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Enhancing adaptation to climate change by fostering collective action groups among smallholders in Punjab, Pakistan

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Climate change adaptation is increasingly recognized by subsistence farmers in Pakistan. The problem of climate change is severe, and smallholders are often resource constrained when it comes to adapting to it. However, such constraints can be overcome through collective responses. Therefore, it is necessary to evaluate the impact of collective action among smallholder farmers to determine how it influences local adaptation processes. This study explores the impact of farmer's collective action groups (CAGs) on adopting climate-smart agricultural (CSA) practices in poverty-stricken areas of rural Punjab, Pakistan. The data was collected through a cross-sectional survey, and for the analysis purpose, the Recursive bivariate probit regression (RBP) model was employed. The first stage estimates of RBP models suggest that the farmer's decision to participate in CAGs is mainly influenced by factors such as education, credit access, climate change risk perception, and peer influence. The second stage estimates showed a positive and significant impact of farmers' participation in collective action groups on adopting climate change adaptation strategies across all three models. The study concludes that the farmers participating in collective action groups have a higher climate change adaptation level. It is recommended that the pro-poor policies be designed to negate the entry barriers, facilitate the inclusion of the farmers in the collective action groups, and enhance climate change adaptation among smallholders.

KEYWORDS

collective action groups, climate change adaptation, recursive bivariate probit regression, Punjab, Pakistan

1. Introduction

Anthropogenetic emanations of greenhouse gasses are intensifying at an alarming rate, causing a destructive impact on ecological systems (The World Bank, 2017; Aryal et al., 2018; Arif et al., 2019). The damages are apparent around the globe; seemingly, the South Asian population is highly vulnerable to such climate extremes due to low adaptive capacity and mitigation awareness (Turner and Annamalai, 2012; Aryal et al., 2020). Recent climate change events, such as droughts, rising temperatures, floods, and consequent yield losses, have endangered the livelihoods of the rural class (Ricciardi et al., 2018; FAO, 2019). Estimations suggest that cereal yield may decline up to 30% by the year 2059 (Parry et al., 2007). The projections indicate that, by the next decade, South Asia will have the maximum number of food-insecure people (Cai et al., 2016; Hasegawa et al., 2021). Pakistan is considered the most vulnerable to the recent climate extremes, ranked 12th on the global climate index (Kreft et al., 2017).

Such catastrophic events need to be tackled via appropriate adaptation strategies. Climate-smart agricultural practices (CSA) follow holistic measures that help achieve socio-cultural, biophysical, and economic benefits from agriculture (Sanz et al., 2017; Awazi et al., 2021; Quandt et al., 2023). Adopting CSA is a viable option, as it can enhance crop production, increase farmers' revenue, and minimize environmental damage (Deressa et al., 2011; Tilman et al., 2011; Manda et al., 2016; Kotu et al., 2017; The World Bank, 2017; Awazi et al., 2019; Jayne et al., 2019). These integrated systems may include organic manure (Ebewore and Emaziye, 2016; Mahmood et al., 2017), integrated pest management (Pretty and Bharucha, 2015), soil and water conservation (Blanco and Lal, 2008), stress-tolerant crop varieties (Raymond Park et al., 2011), and crop management (Congreves et al., 2015; Ghani et al., 2022) among others. These measures enhance agriculture production and ensure economically feasible and socially acceptable usage of natural resources (FAO, 2022). According to Schwilch et al. (2014), institutions significantly influence land-use changes and adoption of sustainable measures. Further, Rasul et al. (2011) documented that institutions usually govern the processes by which technical and scientific knowledge is developed and translated into the application, as well as assist in adopting environmentally sustainable farming methods.

Existing literature has explored a range of institutional factors influencing the adoption of CSA technologies, such as agriculture advisory service (Salaisook et al., 2020), technology transfer (Kassie et al., 2015), market orientation (Ismail et al., 2023), and agriculture supporting services (Huber et al., 2013). However, only a scant portion of the literature discusses the role of collective action groups (CAGs). The empirical evidence focuses on the effectiveness of social groups in smoothing the adoption process through shared information and learning (Foster and Rosenzweig, 1995; Conley and Udry, 2010). Economic theory recommends that a wide range of human decisions, including the adaptation to climate change, are substantially related to the social behavior of groups to which farmers belong (Foster and Rosenzweig, 1995; de Janvry et al., 2017).

The failure to involve local communities in the policy framework has primarily resulted in the lack of climate change adaptation. Multiple studies indicate the effectiveness of local processes in synergy with national adaptation initiatives (Sanginga et al., 2006; Oparok, 2015; Chanie et al., 2017). Brown and Sonwa (2015) posited that interactions between local and national institutions can enhance the adaptation and effectiveness of the national policy. Osbahr et al. (2008) highlighted the adoption of collective land-use management as one of the local solutions to climate threats in Mozambique and recommended strengthening the local institutions. Adger (2010) and Mekonnen et al. (2016) suggested that collective action is crucial to adaptive capacity. This study prompted the need for case-specific research on the importance of collective action for adaptive capacity at the local level in rural agricultural communities.

Collective action groups (CAGs) consist of cooperatives, associations, communal action groups, self-help organizations, and producer organizations intended to protect members' interests. CAGs help farmers access necessary farming inputs and acquire credit and extension services. In other words, CAGs benefit farmers by enhancing their environmental stewardship and reducing global hunger in the face of climate uncertainties (Okumu and Muchapondwa, 2017). Such groups help in engendering a collective response to climate change threats at the micro and macro levels (Aldrich, 2010; Kehinde and Adeyemo, 2020). CAGs can vary in size and structure, ranging from small local cooperatives to larger associations or networks (Bizikova et al., 2020), and serve as valuable platforms for knowledge exchange, capacity building, resource access, and advocacy, all of which contribute to the widespread adoption of climate-smart agriculture technologies (Holloway et al., 2000; Hellin et al., 2009; Meinzen-Dick et al., 2009; Moustier et al., 2010; Trebbin, 2014).

