resilient technologies, systematic evidence on their implementation feasibility, adoption barriers, and the effectiveness of incentive mechanisms and institutional support systems remains limited (Tajpara *et al*., 2020).

Against this backdrop, the present study seeks to critically examine the implementation feasibility of CSA technologies under the NICRA framework, identify key barriers affecting their adoption across different intervention domains, and assess the role of incentives and institutions in promoting and scaling climate-smart practices (Singh *et al.,* 2021; Vinaya and Tapan 2023; Vinaya and Shivamurthy 2021). By capturing the perceptions of farmers, extension personnel, and line department officials, the study provides valuable insights for designing targeted policy interventions, strengthening institutional mechanisms, and enhancing the effectiveness of CSA programmes in climate-vulnerable agro-ecological regions. To assess the implementation feasibility of Climate-Smart Agriculture (CSA) technologies and identify the key barriers, incentive mechanisms, and institutional support influencing their adoption and scaling under the NICRA project.

Materials and Methods

The study was conducted in selected villages covered under the National Innovations in Climate Resilient Agriculture (NICRA) project, where Climate-Smart Agriculture (CSA) technologies have been implemented through participatory demonstrations, capacity-building programmes, and extension activities. An ex post facto research design was adopted to assess the implementation feasibility of CSA technologies and the support mechanisms influencing their adoption and scaling. A total of 540 stakeholders were selected using purposive sampling to ensure representation of key actors involved in CSA implementation. The respondents comprised 90 farmers, 150 Krishi Vigyan Kendra (KVK) staff, and 300-line department officers, all of whom had direct involvement in the planning, implementation, dissemination, or adoption of CSA interventions.

Implementation feasibility of CSA technologies was assessed based on four major dimensions, namely technical feasibility, cost of technology, gender inclusivity, and synergy with existing government schemes. These dimensions were identified through an extensive review of relevant literature and consultations with subject-matter experts. Stakeholders' perceptions on the importance of each dimension were measured using a Likert scale ranging from 0 to 5, where 0 indicated "not relevant" and 5 indicated "very high importance" (Joshi *et al.,* 2015). The Likert scale, widely used in social science research to assess human attitudes as an interaction of cognition, feelings, and actions, was employed to capture the subjective evaluation of respondents (Udmale *et al.,* 2014).

An overall CSA Implementation Feasibility Index (CSA-IF) was computed using a linear additive model by combining the weighted scores of the four feasibility dimensions. The index was expressed as CSA-IF = β_1 (technical feasibility score) + β_2 (cost score) + β_3 (inclusivity score) + β_4 (synergy with government schemes score), where β_1, β_2, β_3, and β_4 represent the relative weights assigned to each component based on expert judgment. Descriptive statistical tools such as mean scores and standard deviations were used to analyze the data and interpret the relative importance of each feasibility dimension. The composite feasibility scores provided insights into the key determinants influencing the implementation and scaling of CSA technologies in the NICRA project areas.

Result and Discussion

Implementation feasibility

Implementation feasibility refers to the extent to which an intervention can be easily implemented using the existing skills and knowledge of farmers. In the present study, implementation feasibility was analyzed in terms of technical feasibility, cost of the technology, gender inclusivity, and synergy with existing government plan

(a) Technical feasibility

Technical feasibility refers to the ability of farmers to adopt CSA interventions using their existing resources, skills, and knowledge. Figure 1 illustrates the technical feasibility of various CSA interventions. CSA technologies related to crop production recorded the highest feasibility scores, indicating that these interventions are comparatively easier for farmers to adopt with the available resources and knowledge. This was followed by water-saving technologies and livestock and fisheries technologies, with feasibility scores of 3.85 and 3.76, respectively. In contrast, institutional interventions and in situ moisture conservation technologies were perceived as comparatively less technically feasible than the other CSA interventions (Das *et al.,* 2014).

