Research Article

Assessment of Rice Farmers' Knowledge on the Mechanization in Climate-Adaptive Cultivation Practices

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Abstract | This study aims to assess the knowledge levels of rice farmers regarding various farm machinery and implements used in rice cultivation and production technology in southern Punjab and Dera Ismail Khan districts, Pakistan. The research was conducted through a survey involving 130 respondents. Data were collected and analyzed by using appropriate statistical tools. Pertinent items covering all aspects of climate adaptation farm machinery and rice production technology were collected. The effectiveness of adaptation practices in response to climate change is a critical issue for farmers globally. This paper examines whether farmers in Pakistan who adapted to climate change obtained productive benefits. The study estimates the impact of on-farm adaptation strategies on rice cultivation in Khyber Pakhtunkhwa, specifically in Dera Ismail Khan, and in Punjab, particularly in Bhakkar. To evaluate the overall knowledge level of rice farmers on mechanization, respondents were categorized into three groups: 19% had low knowledge, 58% had medium knowledge, and 23% had high knowledge. An item-wise response analysis showed high awareness of organic farming (100%), puddler and rotavator use (91%), and climate-related problems (81%). Farmers had limited awareness of cono weeders (48%) and paddy transplanters (54%). There is a need for targeted extension work in rice-growing areas to enhance knowledge and productivity.

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Introduction

Agriculture, defined as the art and science of growing plants and raising animals for food, other human needs, or economic gain, is fundamental to the Pakistani economy, which remains predominantly agrarian. Agriculture not only sustains the country's economy but also contributes significantly to its

food security and employment. Heat stress with a new pattern in climate is becoming a serious threat to agriculture resulting in food shortage. It exerts various abiotic and biotic stresses causing lower agricultural outputs. Ecologists determined that if human activities deteriorating ecosystem continue, a large food scarcity is waiting for upcoming generations. Rice stands as a major food cereal and cash crop in Pakistan, second only to wheat. Recent years have seen a shift toward the cultivation of coarse rice hybrid varieties, with the production comprising 34 percent of basmati (fine) types and 66 percent of coarse types. This shift reflects the increasing demand for more adaptable and higher-yielding varieties to meet both local consumption and export needs. Rice contributes 2.4 percent to the agricultural value added and 0.5 percent to the national GDP. In the 2021-22 period, rice was sown on 3,537 thousand hectares, reflecting a 6.1 percent increase from the previous year, contributing to record-high production levels (GOP, 2022).

Pakistan's agricultural sector is a backbone of the national economy, contributing to its export earnings, especially from crops like rice. With a growing population of 241.5 million people, at a growth rate of 2.55% (GOP, 2024), agricultural productivity remains critical to ensuring food security and supporting livelihoods. Dera Ismail Khan, situated in the arid zone of Pakistan at 71.07° longitude and 31.57° latitude, experiences an arid to semi-arid climate with soil that is mostly clay, highly alkaline, and deficient in organic matter, nitrogen, and phosphorus. Despite its climatic challenges, the region relies heavily on rice farming, with its irrigation system fed by the Indus River.

The effects of climate change, characterized by altered seasonal patterns, unexpected temperature shifts, and changes in rainfall, pose significant threats to agriculture in Pakistan. Climate change has had a pronounced effect on agricultural productivity, with smallholder farmers being particularly vulnerable to crop failure, diseases, water scarcity, and food insecurity. A study by Suri (2011) highlights the role of technological adoption in mitigating these challenges. Farmers who better understand climate variability and adopt adaptive agricultural practices are more resilient to these adverse impacts. Recent studies also underscore the growing vulnerability of Pakistan's agriculture to climate-induced shocks, such as the flooding in 2020 and 2021, which have exacerbated food insecurity in rural areas (GOP, 2023; Stocker *et al*., 2013).

As one of the South Asian countries most susceptible to climate change, Pakistan faces rising concerns over its rice production system. A key question remains whether farm-level adaptation strategies, particularly those that focus on climate-resilient technologies, can mitigate the adverse effects on future crop productivity. Digital platforms, such as precision agriculture tools and mobile-based advisory services, have begun to offer solutions to these challenges by improving farm efficiency and market access. These platforms are transforming rice farming in Pakistan by connecting farmers with suppliers, processors, and markets, enhancing productivity and promoting sustainability (Sanusi *et al*., 2025).