The literature reports the diverse impacts of CAGs in promoting agricultural technologies. Thuo et al. (2014) found that farmer organizations have little effect on adopting improved ground varieties in Kenya and Uganda. Similarly, Mwaura (2014) confirmed that CAG members were less likely to adopt improved pesticides, seeds, and fertilizer in Rwanda. However, Zhang et al. (2023) found that participation in CAGs directly influenced farmers' choices to employ green control technologies among fruits and vegetable growers in China. Ainembabazi et al. (2017) suggested that CAGs significantly and positively affected farmers' adoption of pro-environment agricultural technology and technical efficiency in Africa's Great Lakes region.

The literature considering the relationship between CAGs and the adoption of agricultural technologies varies and is inconclusive. This variability may depend on the specific technology being adopted, access requirements, and the socio-economic profiles of the group members (Chanie et al., 2017; Abdul-Rahaman and Abdulai, 2018; Addai et al., 2021). Moreover, within the context of Pakistan, there is a shortage of literature assessing the effects of farmer-based groups. So far, only a few researchers have discussed the role of CAGs in Pakistan (Murray-Rust et al., 2001; Sabir et al., 2012; Gillani et al., 2022). However, these studies' analyses are primarily correlational, lacking causal inference.

Hence, it necessitates empirical research to determine the impact of farmers' collective action groups on adopting climate-smart agriculture technologies. To our knowledge, no prior study has explored the effects of participation in collective action groups on climate change adaptations, specifically in the South Asian context. Current research aims to fill this gap and adds to the existing literature by examining the relationship between farmers' decisions to join farmer-based collective groups and its effects on adopting CSA technologies in southern parts of Punjab, Pakistan. Both decisions (CAG membership and CSA adoption) are binary and incurred concurrently; hence, CAG membership is likely endogenous. To address the endogeneity and selection bias issues, this study employed the recursive bivariate probit model (RBP) to explore the objectives.

1.1. Conceptual linkage between collective action groups and climate change adaptations

Based on the empirical literature, the current study explains that the contextual factors largely determine farmers' decision to participate in collective action groups. Climate change has halted the progression of the farming sector and inversely affected the farmer's

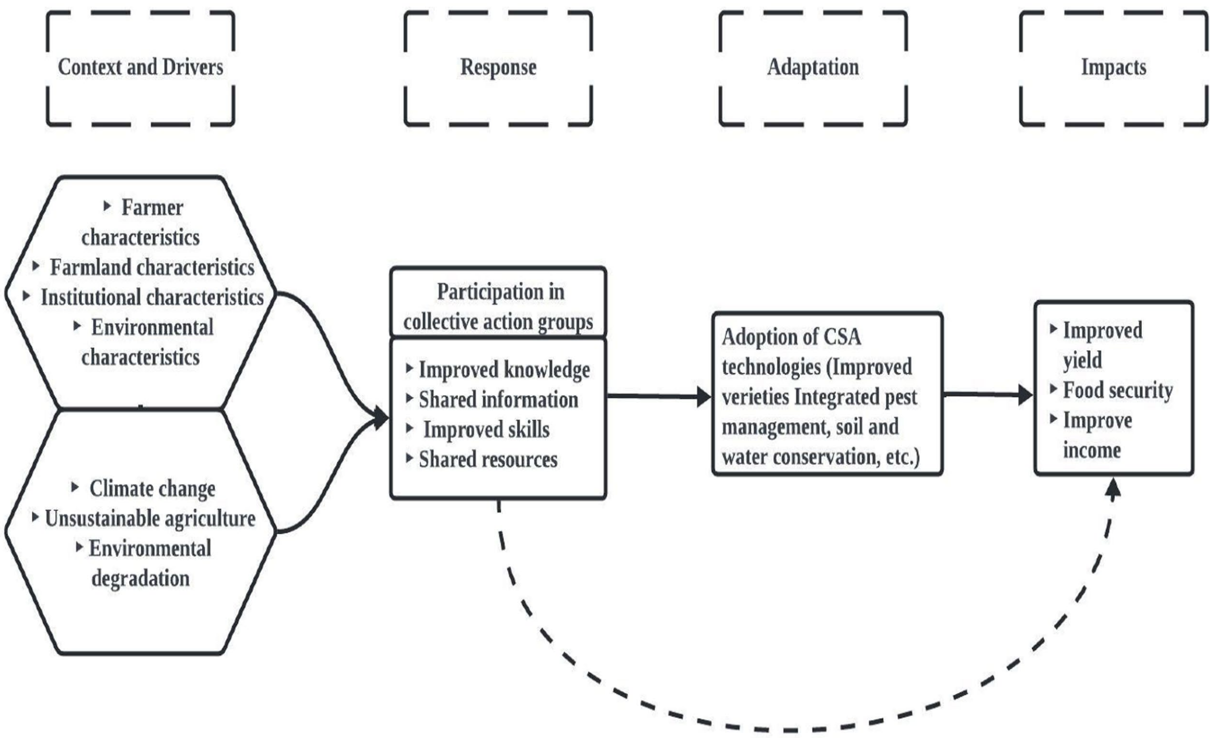

FIGURE 1
Conceptual framework.

livelihood. Hence, adaptation to climate change seems the only viable option to reverse the hazardous impacts of climate extremes. However, Climate-smart agricultural techniques are constrained by market imperfections, lack of awareness and financial resources (Mekonnen et al., 2018). Collective action groups are often described in numerous ways, specifically in the context of smallholder farming. It comprises several actors aiming toward shared purpose or interests among them (Meinzen-Dick et al., 2009; Fernández-Baldor et al., 2012). Collective action is primarily voluntary and takes different forms, such as making collaborative decisions, establishing standards of behavior and asset management, and putting policies into practice that directly affect communities in their daily lives (Ostrom, 2000). Other collective action activities involve pooling labor or financial resources or monitoring compliance with the guidelines.

