Adoption of Climate Smart Agricultural Practices in Punjab (Pakistan)

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Abstract
Pakistan is a vulnerable country in terms of both climate change and food security. With respect to food security, climate change can potentially affect crop production and access to affordable food. This research examined the adoption of Climate Smart Agriculture (CSA) through five key practices: i) balanced use of chemicals, ii) integrated pest management, iii) formal irrigation techniques, iv) knowledge of climate smart varieties, and v) change in crop calendar. The adoption of these CSA practices is assessed for farmers of wheat (a major crop in the food basket of Pakistan). The determinants of adoption were estimated using the Probit model. With the help of Data Envelopment Analysis (DEA) farm efficiency (technical) is calculated employing the survey of 384 farmers from Punjab. The results of the study suggest that only 17.4 percent of the farmers are adopters of CSA practices. The determinants, like farmer education, income, land ownership, etc., have a positive impact on adoption. Whereas age, land use, and distance from nearby city centers have negative associations with adoption. Based on the results and outcomes of the study, CSA practices are critical and hold the key to improving food security in the country. Adoption of CSA practices can help in attenuating the vulnerabilities of farmers to climate change.

Keywords: Climate Smart Agriculture; Adoption of CSA Practices; Food Security; Agriculture.

Introduction
The concept of food security reflects upon the *"physical and economic access to sufficient safe and nutritious food*," which meets the dietary needs for food, helping for an active and healthy life (FAO, 2008). Food security is an integral part of human security which is defined as the non-traditional threats to the security and survival of the individuals (Caballero-Anthony, 2015). A total of 9.8 million acres (4 million hectares) of agricultural land was destroyed in Pakistan in recent floods, which caused $30 billion in financial losses. Besides this crop loss, 927,543 livestock deaths were also witnessed in the floods of 2022 (Chugtai, 2022).
Food security can cause civil unrest and conflict, triggered in many ways like sudden food price rises or unavailability of affordable food basket items for the masses, which may turn into grievance, deteriorating the overall security situation of the country (Khalid, 2018). Unplanned

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urbanization, migration, and human displacements due to climate change can potentially affect both food security and human security, ultimately resulting in a profound conflict (Caballero-Anthony, 2015).

Pakistan remains a highly vulnerable country in terms of both climate change and food security. Though Pakistan is contributing less than 1 percent of GHG emissions however it is one of the most exposed to climate change impacts. Pakistan has an agricultural economy, and changes in glacial melt are threatening the irrigation system along with risks of floods and droughts. According to the latest State of Food Security and Nutrition report, the world is moving backward in terms of eliminating hunger and malnutrition. The number of people who are affected by hunger will be 828 million in 2021 (an increase of about 46 million since 2020). There are around 2.3 billion people in the world who are moderately or severely food insecure as per 2021 statistics (World Health Organization, 2022). The World Food Programme (WFP) estimated that 43 percent of Pakistanis are food insecure, and 18 percent have acute food insecurity (Kamal, 2021).

Both concepts are intertwined and will determine the scale of challenges faced by Pakistan in years to come. To meet non-traditional security challenges where human security is at the core, it is important to assess the adversities of climate change on human life. With respect to food security, climate change can potentially affect crop production and access to affordable food, agricultural livelihood, urban migration, and poverty rate.

Climate Smart Agriculture (CSA) can be comprehended as a strategy that helps to cope with the challenges of climate change and food security through sustainable means, which affect overall yield and productivity, increase climatic resilience, and also help in reducing GHG emissions. Climate Smart Agriculture (CSA) can be basically introduced as an innovative and sustainable agricultural system (Jamil et al., 2021). The adverse impact of climate is associated with the food security issue, which is part of the overall human security paradigm (Khalid, 2018). United States Institute of Peace mentioned that Pakistan is in the midst of a terrible heatwave, and the temperature in parts of the country is exceeding 120F. Massive flooding has damaged infrastructure, and shortages of water in Karachi are creating a weak electrical grid. Moreover, changes in monsoon rain patterns are all threats to agriculture (Siddiqui, 2022). Mustafa et al. (2021) explored that variations in temperature and precipitation generate differences in crop yields. Food Security can be segregated into the following:

1. Availability of Food
2. Accessibility of Food
3. Utilization of Food
4. Prevailing Conditions of Food Insecurity

In this view, CSA helps to achieve food security and long-term development goals (FAO, 2010). Pakistan is now considered to be a highly vulnerable country, faced with the adversaries of climate change, which negatively impacts agricultural productivity, thereby deteriorating the overall food security situation, poverty, and livelihood of the population (Abid et al., 2016; Saeed et al., 2012). Importantly, most of the empirical studies reflect upon the fact that CSA practices and technologies help in the mitigation of the negative impact of climate change. Moreover, the CSA practices also help with crop yield and resource use efficiency (Jamil et al., 2021; Mutenje et al., 2019; Wassmann et al., 2019).

The adversities of climate change, including increased temperatures and other associated extreme events, are a threatening situation for the sustainability of agriculture and, hence, food security in Pakistan, where it can risk the future yield and productivity of all major crops (Sardar et al., 2021). The studies indicate that there are significant variations in the rainfall and the temperatures are also expected to rise in the coming decades (Imran et al., 2018). In light of this, the adoption of CSA measures is imperative, focused on awareness of water use, technology, and climate-resilient inputs (Brandt et al., 2017).

The adoption of Climate Smart Agriculture (CSA) is the adoption of a set of practices that help the current farming systems to improve their climatic resilience alongside resource use efficiency at the farm level (Sardar et al., 2021). Furthermore, it is important to identify the enabling activities and tools and to support the ecosystem through the use of practices like nutrient management, climate-resilient water, and input resource use (Lunduka et al., 2019). Currently, the Government is providing a few interventions regarding CSA, which include the provision of heat-resistant certified seeds for a few crops, water-saving technologies and mechanization, etc. However, some argue that there are social, market as well as institutional barriers with respect to upscaling the adoption of CSA practices.

A vast number of studies and literature reflects on the adoption of CSA practices across the globe and, thereby, the need for a gradual shift from a technology-oriented to a more systems-oriented approach for a better understanding of the complexity of farming systems (Sardar et al., 2021). It includes different interventions like market infrastructure, interaction between the public and the private sectors, and the context in which farming is taking place (Totin et al., 2018; Thornton et al., 2018). Similarly, some studies indicate that the application of CSA practices raises crop productivity, resource use efficiency, and farm incomes (Mutenje et al., 2019)

Adaptation, mitigation, and food security are all interrelated and important pillars of CSA; besides, they have significant implications for farmers, especially the vulnerable ones (Chandra et al., 2018). However, many institutional barriers impede the adoption and upscaling of CSA practices (Chandra et al., 2018). In most of the CSA interventions, location and knowledge of CSA interventions play a pivotal role and, therefore require considerable capacity development (Neufeldt et al., 2013).

A major staple crop of Pakistan is wheat, which also contributes to the dietary needs of the population of the country, and empirical studies suggest that its yield is impacted by climate variability (Sultana, 2020). The aggregate wheat yield is already being affected by the mean variation of temperature and rainfall, especially in the sowing season of wheat crops. In contrast, the rainfall variability is estimated to increase from 10 percent in the year 2050 to 17 percent by 2099. It could result in more adversities for the crop, which will also have socioeconomic costs (Seaman et al., 2014). It is estimated that by 2040, with temperature rising, the aggregate agricultural production may decrease by around 8–10 percent (Cradock-Henry et al., 2020). In recent times, increased temperatures and reduced rainfall, besides increasing wheat prices in Pakistan, have already added to the vulnerability of households at the farm level (Rosenzweig et al., 2018).