In parallel, agricultural mechanization is increasingly recognized as an essential strategy to address labor shortages, reduce production costs, and improve yields in the face of climate change. Mechanization can help mitigate the impacts of labor scarcity and inefficient farming practices, particularly in remote regions like Dera Ismail Khan. Recent research indicates that the adoption of mechanized farming equipment, such as harvesters and tractors, leads to better yield stability and increased production efficiency (Amponsah *et al*., 2018). However, the adoption of such technologies remains low in Pakistan due to financial constraints, limited access to mechanization, and lack of training. The importance of mechanization in enhancing rice productivity has been highlighted in studies across other South Asian regions, including India and Bangladesh, where mechanization has led to significant improvements in yields and farmer incomes (Luqman *et al*., 2025; Alam *et al*., 2025).

This study aims to assess the knowledge levels of rice farmers regarding agricultural mechanization, specifically in the context of climate change. Understanding the barriers and opportunities for adopting mechanization is crucial to improving the resilience and productivity of rice farming in Pakistan. The research also explores the broader implications of climate change adaptation and how mechanization can contribute to sustainable rice farming practices in regions like Dera Ismail Khan. Another objective is to provide awareness about climate change, heat stress and rice mechanization through surveys. To

ascertain the level of adaptation rice mechanization in two districts of two provinces and to identify critical knowledge about modern cultivation of rice farmers that required by government and other private stake holders for rice production support.

Despite the increasing importance of climate-resilient technologies in rice production, limited empirical evidence exists on the actual knowledge levels of smallholder farmers regarding mechanized practices in climate vulnerable areas of Pakistan. Most prior investigates focus either on technological adoption or climate resilience separately. There is a notable gap in understanding how knowledge of mechanization intersects with climate change adaptation among rice farmers, particularly in underrepresented districts such as Bhakkar and Dera Ismail Khan. This study fills this gap by quantitatively assessing farmer awareness and identifying knowledge deficits related to agricultural mechanization under changing climate conditions.

Materials and Methods

The study was conducted in Bhakhar (Punjab) and Dera Ismail Khan (KPK), Pakistan, during the year 2021-22. Knowledge is an essential component for the adoption of any innovation because it helps farmers to fully comprehend and appreciate the mechanization practices in rice cultivation in the climate change scenario. As a result, it is critical to assess farmers level of knowledge on mechanization in rice cultivation. In the present study, knowledge had been operationalized as the body of information understood and possessed by the respondents on mechanization in rice cultivation. Farm machinery pictures were added to the questionnaire and distributed to farmers for identification and to raise awareness about their uses. The overall knowledge level and response analysis of knowledge items by the rice farmers were studied, and the findings were presented. The level of knowledge was measured by using 60 items derived from the knowledge test developed for the study.

Results and Discussion

In order to assess the overall knowledge level on the mechanization in the climate change scenario by the rice farmers, necessary data were collected, and the respondents were segregated into three groups *viz.*, low, medium and high by using mean and standard deviation and the results were illustrated in Table 1 and Figure 1.

Table 1: *Distribution of rice farmers according to their overall level of knowledge on farm mechanization in rice (n=130).*

S. No.	Category	Frequency	Percentage (%)
1	Low level of knowledge	25	19
2	Medium level of knowledge	75	58
3	High level of knowledge	30	23
	Total	130	100.00

Mean: 29.63; SD: 9.10

It is evident from Table 1 and Figure 1, more than half (58.00 %) of the respondents had a medium level of knowledge followed by 30.00 and 19.17 percent of respondents with high and low levels of knowledge respectively.