A meta-analysis considering the adoption of soil management techniques emphasizes the positive role of information access in smoothing the way of adoption (Knowler and Bradshaw, 2007). Access to information can be gaged through group memberships (Lu et al., 2002; Mugonola et al., 2013; Kansiime et al., 2014). Membership in farming groups is crucial because it effectively disseminates information regarding new technologies and other activities related to market access. The empirical evidence shows the effectiveness of social networks in smoothing the adoption process through shared knowledge and learning from each other (Conley and Udry, 2010). A collection of networks (edges) between the cluster of individuals (nodes) signifies a network through which goods, services, and money flow (Maertens and Barrett, 2013). Collective groups facilitate interactions among the members, and decisions to adopt any agricultural innovation are influenced by shared experiences (Raymond Park et al., 2011). In the wake of natural disasters and low human index, multiple governments and non-governmental farmers' organizations (cooperatives, associations, producer organizations, etc.) are emerging in the region to improve farmers' well-being by connecting local communities and implementing integrative sustainable rural development. Adopting climate change adaptation techniques depends on farmers' perceptions of climate change and is primarily influenced by available information, socio-economic conditions, and agricultural operations (Kangalawe et al., 2017). Adoption is the extent to which farmers implement a new technology after receiving enough information about it and its potential benefits (see Figure 1).

2. Methodology

2.1. Study area and data collection

The study region is located in the southern parts (Figure 2) of Punjab, Pakistan. Such parts of the province are often vulnerable to climate catastrophes, such as floods, extreme temperatures, rainfall variations, and droughts; thus, most of the population suffers from poverty and malnutrition. Such parts carry the region's poorest, most vulnerable farming classes (Suleri and Iqbal, 2019; Jabbar et al., 2020a,b).

In the wake of natural disasters and low human index, multiple governments and non-governmental farmers' organizations are emerging in the region to improve farmers' well-being by connecting local communities and implementing integrative sustainable rural development. Numerous farmer-based groups exist in southern Punjab, Pakistan, such as cooperatives, associations, and producer organizations

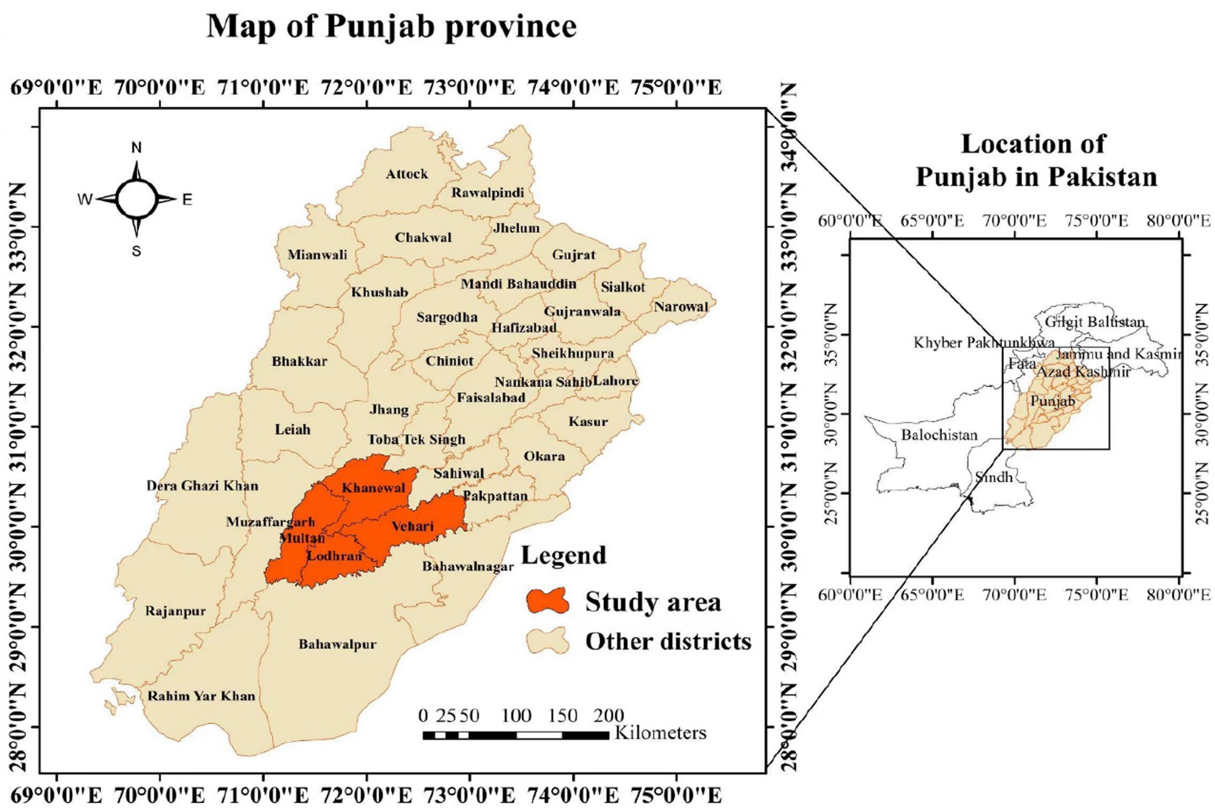

FIGURE 2
Location of the study area.