As for agricultural productivity, the studies indicate that increasing temperatures affect the growth of rice, wheat, and cereals (Lobellet al., 2011). Different varieties of agricultural products are adversely affected by the changing climate. Countries must adopt techniques and technologies that are crucial for agricultural sustainability to adequately address food insecurities (Khalid, 2018).

The empirical research points out that in irrigated and other farming systems, the crops are sensitive to fluctuations in temperature and water use. Different simulation models suggest a reduction in crop yield, particularly of wheat and rice, and a reduction of almost 6 percent in the yield of wheat in almost all the agro-climatic systems, except for the northern regions of Pakistan (Syed et al., 2022). A variety of reasons were identified that affected the yield, including agronomic and socioeconomic reasons like temperature variability, water accessibility, use of pesticides, and labor availability and awareness.

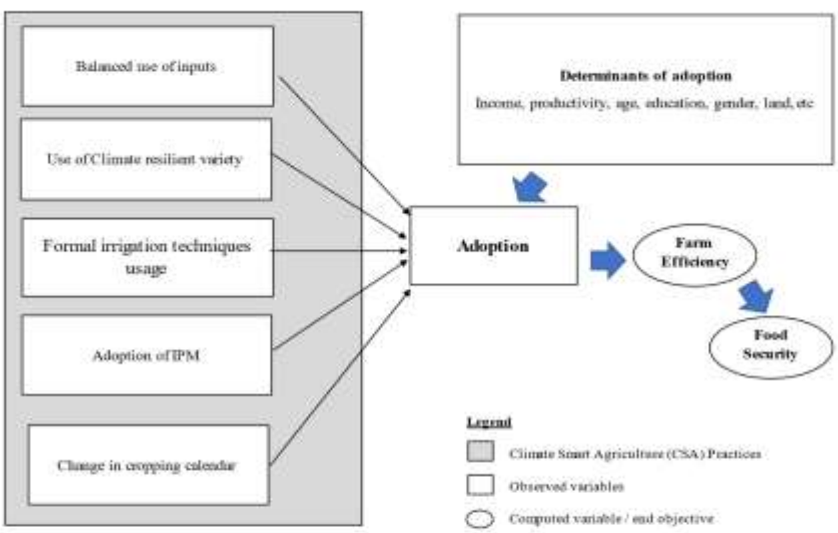
Objectives of the Study

This research emphasizes the following key objectives:

1. To measure the adoption of farmers with respect to the Climate Smart Agricultural (CSA) practices in Punjab, Pakistan, and find out the determinants of adoption.
2. Computation and comparison of efficiency of adopters and non-adopters.
3. Policy recommendations for better adoption by farmers for climate resilience

The conceptual framework of this study, in Figure 1, consists of three main factors: i) Adoption of CSA practices, ii) Determinants of this adoption, and iii) Efficiency of the farm.

Figure 1: Conceptual framework of the study



Within these components different determinants and indicators, as illustrated below will be assessed. Based on the results, the study aims to investigate the adoption practices that are helping in Climate Smart Agriculture and to cope with climate vulnerability, in the selected districts of Punjab. Farmers' knowledge and awareness of CSA practices, and other social and institutional supports will be part of theoretical framework. The indicators of the adoption selected for the study are: -

1. Balanced use of inputs like fertilizer and chemical
1. Use of climate resilient varieties
2. Use of formal irrigation techniques /Water Usage
3. Adoption of Integrated Pest Management (IPM)
4. Change in crop calendar according to climate change.