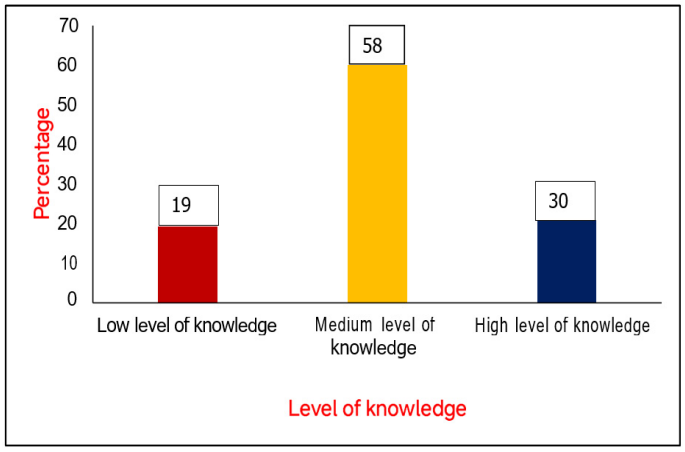

Figure 1: *Distribution of rice farmers according to their level of knowledge.*

Majority of rice farmers were found to have a medium to high level of knowledge on various farm machinery and implements used in rice cultivation in changing climate knowledge. The probable reasons for the above trend might be due to their experience in farming and paddy being labor intensive crop demands more labor which forced them to look for other alternatives (Amponsah *et al.*, 2018). Rice growers pinpoint some limiting factors responsible for low grain yield. Labor shortages at the time of transplanting, delay in transplanting, suboptimal plant population, fertilizer shortage, weeds and weedicides, poor plant protection measures and heavy or low rain have kept the rice production level low. Besides rice farming on sodic or highly alkaline soil having negative impact on yield, without taking some preventive measures (Rani, 2020).

Majority of rice farmers had an education level ranging from intermediate to graduate. This education level enabled farmers to access mass media and ICT tools, which in turn allowed them to gain knowledge about various farm mechanization implements such as mould board plough, harrow, cage wheels, puddler, rotavator, paddy drum seeder, seed drill, paddy transplanter, weeder, knapsack sprayer, combine harvester, paddy reaper, straw baler. Climate change, temperature, edaphic conditions, weed resistance and organic farming. For their identification farm machinery pictures also helped in understanding surveys.

Further, these kinds of implements were also available in custom hiring centers of the study area. Hence, the above trend of medium to high level of knowledge possessed by the majority of rice farmers on mechanization in rice cultivation.

Response analysis in rice cultivation

To know the detailed and comprehensive idea on the knowledge level of rice farmers on mechanization in changing climate knowledge, an item wise response analysis was carried out and the results were presented in Table 2.

The most pronounced impacts of climate change, such as heat, drought, water stress, soil salinity, and herbicide resistance in weeds, have limited rice production per unit area. Farmers' knowledge and responses to these factors are generally positive; they noted that higher temperatures have enhanced their rice production. However, there is limited knowledge about herbicide-resistant weeds (70%) and strong awareness (76%) as causes of smog in autumn (76%) by burning stubbles of rice. Farmers identified the causes of low rice production per unit area and expressed dissatisfaction with their yield (100%). Most farmers utilize solar energy (77%) and benefit from high water tables in the soil. They are fully aware of organic farming (100%) but have limited knowledge about corporate farming (50%) and mechanized farming (66%).

Jaganathan *et al.* (2012) investigated a survey about adoption of organic and mechanized farming in India. They concluded that organic farming in future will produce more than in-organic cultivation of rice and other crops.

Table 2: *Response analysis of knowledge items by the rice farmers on mechanization.*

S. No.	Item	Rice farmers (n= 130)	
		Frequency	Output max. (%)
1)	Do you know mechanized farming? a (yes) b (no)	86 (a) 44 (b)	66
2)	Do you know about corporate farming? a (yes) b (no)	65 (a) 65 (b)	50
3)	Low rainfall and drought are mitigated with irrigations. a (yes) b (no)	100 (a) 30 (b)	77
4)	Farmers' knowledge climate change 0% 5-10% 11-15% 16-20%	120 (d) 10 (a) 0 (b) 0 (c)	92
5)	Have farmers recorded temperature and rain? a (Yes) b (No)	90 (a) 40 (b)	70
6)	High temperature favors the rice production? a (yes) b (No)	130 (a) 0 (b)	100
7)	Due to use of weedicides, weeds resistance against herbicides found. a (yes) b (no)	91(a) 39 (b)	70
8)	Preference rice cultivation over other kharif crops. a (yes) b (no)	120 (a) 10 (b)	92
9)	D.I. Khan and Bhakhar's agro-climate is suitable for rice cultivation. A (yes) B (no)	105 (a) 25 (b)	81
10)	Problem faced by rice farmers a (weeds) b (water deficiency) c (disease) d (climate change)	106 (a) 10 (b) 10 (c) 4 (d)	81
11)	Storage facilities available a (bags) b (store house) c (ware house) d (muddy bins)	100 (a) 20 (b) 6 (c) 4 (d)	76
12)	Sources of information about climate and extension services. a (fallow farmers) b (extension services) c (newspaper) d (social media)	90 (a) 20 (b) 10 (c) 10 (d)	69

Table continues on next page.....