intended to protect members' interests. The study districts are homogenous in ecology and play a vital role in the country's agriculture.

$$n_0 = \frac{z^2 pq}{e^2} \frac{(1.64)^2 (0.5),(0.5)}{(0.04)^2} = 420 \quad (1)$$

Before data collection, a training session was conducted with a group of local university students for the enumeration purpose and all the guidelines concerning the data collection were communicated. We used a simple random sampling technique and a well-structured questionnaire to collect data. Based on the empirical evidence, we utilized the Cochran formula to determine the sample size of 420 (Equation 1) (Mukasa et al., 2020; Ojo and Baiyegunhi, 2020; Jabbar et al., 2020b; Myeki and Bahta, 2021). In the execution stage, verbal consent was obtained from the farmer at the start of an interview.

A prior stratification was not applied during the sampling procedure, ensuring equal chances of occurrences. At the first stage of data collection, the southern parts of Punjab province were purposively selected due to their agricultural contribution and the presence of collective action groups (Figure 3). In the second phase of data collection, four districts (Vehari, Khanewal, Multan, Lodhran) were chosen randomly. Sequentially, in the third phase, two sub-districts were further chosen. Subsequently, four union councils were selected from each of the sub-districts. In the fifth stage, five villages was selected from each union council. In the last step, 20 farmers from each village and 420 farmers were randomly selected in the fifth stage.

2.2. Data analysis

The data analysis for the existing study contains both descriptive and empirical research.

This study utilized the statistical package of Stata 14.0 for both the descriptive and empirical statistics. The descriptive analysis for this study explains the socio-economic characteristics of both the CAG members and non-members. The study utilized the recursive bivariate probit model to investigate the objectives. The RBP model seems a suitable option to examine the impact of binary endogenous treatment variables (Membership to collective action groups) on adopting binary outcomes (CSA technologies). RBP model is also helpful in controlling the observed and unobserved heterogeneities.

In comparison, the endogenous switching probit (ESP) model is also a sound econometric technique controlling for sample selection bias and endogeneity issues, but it lacks in estimating the marginal effects. Hence, given our interest in assessing the intensity and impact of the CAG membership on adopting CSA technologies, this study utilized the RBP model. It simultaneously estimates the choice of CAG membership and adoption of CSA technologies through the full information maximum likelihood (FIML) approach.

The following econometric framework explores the connection between farmers' decision to join CAGs and adopting CSA technologies (Abebaw and Haile, 2013; Ma et al., 2018).

$$y_1^* = \gamma Z' + \varepsilon, \text{ where } y_1 = 1 \; if \; y_1^* > 0, \text{ otherwise } y_1 = 0 \quad (2)$$

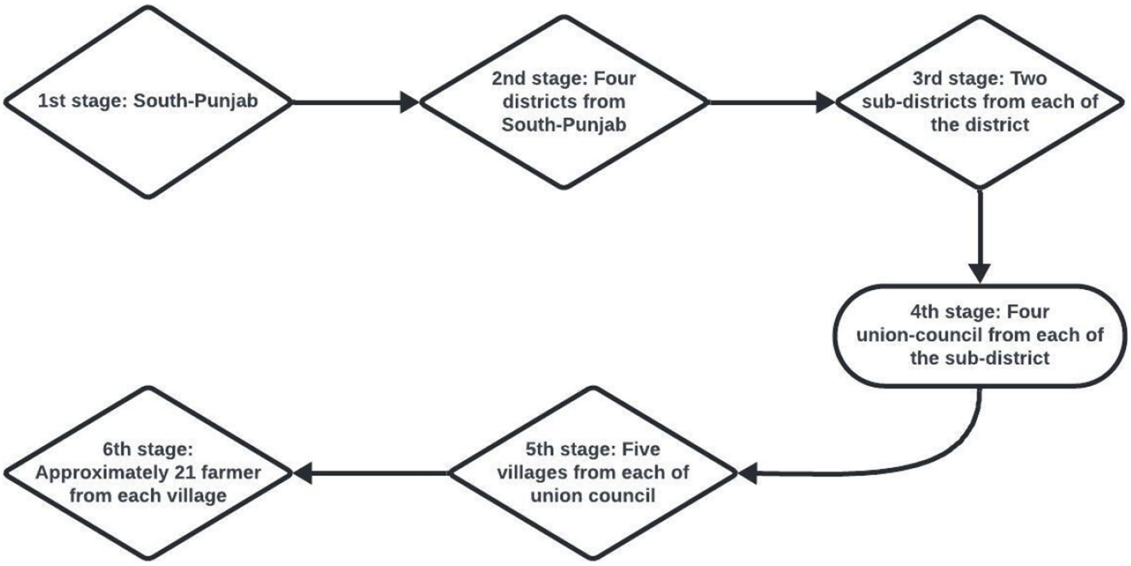

FIGURE 3
Sampling framework.

$$y_2^* = \varphi y_1^* + \lambda X' + \mu,\ \text{where}\ y_2 = 1 if\ y_2^* > 0,\ \text{otherwise}\ y_2 = 0 \quad (3)$$

y_1^* is an unobserved latent variable reflecting group participation, similarly y_2^* Specifying the climate change adaptation. The y_1^* the variable displays endogeneity in the y_2^*. y_1 and y_2 signify the observable choices (0 or 1), where X and Z are vectors of covariates while λ and γ are vectors of unknown parameters to be projected. The terms μ and ε are residuals expected to be normally distributed, with a variance of 1 and zero mean and a correlation coefficient equal to ρ (Cameron and Trivedi, 2010). ρ specifies the association among the unobservable explanatory variables in three models. A full information maximum likelihood (FIML) was applied to counter endogeneity issues (Wooldridge, 2010). Likewise, Chang and Mishra (2008) mentioned four possible outcomes of RBP models, as discussed below.