Materials and Methods

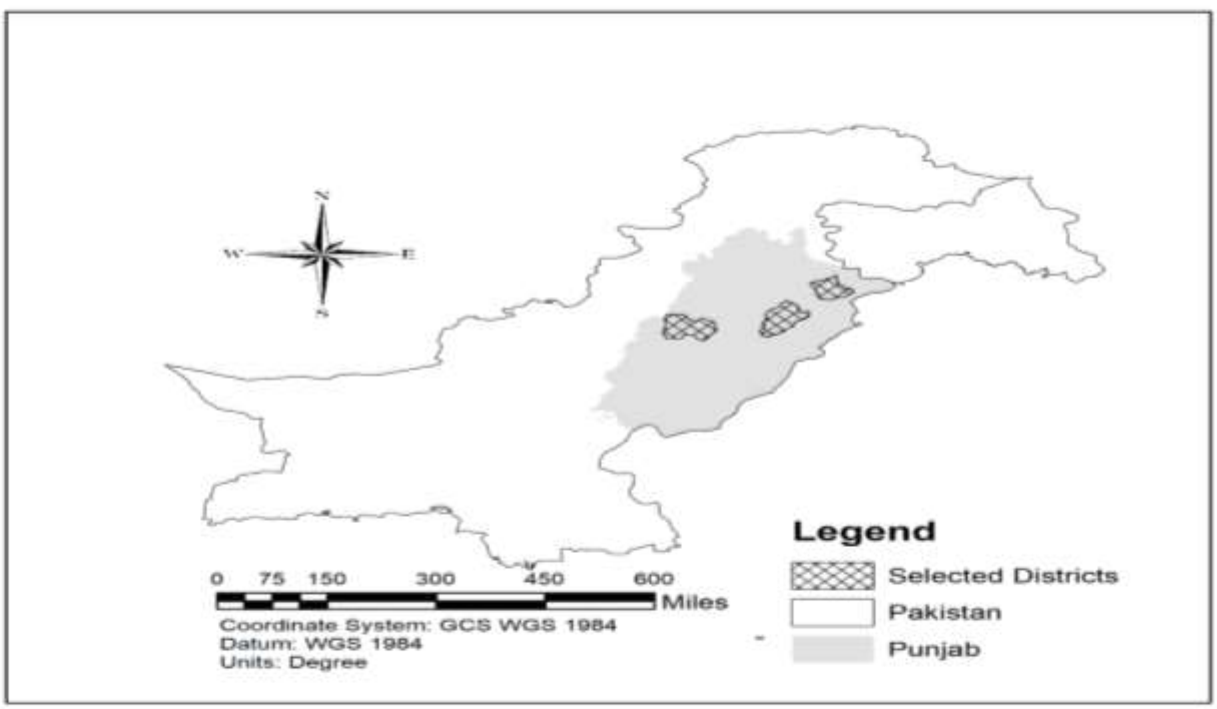
In Punjab, there are major agri-zone (cotton zone, rice zone, and mix cropping zone), and within them there are three districts which are purposively selected for the study based on climatic and agro-ecological cropping patterns. In total 384 farmers/growers, cultivating wheat on their lands, were surveyed. The 3 districts selected (Figure 2) for the study are also among top 10 wheat-producing districts, are namely;

1. Layyah (Wheat/Cotton agri-zone)
2. Faisalabad (mix agri-zone)
3. Gujranwala (Wheat/Rice agri-zone)

In the study the primary data has been collected from the farmers of the rural and semi-urban areas of the three districts: i) Faisalabad, ii) Gujranwala and iii) Layyah. The data has been mainly collected through survey with fully structured questionnaire. Data was collected by applying the random sampling technique from both rural/semi-urban areas. Out of total sample, 160 farmers were selected from Faisalabad, subsequently 128 farmers from Gujranwala and 96 framers from Layyah.

The sample contains information to assess the determinants and consequently the adoption of Climate Smart Agriculture practices. In the presence of principal and associated researchers where they helped to explain the purpose and objective of the study besides helping the farmers to understand the questions where needed. The inquiries in the survey were primarily to measure the adoption of CSA practices and related to the key determinants of the study which were about the Farmers' education, age, income, any kind of subsidy, area used for wheat, land ownership, distance of farm from city, productivity etc. Lastly, the efficiency of farmers was estimated by comparing performance of adopter/non-adopters.