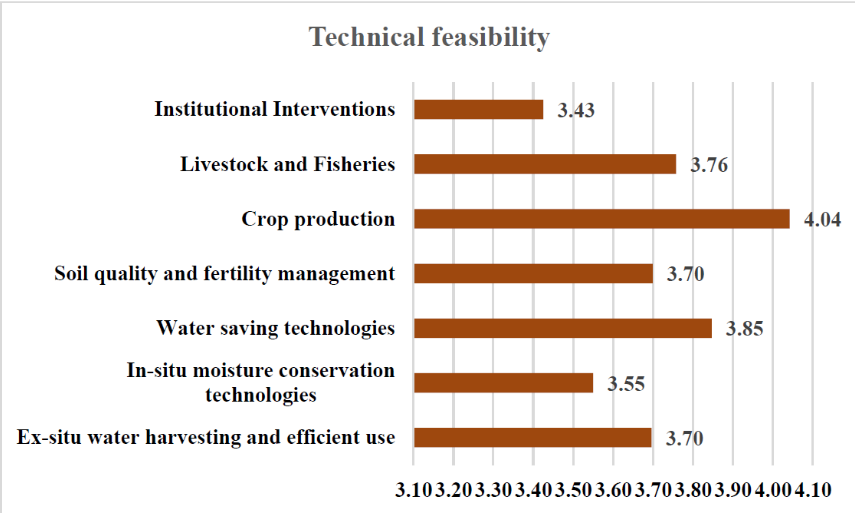

Fig. 1 : Technical feasibility of Climate Smart Agriculture

(b) Cost Feasibility

The cost of implementation is another critical factor influencing the level of adoption of CSA interventions. Among the various CSA interventions analyzed, soil quality and fertility management practices were perceived as the most cost-feasible, followed by crop production technologies. These interventions generally require comparatively lower investment and can be adopted partially depending on the availability of funds. In contrast, ex situ water harvesting interventions recorded the lowest feasibility scores, indicating that they are difficult to implement primarily due to their high cost requirements (Kumar and Singh, 2019).

Table 1: Cost Feasibility of Climate Smart Agriculture

S. No	Interventions	Cost	
		Individual	Group
1.1	Ex-situ water harvesting and efficient use	2.47	2.57
1.2	In-situ moisture conservation technologies	3.22	2.49
1.3	Water saving technologies	3.45	2.30
1.4	Soil quality and fertility management	3.78	2.68
2	Crop production	3.40	2.69
3	Livestock and Fisheries	3.25	2.24
4	Institutional Interventions	2.69	2.79

(c) Synergy with government plans

Synergy with government schemes refers to the extent to which an intervention is supported by existing government programmes and plans. CSA interventions that align well with government schemes tend to have higher adoptability, as part of the implementation burden is shared through subsidies, technical support, or institutional assistance. Among the interventions analyzed, technologies related to ex situ water harvesting and efficient water use exhibited the highest synergy with government schemes, with a score of 3.66, followed by crop production technologies. In contrast, in situ moisture conservation technologies showed the lowest level of synergy with government schemes (Meena *et al.*, 2016).