(1) Farmer joins the group and adopts a CSA technology $(y_1 = 1,\ y_2 = 1)$
(2) Farmer joins group but does not adopt a CSA technology $(y_1 = 1,\ y_2 = 0)$
(3) Farmer does not join the group and adopt a CSA technology $(y_1 = 0,\ y_2 = 1)$
(4) Farmer does neither join the group nor adopt a CSA technology $(y_1 = 0,\ y_2 = 1)(y_1 = 0,\ y_2 = 0)$

2.3. Variable specification

This study intends to explore the impact of farmer-based groups on adopting climate change adaptation strategies. Hence, the treatment variable for farmers' group membership is a dummy where 1 = if the farmer is a CAG member and otherwise = 0. The food production system is challenging, interconnected, and heavily reliant on natural ecosystems. For developing economies, adaptation to the effects of climate change is crucial. In agricultural systems, intentional and accidental responses to climate vulnerability preserve ecological balance and reduce financial losses. Climate change and adaptation strategies should work in synergy to make it easier for the country to adapt to recent challenges. With farm, sectoral, and national policy backing, farm-level adaptation measures can reduce climate losses.

We selected three frequently applied CSA technologies, including climate-resilient improved verities (IV), soil and water conservation (SWC) techniques, and integrated pest management (IPM) by the smallholders in Punjab, Pakistan (Ali et al., 2015; Abid et al., 2016; Ali and Erenstein, 2017; Jabbar et al., 2020b). Improved verities are genetically modified cultivars to boost yield and resilience against diseases, insect pests, drought, parasitic weeds, and other environmental factors (Joshi et al., 2017). Soil and water conservation are local actions that maintain or improve the productive potential of the land, including soil, water, and vegetation, in places prone to degradation (Bashir et al., 2018). IPM is an ecosystem-based strategy that focuses on long-term pest or damage prevention using a combination of tactics such as biological management, habitat manipulation, and cultural practice modification (Heeb et al., 2019). All adaptation strategies were taken as the dummy variable where if the farmer adopts any climate change adaptation strategy =1 otherwise = 0. We used current literature (Fischer and Qaim, 2012; Verhofstadt and Maertens, 2014; Mojo et al., 2017; Wossen et al., 2017) and anecdotal evidence to build the set of inputs or explanatory variables on what motivates farmers to join social groups. The following proxy variables could influence farmers' willingness to join CAGs. These include age, gender, education level, family size, land size, extension access, and peer influence (see Table 1 for definitions).

3. Results

3.1. Descriptive statistics

The membership status described in Table 1 reveals that approximately 63 of the sampled farmers were affiliated with

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non-government farmer development organizations in the study area. Additionally, around 51 and 48 of farmers were members of farming associations and cooperatives.

Table 2 shows the descriptive statistics reflecting an average year of schooling of 8, specifying that most farmers could read and write at an average age of 44 years; 75% percent of the respondents were males, and 57% were willing to take the risk. The average family size of 5.3 members per household. The average farm size was 3.24 acres, where 72% were owners. Around 62% of farmers were engaged in some off-farm activities. Among the institutional factors, nearly 48% of farmers had accessed credit, and 54% received an agricultural advisory recently. The average distance from the village to the main road was 3 kilometers. Peer influence is a crucial factor in stimulating the participation of farmer groups; peers' opinions influenced 58% of the participants. Nonetheless, it should be noted that the mean difference comparison may not consider other factors, which may compound the impact of CAG participation (Table 3).

3.2. Goodness of fit

We applied Murphy's score and Hosmer–Lemeshow tests to ensure the suitability of the RBP model. The findings showed that the p values are insignificant for both diagnostics mentioned above, suggesting the rejection of the Null hypothesis of normality and ensuring the suitability of the RBP model.

3.3. Recursive bivariate probit model

Table 4 presents RBP estimations for the determinants of CAGs membership and adopting CSA technologies. We also calculated the marginal effects for a better picture and meaningful results (Table 5). The Wald test for evaluating the null hypothesis that is statistically significant for all models suggests that the probability of farmers joining CAGs is indeed connected with their propensity to adopt CSA technologies. The rho across all three models significantly differs from

TABLE 1 Description of CAG members.

Membership status	No of CAG members
Member of farmer development organizations	63
Member of farmer associations	51
Member of agricultural cooperatives	48
Member of other self-managed farming groups	35
Total membership in collective action groups	197

TABLE 3 Goodness of fit measures for the RBP model.

	Hosmer–Lemeshow test	Murphy's score test
CAG membership and IPM adoption	chi2(9) = 11.52 Prob > chi2 = 0.2419	chi2(9) = 29.22 Prob > chi2 = 0.1089
CAG membership and SWC adoption	chi2(9) = 2.64 Prob > chi2 = 0.9767	chi2(9) = 12.57 Prob > chi2 = 0.9229
CAG membership and IV adoption	chi2(9) = 14.53 Prob > chi2 = 0.1048	chi2(9) = 17.95 Prob > chi2 = 0.6521

TABLE 2 Description and differences in characteristics of members and non-members statistics of the study.