Figure 2: Study area map showing the selected districts



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The data was collected from two types of farmers, based on the adoption of climate smart practices; farmers who adopted (with score 1) and those who have not adopted (with score 0). Following are the key dimensions of adoption/non-adoption of farmers.

1. Irrigation technique (e.g., use of formal irrigation like drip, sprinkle, furrow etc.)
2. Use of crop calendar according to climate change
3. Use of climate resilient variety
4. Use of balanced chemicals and fertilizers
5. Integrated Pest Management

Probit model restricts and estimates of the probabilities between 0 and 1 and relaxes the constraint as such that the effect of the independent variable remains constant across different predicted values of the dependent variable (Sebopetji & Belete, 2009). The model which is also referred to as the 'probit regression' is a method of performing binary outcome variable regression. The binary outcome variables are basically the dependent variables with only two options, such as yes/no, positive/negative test results, or single/ no single. The name "Probit" comes from "probability" and "unit"; the Probit model estimates the likelihood that a certain outcome may or may not fall into one of two binaries (i.e., unit) outcomes. For dichotomous or binary outcome variables, Probit regression is popularly used in economics because the error term of this model is drawn from normal distribution directly.

For this study, the Probit Model is used to estimate the determinants for the adoption of CSA practices. The dependent variables of the model, which is adoption in binary form i.e. for adopter the score was 1 and for non-adopter the score was 0. Forthcoming, the independent variables are as follows:

Table 1: Independent variables

1. Farmer education:	Education in number of schooling years
2. Age:	Age of the farmer in years
3. Income:	In thousand Rupees
4. Subsidy:	Binary variable (if got subsidy score=1 otherwise =0)
5. Wheat area:	Acres of land
6. Ownership of land:	Binary variable (If farmer owns the land (1) or rented (0))
7. Distance from city:	In Kilometers
8. Wheat productivity:	Maunds per acre
9. Gender :	Binary variable (if male score = 1, for female score =0)

Data Envelopment Analysis (DEA)

The research method of the study is based on the Data Envelopment Analysis (DEA) which is primarily a non-parametric approach, helps in measuring the efficiency (technical) with a set of decision-making units, including multiple inputs and outputs with the application of mathematical programming (Gökşen *et al.*, 2015). When the DEA model is applied with respect to the input orientation, it focuses on the input reduction to achieve the efficiency whereas in the output orientation, there is output enhancement with given set of inputs to achieve the efficiency. In both orientations, a DEA relatively efficient decision-making unit will always have 100 percent efficiency. The present study estimated technical efficiency of farming households under output-oriented technique explaining that how much feasible output is maximized for given level of inputs.

The DEA efficiency estimation technique gives the efficiency boundary from the sample of production units which in our case are the farmers of wheat. The estimation of technical efficiency through DEA can be input or output oriented under the constant as well as the variable returns to scale (CRS and VRS). According to (Coelli, 1996), the scores of technical efficiency obtained by input and output-oriented methods have similar values under constant returns but are normally different under variable returns to scale technology. In this examination, output oriented technique is used under CRS and VRS.
Data Envelopment Analysis Program (DEAP) is computer software for the assessment of the efficiency. This computer software can consider a wide range of models (Leal & Cepeda, 2013).

Why DEA is Suitable?
Data Envelopment Analysis (DEA) is used for benchmarking in management. The decision making units' (DMUs) productive efficiency is measured using DEA. DEA is one of the most commonly used non parametric methods and it is efficient. The start of DEA has been started from CCR model when input and output orientation is done in such a way that their technical efficiency and varying returns to scale are gauged. Charnes, Cooper and Rhodes in 1978 developed basic DEA model which defines efficiency. DEA is more suitable that other approaches because there is no requirement of explicitly defining mathematical form in DEA. It is capable of handling multiple inputs and outputs. This is helpful in analyzing sources of inefficiency (Camanho & D'Inverno, 2023). DEA is suitable approach for this study as it does not focus on explaining variances however it explains the efficiency of inputs to yield output. the comparison of efficiency of CSA adopters and CSA non adopters is compared using DEA model.
Data envelopment analysis program as explained can use multiple models to estimate efficiency however the basic DEA model explained by Charnes, Cooper and Rhodes in 1978 was