S. No.	Item	Rice farmers (n= 130) Frequency	Output max. (%)
13)	Are you satisfied with your grain production of rice. a (yes) b (no)	130 (a) 0 (b)	100
14)	Burning of rice stubbles in the field cause smog, are you aware? a (yes) b (no)	100 (a) 30 (b)	76
15)	Rice production has some impact on edaphic condition bad or best. a (bad) b (best)	89 (a) 41 (b)	68
16)	Have you used solar power for irrigation a (yes) b (no)	100 (a) 30 (b)	77
17)	Are you aware about organic farming? a (yes) b (no)	130 (a) 0 (b)	100
18)	Do farmers predominantly utilize animal-drawn moldboard (MB) plows, or are tractor-drawn plows more commonly employed in their fields? a (only animal drawn MB) b (Only tractor drawn MB) c (both a & b) d (don't know)	5 (a) 9 (b) 116 (c) 0 (d)	95
19)	Is it necessary to use a moldboard (MB) plow annually? If the answer is yes, for how many years should it be used? a (3) b(1) c (2) d (don't know)	105 (a) 10 (b) 15 (c) 0 (d)	81
20)	After employing an animal-drawn plow, to what extent does unplowed land remain? a (0%) b (<5%) c (5-10%) d (10-20%)	0 (a) 10 (b) 29 (c) 91 (d)	70
21)	What is the function of a harrow? a (ploughing) b (smoothing of clods c (n one) d (don't Know)	115 (a) 10 (b) 5 (d)	88
22)	To what depth does a harrow typically operate? a (5-10cm) b (10-20cm) c (20-30cm) d (don't know)	98 (a) 12 (b) 15 (c) 5 (d)	76

Table continues on next column.....

S. No.	Item	Rice farmers (n= 130) Frequency	Output max. (%)
23)	What kind of blade is typically utilized in a harrow? a (straight blade) b (curved blade) c (inclined blade) d (none)	97 (a) 12 (b) 21 (c) 0 (d)	72
24)	How often is the harrow blade cleaned during field operations? a (at the end of each headland) b (twice consecutively) c (only when it becomes clogged with weeds) d (never)	65 (a) 30 (b) 16 (c) 19 (d)	50
25)	How many gears does a power tiller typically have? a (4 gear) b (3 forward & 1 reverse gear) c (5 gears) d (n one)	97 (a) 30 (b) 3 (c) 0 (d)	75
26)	What kinds of implements are compatible with a power tiller? a (MB plough) b (rotary plough) c (disc plough) d (all)	99 (a) 25 (b) 4 (c) 2 (d)	75
27)	What are the different types of cultivators? a (ridge tyne type) b (spring tyne type) c (duck foot cultivator) d (don't know)	86 (a) 25 (b) 19 (c) 0 (d)	76
28)	What is meant by a half cage wheel? a (its having width of one feet) b (its fitted with black tyre of tractor) c (its fitted with hub of the tractor wheel) d (none)	96 (a) 20 (b) 14 (c) 0 (d)	74
29)	What are the purposes of using cage wheels? a (for puddling wet soil) b (for puddling after harvesting of paddy) c (both a & b) d (don't know)	12 (a) 25 (b) 89 (c) 4 (d)	68
30)	What is the purpose of using a puddler? a (to stir the soil) b (to make favourable condition for Paddy) c (to increase water holding capacity) d (don't know)	10 (a) 118 (b) 2 (c) 0 (d)	91
31)	What benefits does a Rotavator provide? a (used for ploughing) b (used for loosening of soils) c (used for crushing of crop residues) d (both b & c)	10 (a) 118 (b) 2 (c) 0 (d)	91

Table continues on next page.....