Variable	Description	Mean	Non-members	Members	*T*-test
Integrated pest management (IPM)	Farmer adopt integrated pest management (1 = yes; 0 = no)	0.337	0.303	0.384	−1.773*
Improved verities (IV)	Farmer adopt improved verities (1 = yes; 0 = no)	0.357	0.311	0.423	−2.418**
Soil and water conservation (SWC)	Farmer adopt Soil and water conservation (1 = yes; 0 = no)	0.341	0.303	0.395	−2.009**
HH Age	Age number of years	44.756	44.614	44.956	−0.261
HH Education	Years of schooling	8.790	5.626	6.021	−9.185**
HH gender	Farmer is male (1 = yes; 0 = no)	0.753	0.754	0.752	0.050
Family size	Number of family members	5.380	5.015	5.895	−6.116
Risk attitude	Farmer is willing to take risk (1 = yes; 0 = no)	0.571	0.552	0.598	−0.966
ICT usage	Farmer is ICT user (1 = yes; 0 = no)	0.544	0.560	0.521	0.793
Farm ownership	Land owned in acres	3.216	3.322	3.065	0.512
Access to off-farm	Farmer is engaged in the off-farm activities (1 = yes; 0 = no)	0.620	0.636	0.696	1.331*
Credit access	Farmer has access to formal and non-formal credit services (1 = yes; 0 = no)	0.482	0.517	0.434	1.725*
Extension access	Access to extension services (1 = yes; 0 = no)	0.587	0.386	0.473	−4.169***
Risk perception of extreme temperature	Farmer perceive the risk extreme temperature (1 = yes; 0 = no)	0.722	0.739	0.697	0.955
Risk perception of rainfall variation	Farmers perceive the risk of rainfall variation (1 = yes; 0 = no)	0.548	0.490	0.631	−2.959**
Distance to the main road	Distance to the main road in kilometers	3.003	3.063	2.920	0.676
Peer influence	The nearest neighbor is an organizational member (1 = yes; 0 = no)	0.460	0.369	0.587	−4.618**

***, **, and * specify significance level at $p \leq 0.005$, $p \leq 0.05$, and $p \leq 0.1$, respectively.

TABLE 4 The estimates of the RBP model for the impact of collective action groups on adopting climate smart agriculture practices.

	Model 1		Model 2		Model 3	
	CAG membership	IV	CAG membership	IPM	CAG membership	SWC
HH age	0.002 (0.005)	−0.001 (0.004)	0.003 (0.005)	0.003 (0.004)	0.003 (0.005)	0.003 (0.004)
HH gender	−0.024 (0.164)	0.204 (0.143)	−0.025 (0.166)	0.148 (0.144)	−0.014 (0.165)	0.164 (0.142)
HH size	0.033 (0.022)	0.008 (0.018)	0.027 (0.022)	0.012 (0.018)	0.024 (0.022)	0.012 (0.019)
HH education	1.161*** (0.134)	−0.278 (0.176)	1.151*** (0.133)	−0.291 (0.195)	1.151*** (0.134)	−0.340 (0.196)
Risk attitude	−0.078 (0.172)	0.154 (0.147)	−0.133 (0.179)	0.050 (0.154)	−0.151 (0.178)	0.034 (0.151)
ICT usage	0.099 (0.175)	0.059 (0.147)	0.170 (0.185)	0.336** (0.159)	0.191 (0.185)	0.306* (0.156)
Farm size	0.011 (0.014)	−0.002 (0.011)	0.014 (0.014)	0.001 (0.012)	0.015 (0.014)	0.001 (0.011)
Distance to main road	−0.036 (0.031)	−0.032 (0.029)	−0.038 (0.031)	−0.024 (0.029)	−0.038 (0.031)	−0.029 (0.029)
Access to off-farm	0.075 (0.194)	−0.439** (0.162)	0.051 (0.193)	−0.631*** (0.171)	0.051 (0.193)	−0.613*** (0.170)
Access to off-farm	0.075 (0.194)	−0.439** (0.162)	0.051 (0.193)	−0.631*** (0.171)	0.051 (0.193)	−0.613*** (0.170)
Risk perception of rainfall variation	−0.259 (0.164)	0.160 (0.142)	−0.262 (0.167)	0.127 (0.142)	−0.244 (0.132)	0.148 (0.140)
Risk perception of extreme temperature	0.377** (0.144)	0.011 (0.140)	0.361** (0.143)	0.024 (0.150)	0.369** (0.142)	−0.014 (0.146)
Credit access	−0.439** (0.144)	0.243* (0.130)	−0.423** (0.146)	0.168 (0.133)	−0.426** (0.145)	0.157 (0.132)
Extension access	0.310** (0.101)	0.141* (0.040)	0.121** (0.036)	0.108 (0.101)	0.226** (0.045)	0.119 (0.122)
CAG membership		1.234*** (0.385)		1.249** (0.433)		1.356*** (0.394)
Peer influence	0.458** (0.168)		0.449** (0.174)		0.391** (0.188)	
Constant	−6.946*** (0.862)	0.630 (0.950)	−6.877*** (0.858)	0.507 (1.064)	−6.882*** (0.865)	0.742 (1.042)
Rho ρ	−0.812* (0.420)		−0.967* (0.550)		−0.837 (0.211)	
Log-likelihood	−473.995***		−459.039		272.66***	
Wald x^2	193.79		252.75***		2.918*	
Wald test rho $\rho = 0$: x^2 (1)	3.7373*		3.082***			

***, **, and * specify significance level at $p \leq 0.005$, $p \leq 0.05$, and $p \leq 0.1$, respectively.

zero, indicating the possibility of selection bias resulting from unobserved variables. The results in columns one, three and five showed that education, credit access, extension access, climate change risk perceptions, and peer influence significantly determined farmers' decisions to participate in collective action groups. The results considering the adoption of CSA technologies are presented in columns two, four, and six of Table 2. Findings highlighted the significant effects of ICT usage, off-farm participation, credit access, and CAGs membership on adopting CSA technologies.