$$\varnothing_j = \frac{m=1}{\Sigma_{n=1}^{N} x_n^j v_n^j} \quad (1)$$

Where DMU'_js known M outputs (are multiplied by the respective weights) and are divided by N inputs multiplied by their respective weights, the efficiency score maximum under the constraints of the weights however no efficiency score exceeds 1. The approach of DEA is very successfully implemented in public policies and management decisions.

$$\frac{\Sigma_{m=1}^{M} y_m^k v_m^j}{\Sigma_{n=1}^{N} x_n^j v_n^j} \leq 1 \quad (2)$$

The production efficiency estimation has implications in economic theory as well as policies. This analysis is primarily the assessment of probable increase in output tied with the efficiency enhancement (Farrell, 1957). In line with this, technical efficiency is estimated under CRS and VRS by using output (wheat production) and inputs (labor, quantity of seed, fertilizer, pesticides, land rent, land preparation, irrigation, harvesting, threshing, transportation etc.) by using output-oriented efficiency technique. Moving forward, these estimations were used to compare efficiency of adopters and non-adopters of CSA.

Results

The results as illustrated by table 1 reflect that out of 384 farmers, 68 farmers i.e. 17.8 percent were found to adopt CSA practices.

Table 2: Descriptive statistics of the adopter vs non-adopter farms of CSA practices

Variable	Adopter	Non-Adopter	Total
Frequency (numbers)	68	314	382
Education in years (mean)	13	3	8
Age (mean)	37	51	44
Family Size (mean)	6	8	7
Income in thousand Rs, (mean)	2,914	637	1,775.5
Area in acres (mean)	22	5	13.5
Wheat Yield Maunds/acres (mean)	57	34	45.5

The mean education of adopter (farmer who adopts CSA) was 13 years of schooling, whereas for non-adopter it was 3 years. The average age of adopter was 37 years, and for non-adopter its 51 years. The mean family size of adopters was 6, whereas for non-adopter it was 8. The mean annual income of the adopters was 2.9 million, whereas for non-adopters it was 0.63 million. The mean area of adopters was found to be22 acres, and for non-adopter 5 acres. The productivity of wheat was higher for adopter than the non-adopter.

The socio-economic determinants for adoption of CSA practices are shown in the table below. Farmer education has a positive and significant relationship with the adoption. As the Probit model predicts the probability with a non-linear link function. The marginal effect on the probability of each variable depends not only on the estimated coefficient of the variable but also on the values of the variable. However, a positive Probit model coefficient means that the likelihood of the adoption (in our case) increases as education of farmer (in our case) increases. Similarly with every one-unit increase in income and ownership of land the probability of farmers to become adopters of Climate Smart Agriculture practices also increases. The same results indicate that age, wheat area and distance from city do not have a significant relationship with the adoption however, their coefficients are negative. Male farmers are more likely to adopt CSA compared to female farmers; however, the coefficient is not statistically significant.

Table 3: Socio-Economic determinants of adoption of CSA practices

Parameter	Estimate	Std. Error	Sig.
Farmer Education	0.062	0.021	0.004
Age	-0.005	0.009	0.576
Income	0.230	0.147	0.119
Subsidy	2.397	0.600	0.000
Wheat Area	-0.010	0.005	0.027
Ownership of Land	0.677	0.349	0.053
Distance from City	-0.036	0.024	0.141
Wheat Productivity	0.011	0.007	0.087
Gender	0.031	0.318	0.923
Intercept	-8.640	1.428	0.000

Technical efficiency of adopters and non-adopters in selected districts was calculated under constant and variable returns to scale (CRS & VRS). Table 3 depicts that small farmers from adopters were technically more efficient under CRS with an efficiency score of 0.636, while medium and larger are comparatively less efficient. It is also important to note that farmers who are adopting Climate Smart Agriculture practices are technically more efficient under CRS as compared to non-adopters.