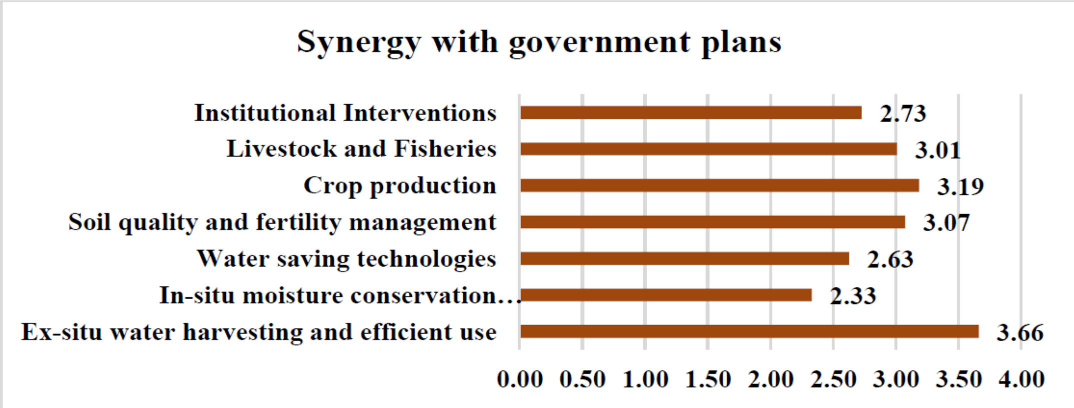

Fig. 2 : Synergy with government plans

(d) Inclusivity of women

This indicator captures the suitability of CSA interventions for women, as technologies that are appropriate for both men and women tend to have higher adoptability. Among the various CSA interventions, livestock and fisheries technologies recorded the highest female inclusivity scores, followed by crop production technologies, indicating that these interventions are comparatively more suitable for women than others. In contrast, water-saving technologies registered the lowest inclusivity scores, followed by in situ moisture conservation technologies.

Table 2: Inclusivity of women of Climate Smart Agriculture

S. No	Interventions	Inclusivity	
		Male	Female
1.1	Ex-situ water harvesting and efficient use	3.60	2.48
1.2	In-situ moisture conservation technologies	3.51	2.26
1.3	Water saving technologies	3.55	2.11
1.4	Soil quality and fertility management	3.70	2.35
2	Crop production	3.68	3.34
3	Livestock and Fisheries	3.07	3.35
4	Institutional Interventions	3.37	2.70

(e) Overall feasibility

The overall implementation feasibility of CSA interventions is presented in Figure. 3. Crop production technologies emerged as the most feasible interventions, with a feasibility score of 3.57, followed by livestock and fisheries technologies. In contrast, institutional interventions recorded the lowest feasibility scores, followed by in situ moisture conservation interventions.

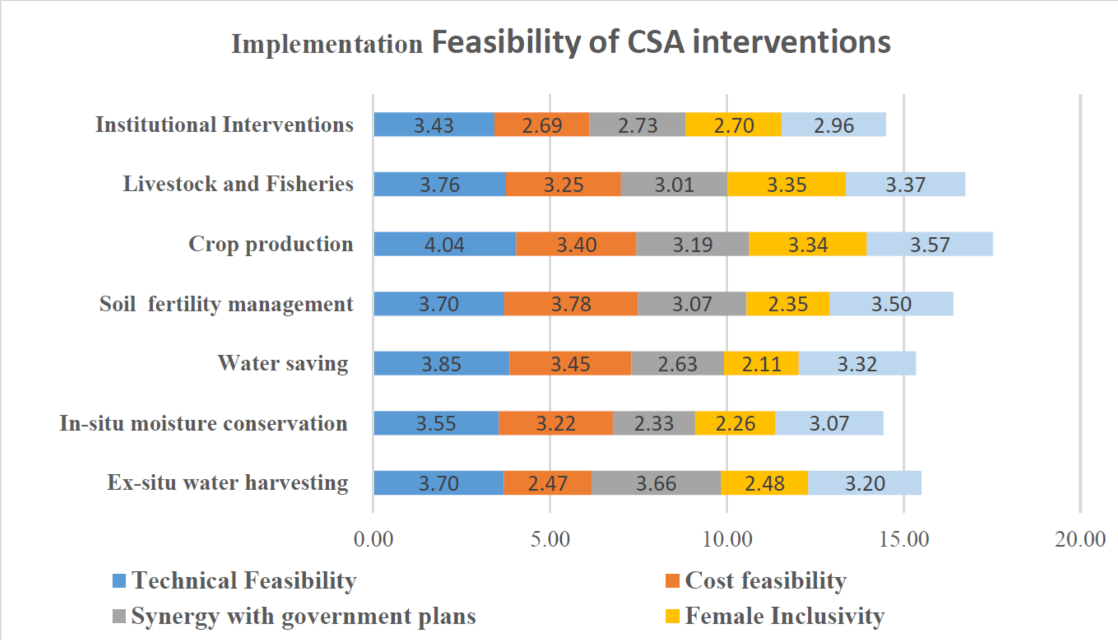

Fig. 3 : Implementation Feasibility scores of CRTs

1. Assessment of Adoption Barriers

Despite a strong felt need among farmers, the adoption of CSA technologies is constrained by several factors. Key barriers identified include availability of finance, availability of inputs, awareness of the technology, acceptability of the technology, availability of labour, availability of water, access to government support, and access to extension services. These barriers were assessed by various stakeholders using a 0–5 ranking scale. Among them, acceptability of CSA technologies emerged as the most critical barrier to adoption, with an overall score of 3.26. The low acceptability can be attributed to a variety of factors influencing farmers' perceptions and willingness to adopt these technologies. Lack of awareness about CSA technologies was identified as another major barrier, with a score of 2.98, as many farmers remain insufficiently informed about the benefits and long-term advantages of CSA interventions.