4. Discussion

Based on the cross-sectional survey across the disaster-prone areas of the Punjab province, Pakistan, this study examines the impact of collective action groups in adopting climate-smart agricultural practices. The research utilized the recursive bivariate probit model to explore the objectives. The below section aligns the findings of this study with the empirical literature and intricate the policy implications.

4.1. Determinants of CAG membership

The years of educational attainment are positive and significantly related to farmers' decisions to participate in collective action groups. Education increases the farmer's awareness and ability to obtain necessary information considering farming decisions. Likewise, Chanie et al. (2017) confirmed a significant positive role of education in participating in farmers-based groups in Ethiopia. Similarly, Gurung and Choubey (2023) also reported a significant and positive relation between education and farmers decision to participate in farmer-based groups in India.

The scarcity of financial resources is one of the core reasons to participate in collective action groups (Gertler, 2004). Thus, farmer groups are likely to resolve financial constraints. This study reported significant mean differences among households having a credit source other than the farmer organization, suggesting that the probability of joining a CAG is less when the household has access to additional credit sources. Hence, the probability of accessing alternative financial resources influences the likelihood of joining a farmers-based organization. Accordingly, Nugusse et al. (2013) supported financial institutions' significant influence in determining farmers' decision to join agrarian groups.

Risk perception of extreme temperature is significantly and positively related to farmer-based groups' participation. Farmers with climate change risk perception are likelier to participate in farmers-based groups. Smallholders are often more vulnerable to climate extremities due to low adaptive capacity. Collective action groups mobilize the information and resources to address climate change threat (Ireland and Thomalla, 2011). Likewise, Ombogoh et al. (2018)

TABLE 5 Marginal effects of RBP model for the impact of collective action groups on adopting climate-smart agriculture practices.

	CAG membership	IV	CAG membership	IPM	CAG membership	SWC
HH age	0.001	0.001	0.000	−0.000	0.000	0.001
HH gender	−0.003	0.050	−0.006	0.066	−0.006	0.046
HH education	0.006	0.003	0.008	0.002	0.007	0.004
Family size	0.309	−0.105	0.308	−0.090	0.307	−0.091
ICT usage	0.051	0.095	0.026	0.019	0.045	0.105
Risk attitude	−0.040	0.010	−0.020	0.050	−0.035	0.015
Access to off-farm	0.013	−0.190	0.019	−0.142	0.013	−0.197
Farm ownership	0.004	0.000	0.003	−0.000	0.003	0.000
Distance to main road	−0.010	−0.009	−0.009	−0.010	−0.010	−0.007
Risk perception of rainfall variation	−0.065	0.046	−0.069	0.052	−0.070	0.039
Risk perception of extreme temperature	0.099	−0.004	0.100	0.003	0.096	0.007
Extension access	0.034	0.082	0.031	0.029	0.025	0.104
Credit access	−0.114	0.048	−0.116	0.079	−0.113	0.052
CAG membership		0.420		0.401		0.391
Peer influence	0.105		0.121		0.120	

and Ogunleye et al. (2021) support farmers-based groups' positive role in enhancing smallholders' adaptive capacity against climate variability.

Access to extension services is significantly and positively related to joining farmer-based organizations. Extension advisory communicates the benefits and persuades farmers to join farming associations. Circumstantially lacking information considering the farmer-based organization's benefits is a crucial reason for not joining CAGs (Thuo et al., 2014). Hence, access to information through governmental and non-governmental sources enhances the likelihood of joining CAGs. Accordingly, Nugussie (2010) suggests that recurrent extension visits increase farmers' awareness concerning the importance of farming organizations. Similarly, (Adi et al., 2021) found significant and positive impact of extension access and joining collective action groups among the Indonesian tobacco and sugarcane growers.

The association between peer influence and farmers' decisions to join agricultural organizations is significant and positive. Peer influence develops trust and willingness among households to join farmer groups and enjoy the same privileges as their peers. The findings also derive support from Ma and Abdulai (2016), who suggested the positive role of peers in stimulating the inclination toward joining agricultural organizations.

4.2. Determinants of adopting CSA technologies

Considering the usage of ICT, the results specify the significant and positive association between ICT usage and climate change adaptations, as the ICT users were 1.9 and 10% more likely to adopt IPM and SWC practices, respectively. The findings imply that endorsing ICT usage via a well-integrated approach by linking experts from different areas such as meteorology, crop protection, crop production, and input markets may broaden the ICT range. As suggested by Quandt et al. (2020) ICT should be a compulsory part in any government and non-government extension programs. Likewise, Ma and Wang (2020) reported a significant and positive relationship between ICT usage and the adoption of CSA technologies.

The coefficient of off-farm participation is significant and negative, indicating the inverse relationship between off-farm participation and adoption of CSA technologies. Off-farm work involves considerable labor, leaving little time to engage in on-farm activities. Besides, some farmers quit farming in the harsh climate and shifted to non-farm work. Ouma and Abdulai (2009) and Huang et al. (2019) also found that farmers with alternative sources of income are less likely to invest in sustainable agriculture practices. Contradictorily, Issahaku and Abdul-Rahaman (2019) reported a significant and positive impact of off-work in adopting soil and water conserving practices in the rain-fed areas of Ghana.