Table 4: Comparison of efficiency between adopter and non-adopter of CSA practices

Land Holding	Adopters		Non- Adopters	
	CRS	VRS	CRS	VRS
Small (0-11.9 acres)	0.680	0.889	0.602	0.814
Medium (12-24.5)	0.636	0.807	0.592	0.767
Large (< 25)	0.588	0.774	0.517	0.699
Average	0.634	0.823	0.570	0.760

The small farmers of adopters were technically more efficient under VRS with an efficiency score of 0.889, while the medium and larger are comparatively less efficient. It is also important to note that farmers who are adopting Climate Smart Agriculture practices are technically more efficient under VRS as compared to non-adopters. The efficiency scores reflect that farmers who are adopting CSA practices are performing more efficiently than the non-adopters under CRS and VRS.

Discussion

In this study, we have investigated the determinants of the adoption of CSA practices and compared the efficiency of adopters with non-adopters. Only 17.4 percent of farmers out of a total of 384 were found to be adopters, which is significantly less. In the wake of severe climate changes in the future (Seaman et al., 2014; Imran et al., 2018), this result points out that the climate vulnerabilities of the farmers will grow over time.

From the Probit model results, it is evident that the probability of adoption (CSA practices) increases with education, which means people with higher education are more likely to adopt CSA practices (Kouamé, 2010; Dill et al., 2015). Similarly, the farmers in the younger age groups were also observed to be better in the adoption of CSA practices as compared to farmers in the older age group. Distance of farms from the city was also one factor that affected the adoption, as farmers working on the farms closer to the city are more likely to adopt CSA practices. The results also support that the adopters of CSA practices have higher efficiency scores and higher farm incomes, as previously argued by Mutenje et al. (2019).

Conclusion

In Punjab, most of the farmers with less landholding have normally low efficiency. Additionally, the farmer's education and access to government initiatives like subsidies and advisories are below par. Moreover, CSA practices like modern irrigation techniques, access to certified climate-reliant seed varieties, and inputs like fertilizers and chemicals are costly, which undermine the farmers' capability to adopt CSA practices. Therefore, the overall adoption of CSA practices is low in the province.

Furthermore, the farmers with more land available for cropping of wheat tended to use traditional methods of sowing practices, not in line with the CSA practices. On the other hand, wheat is a traditional crop, and farmers prefer traditional methods (like flood irrigation and the use of home-grown seed, etc.) to cultivate the crop. While the farmers with lesser area for growing wheat rather adopt CSA practices more to efficiently utilize the available land resources by adopting CSA. The findings of the study suggest that adoption also has a positive relationship with the productivity of wheat, and the farmers who were adopters were performing more efficiently. Therefore, moving forward adoption of CSA practices is critical and holds the key to improving food security in the country. Considering the adversities of climate change, which are eminent and coming at a rampant pace, the adoption of CSA practices can help in producing climate-resilient crops and help to lessen the vulnerabilities of farmers.
In light of the findings, the policy recommendations are:

1. The cost to adopt CSA practices is much higher than traditional cropping practices, which demands that the policymakers incentivize these with financial assistance programs like subsidies. This will not only help with cost reduction but also scale up the use of CSA.
2. Mass awareness amongst farmers to adopt CSA practices needs to be prioritized, including showcasing its benefits like enhanced production efficiency.
3. Piloting and promoting CSA practices is important for scaling up the CSA practices in a country like Pakistan. Without government intervention in this regard, this will be virtually impossible.
4. There needs to be separate policies for different crops, including wheat, regarding the adoption of CSA practices, ensuring its implementation on the ground.

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