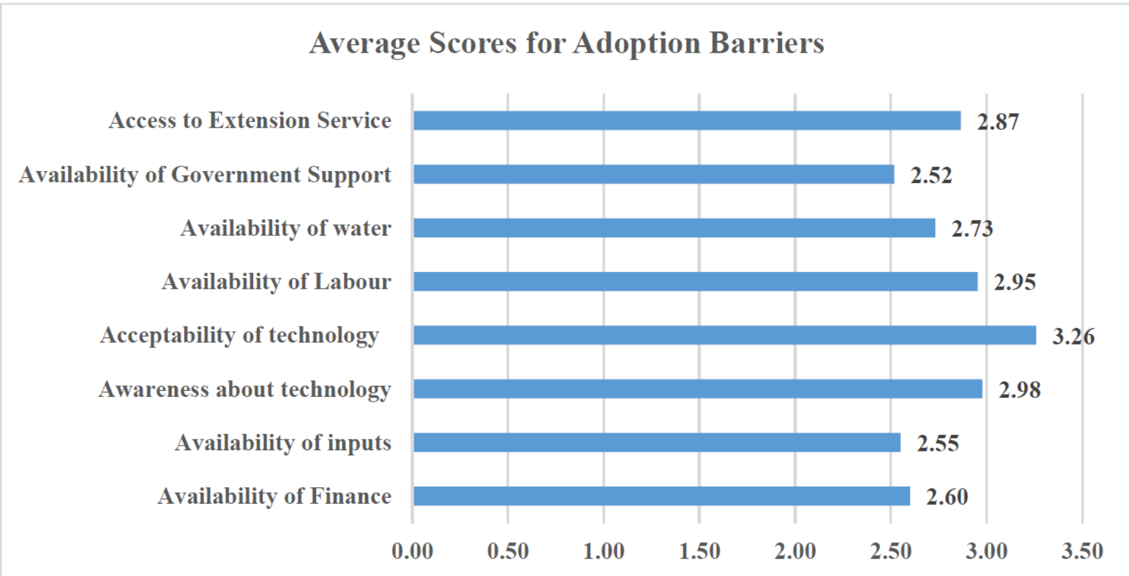

Fig. 4 : Average Scores for adoption barriers

Implementation Feasibility scores of CRTs

An examination of adoption scores across barriers indicates that acceptability of technology emerges as the major constraint for most technology groups, except crop production and livestock and fisheries technologies. In the case of crop production technologies**,** availability of labour is the most critical barrier, whereas lack of awareness about the technology ranks first for livestock and fisheries technologies. Further, awareness about technology occupies the second rank for ex-situ water harvesting and efficient use**,** in-situ moisture conservation, and water-saving technologies**,** while availability of government support ranks second for both livestock and fisheries technologies and institutional interventions.

For CSA technologies related to ex-situ water harvesting and efficient use, acceptability of technology, awareness about the technology, and access to extension services emerge as the major barriers, occupying the first three ranks, respectively; hence, addressing these constraints should be prioritized to enhance adoption. Similarly, awareness about the technology and acceptability of technology, together with availability of labour, constitute the top three barriers affecting the adoption of in-situ moisture conservation technologies, water-saving technologies, and soil quality and fertility management practices (Sharma *et al.,* 2015).