The findings indicated that farmers with credit access are 4,7, and 5% more likely to adopt improved verities, integrated pest management, and soil and water conservation practices. Credit arrangements are crucial in arranging the finance required for capital-intensive agricultural technologies. Likewise, Deressa et al. (2009) found a significant and positive relationship between credit access and climate change adaptation decisions in Nile basin of Ethiopia. Similarly, Olutumise (2023) also reported a significant and positive impact of credit access on adopting CSA technology among the smallholders of Nigeria.

Access to extension services is significantly and positively related with farmers decision to adoption improved verities. The extension advisory assists farmers in adopting a CSA technology and communicates its benefits. Circumstantially lacking information considering the CSA benefits is a crucial reason for not adoption. Hence, access to extension advisory enhances the probability of adopting CSA technologies. Similarly, Afroz and Akhtar (2017) found significant and positive impact of extension access and adoption CSA technologies among the Malaysian farmers.

Farmers' membership to collective action groups (CAGs) was significantly and positively related to the adoption of CSA technologies, as members were 42, 40, and 39% more likely to adopt improved verities, integrated pest management, and SWC practices, respectively. CAGs enable a collective environment that facilitates the optimization of shared resources such as funds, skills, knowledge, and labor. It improves farmers' adaptive capacity and awareness level, which ultimately promotes sustainable agriculture. Social contacts help disseminate information and increase awareness about agriculture technologies suitable for adaptation. Similarly, Awazi et al. (2019) stressed upon the importance of information access on farmers climate change adaptation decisions. Empirical evidence confirms the effectiveness of social networks in smoothing the adoption process of shared information and learning from each other (Foster and Rosenzweig, 1995; Conley and Udry, 2010). Likewise, Wossen et al. (2017) indicated that farmers with group membership were likelier to adopt the latest agricultural technologies than non-members. Further, in a review-based study, Bizikova et al. (2020) found that CAG members are more environmentally responsible and likely to adopt sustainable agricultural methods. Hence, policymakers should encourage social interactions among farmers, as peer influence can motivate others to join CAGs and embrace environment-friendly farming technologies (Ma, 2016).

4.3. Policy implications

This research provides useful, practical implications. It provides deep insights into the current literature on climate change adaptation, organic farming, and sustainable agriculture. A key finding of this study shows that CAGs contribute to the widespread adoption of CSA technologies in developing countries. It describes how the institutional role of CAGs manifests in adopting CSA technologies in developing countries. It advocates institutional transformation to promote and broaden climate-smart farming strategies. Hence, it is crucial to consider local institutional arrangements for collective action and governance processes to prepare for climate risks and adapt accordingly. Farmers can gain access to resources, skills, practices, and information due to improved governance processes within farmer groups. The creation of social safety nets and the application of risk reduction mechanisms can contribute to the reduction of vulnerability to climatic risks in the study sites. It is imperative to enhance technological skills and strengthen rural institutions' capacity to act collaboratively to facilitate adaptation. Thus, farmer groups must develop soft skills (critical thinking, problem solving, interpersonal, adaptability, etc.), as the capacity of governance processes and collective action for smallholder farmer groups depends on soft skills. To ensure access and benefit sharing, households must also learn how to mobilize and manage physical and financial assets. Though there is a strong presence of multiple government and non-government projects aiming to enhance climate change adaptation in the study area, smallholder farmers need to be recognized and involved in adaptation planning at the local level.

5. Conclusion

Climate change has affected every aspect of human life in the worst possible way. Developing countries continue to face devastations caused by climate change in the form of low crop yield, floods, food insecurity, and poverty. Lack of resources is considered the pertinent hindrance to climate change adaptation. To this end, smallholders in developing countries form groups to overcome resource and information constraints. Farmers' groups disseminate information about agricultural technologies and lessen the transaction cost to manage the risk associated with climate change. In this study, we examined the impacts of collective action groups on adopting CSA technologies among smallholders in rural Punjab, Pakistan. We employed the recursive bivariate probit model to explore the objectives. The first stage probit estimates of the RBP model showed that the decision to join CAGs is primarily determined by non-farm participation, credit access, extension access, and peer influence. The second stage estimates of the RBP model showed that CAG members are more likely to adopt CSA technologies.

Notably, extension access and peer influence positively influence the farmers' decision to join the CAGs. The findings call for strengthening the extension system at the governmental and non-governmental levels to encourage the formation of CAGs. Relevant agencies should pay attention to spreading awareness, advancement of institutional coverage, and rural infrastructures to stimulate the rural public in forming social networks, thus solving socio-economic and food security issues. In designing policies to encourage the voluntary adoption of CSA technologies, it is imperative to consider the importance of social interactions among farmers. Policymakers should specifically consider supporting collective group initiatives, where farmers can exchange information and share their farming experiences with fellow group members.

Further, policymakers should ensure that CAGs access better seeds, farming inputs, organic fertilizer, and integrated pest management equipment, which can be better achieved through public–private partnerships. The pro-poor policies must be designed to eliminate entry barriers and facilitate inclusion in the farmers' group activities. Future research may consider the influence of social norms and beliefs on smallholders' climate change adaptation decisions and group participation decisions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AJ: conceptualization, data analysis, data description, explanation of results, and writing. WL and JL: data analysis and writing. YW and JP: conceptualization, methodology, explanation of results, reviewing, and editing. JZ and QW: conceptualization, explanation of results, reviewing, and editing. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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