In the case of crop production technologies**,** availability of labour is the foremost constraint, followed by acceptability of technology and availability of government support. For livestock and fisheries technologies, awareness about the technology, availability of government support, and availability of finance are identified as the top three barriers to successful adoption. Finally, for institutional interventions**,** the key constraints that need to be addressed to improve adoption are acceptability of technology, availability of government support, and awareness about the technology**.**

Table 3: Interventions wise Scores of Adoption Barriers

S. No	CSA Interventions	Availability of Finance	Availability of inputs	Awareness about technology	Acceptability of technology	Availability of Labour	Availability of water	Availability of Government Support	Access to Extension Service
1.1	Ex-situ water harvesting and efficient use	2.53	2.70	3.53	4.09	3.14	2.89	3.00	3.35
1.2	In-situ moisture conservation technologies	2.93	2.67	3.40	3.71	3.30	2.81	2.36	3.16
1.3	Water saving technologies	2.97	2.61	3.37	3.61	3.21	3.37	2.47	3.10
1.4	Soil quality and fertility management	2.60	2.86	2.98	3.26	3.21	2.91	2.06	3.12
2	Crop production	2.38	2.39	2.45	2.94	3.18	2.25	2.63	2.36
3	Livestock and Fisheries	2.67	2.46	2.73	2.63	2.28	2.61	2.69	2.61
4	Institutional Interventions	2.12	2.17	2.39	2.58	2.36	2.29	2.42	2.37

2. Incentive mechanisms to promote CSA interventions

The results in Fig.5, indicate that access to capacity building was the strongest driver for adopting climate-resilient technologies (mean score: 3.23), emphasizing the role of training and technical support. Market linkages also influenced adoption positively (2.60).

In contrast, access to subsidies (1.97) and affordable credit (1.54) were perceived as weak enablers, showing limited effectiveness of financial support. Overall, the findings highlight that knowledge-based support is more critical than financial incentives in promoting the adoption of climate-resilient technologies. These findings are in align with Pokiya *et al*. (2024).

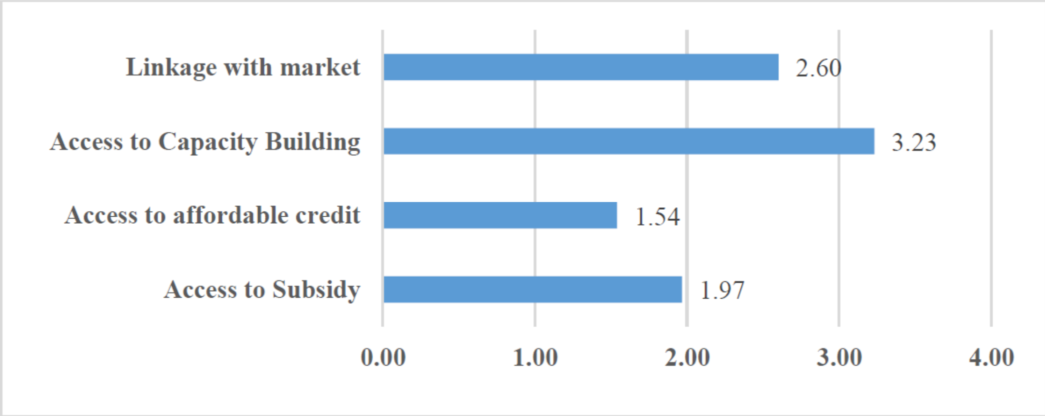

Fig. 5 : Average Scores for Incentives

Table 4: Interventions wise Scores for various incentives

S. No	CSA Interventions	Access to Subsidy	Access to affordable credit	Access to Capacity Building	Linkage with market
1.1	Ex-situ water harvesting and efficient use	3.02	1.37	3.16	2.86
1.2	In-situ moisture conservation technologies	1.18	1.37	3.32	2.35
1.3	Water saving technologies	1.64	1.59	3.63	2.78
1.4	Soil quality and fertility management	1.63	1.12	3.54	2.57
2	Crop production	1.92	1.54	2.98	3.01
3	Livestock and Fisheries	2.46	1.89	3.04	2.11
4	Institutional Interventions	1.90	1.90	2.94	2.53

4. Key Institutions to Scale out CSA

The findings in Fig.6, show that Custom Hiring Centres provided the strongest institutional support for adopting Climate-Resilient Technologies (CRTs) (mean score: 2.26). This was followed by Youth Farmers' Groups (2.06) and Women Self-Help Groups (2.02), highlighting the importance of community-based and collective mechanisms.

Moderate support was observed from Farmer Producer Organizations (FPOs) (1.20) and NGOs (1.12), while private sector retailers showed the weakest support (0.66). Overall, the results indicate that public and community institutions play a more effective role than private actors in promoting CRT adoption.

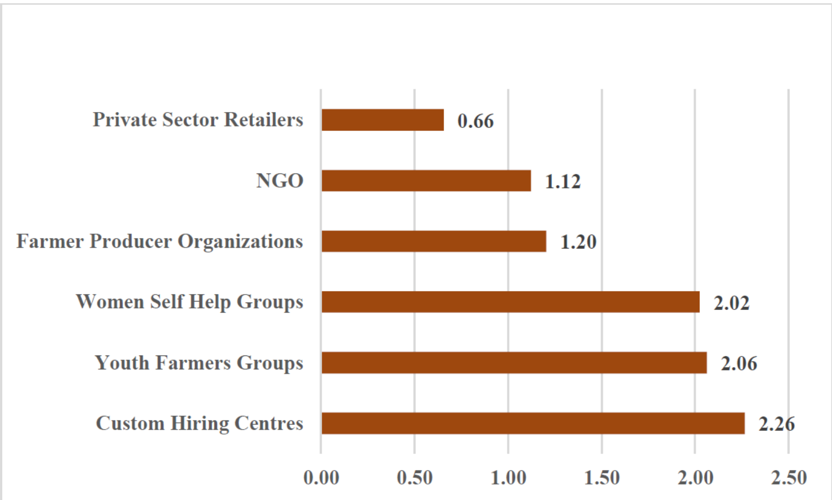

Fig. 6 : Key Institutions to Scale out CRT interventions

Table 5: Interventions wise scores for Key Institutions

S. No	CSA Interventions	Custom Hiring Centres	Youth Farmers Groups	Women Self Help Groups	Farmer Producer Organizations	NGO	Private Sector Retailers
1.1	Ex-situ water harvesting and efficient use	2.32	2.02	2.32	1.02	1.68	0.51
1.2	In-situ moisture conservation technologies	2.06	1.84	1.77	0.92	0.88	0.40
1.3	Water saving technologies	2.41	2.11	1.44	1.19	1.14	0.66
1.4	Soil quality and fertility management	2.34	2.02	2.05	0.89	0.95	0.77
2	Crop production	2.34	2.12	2.13	1.49	0.80	0.36
3	Livestock and Fisheries	2.06	2.05	2.18	1.33	1.20	0.81
4	Institutional Interventions	2.32	2.28	2.29	1.60	1.21	1.07

Conclusion

The study highlights that the adoption of Climate-Smart Agriculture (CSA) technologies is closely linked to their implementation feasibility and the nature of constraints perceived by stakeholders. Crop production technologies were found to be the most feasible, followed by livestock and fisheries technologies, whereas institutional interventions and in-situ moisture conservation technologies showed relatively lower feasibility. Across most CSA domains, acceptability of technology and awareness about the technology emerged as the most significant barriers, although their relative importance varied by intervention type. Labour availability was the major constraint for crop production technologies, while awareness, government support, and access to finance were critical for livestock and fisheries technologies. Water- and soil-related interventions were constrained by a combination of awareness, acceptability, labour limitations, and restricted access to extension services, underscoring the need for technology-specific adoption strategies.

The findings further reveal that capacity building and extension support are more influential than financial incentives in promoting CSA adoption. Community-based and public institutions, particularly Custom Hiring Centres, youth groups, and women self-help groups, played a vital role in facilitating access to CSA technologies and overcoming implementation barriers, whereas private sector support remained limited. Overall, the study emphasizes that strengthening awareness, improving technology acceptability, enhancing extension services, and ensuring convergence with government schemes are crucial for scaling CSA interventions. A coordinated and targeted institutional approach is therefore essential to translate CSA innovations into sustained climate resilience and improved livelihoods in vulnerable agro-ecological regions.

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