S. No.	Item	Rice farmers (n= 130) Frequency	Output max. (%)
32)	Have you ever come across an animal-drawn Rotavator? a (yes) b (no)	125 (a) 5 (b)	96
33)	What operation is not performed by a paddy drum seeder? a (weeding) b (fertilizer application) c (land preparation) d (nursery)	90 (a) 20 (b) 10 (c) 0 (d)	68
34)	Is the cost of cultivating with a paddy drum seeder lower compared to other cultivation methods? a (yes) b (no)	100 (a) 30 (b)	76
35)	What functions does a seed drill perform? a (to carry the seeds) b (to open furrows at uniform rates) c (to meter the seeds) d (to cover the seeds)	10 (a) 15 (b) 10 (c) 95 (d)	74
36)	How many trays are needed for transplanting one acre of paddy using a paddy transplanter? a (80) b (100) c (120) d (don't know)	70 (a) 40 (b) 20 (c) 0 (d)	54
37)	Have you ever encountered a Cono weeder? a (don't know about that) b (yes, seen in paddy fields) c (seen in university/TV) d) Don't Know	60 (a) 30 (b) 30 (c) 10 (d)	48
38)	What is the tank capacity of a knapsack sprayer? a (9-22.5 liter) b (10-15 liter) c (15-30 liter) d (none)	100 (a) 20 (b) 10 (c) 0 (d)	76
39)	What tasks does a combine harvester perform? a (only threshing can be done) b (both harvesting and threshing can be done) c (only used for harvesting) d (don't know)	20 (a) 10 (b) 105 (c) 0 (d)	81
40)	What is the initial function of a combine harvester? a (harvesting) b (threshing) c (winnowing) d (don't know)	20 (a) 10 (b) 0 (c) 100 (d)	76

Table continues on next column.....

S. No.	Item	Rice farmers (n= 130) Frequency	Output max. (%)
41)	What is the function of a paddy reaper? a (Sowing) b (Grain Harvesting) c (spraying) d (none)	40 (a) 60 (b) 30 (c) 0 (d)	48
42)	What type of crops can be threshed by olpad type thresher? a (gram) b (wheat) c (Both a & b d (none)	30 (a) 20 (b) 67 (c) 13 (d)	51
43)	How tractor operated thresher works? a (it takes power from draw box) b (it takes power for hydrolic) c (it takes power from PTO) d (don't know)	32 (a) 72 (b) 26 (c) 0 (d)	55
44)	What is the working capacity of multicrop thresher? a (1000kg/hr) b (200-2500kg/hr) c (2500kg/hr) d (<300kg/hr)	89 (a) 30 (b) 10 (c) 1 (d)	68
45)	What is the use of Straw baler? a (intercultural operations) b (land protection) c (post harvest operation) d (none)	65	50
46)	Straw baler can reduce the impact of air pollution a (yes) b (no)	74 (a) 56 (b)	57
47)	Straw baler adds additional income to the farmer a (yes) b (no)	90 (a) 40 (b)	69
48)	Mention any one point that emphasizes the importance of mechanization	130	100.00
49)	Mention any one company that is worked with agricultural mechanization a (yes) b (no)	120 (a) 10 (b)	92
50)	Mention any one machinery name that are used in harvesting and post harvesting a (yes) b (no)	100 (a) 30 (b)	77
51)	Mention any one disadvantage of agricultural mechanization a (yes) b (no)	130 (a) 0 (b)	100.00
52)	Mention any one location where farm machinery and tools are sold a (yes) b (no)	130 (a) 0 (b)	100.00

Table continues on next page.....

S. No.	Item	Rice farmers (n= 130)	
		Frequency	Output max. (%)
53)	State any one major function of diesel engine a (yes) b (no)	100 (a) 0 (b)	77
54)	Custom hiring model of farm implements for rice based farming farmin is useful is useful to the farming community a (true) b (false)	100 (a) 30 (b)	77
55)	I feel the custom hiring and co-operative farming farmer group concept can effectively. So, solve the problem of farm mechanization a (true) b (false)	100 (a) 30 (b)	77
56)	Drum seeder/direct sowing method of paddy cultivation can reduce the cost of labour a (true) b (false)	90 (a) 40 (b)	69
57)	Whether RBK's are useful for farming mechanization a (true) b (false)	116 (a) 14 (b)	89
58)	Mechanization can lead to increased yields and profitability for farmers a (true) b (false)	96 (a) 34 (b)	74
59)	Farm mechanization can have a negative impact on environment a (true) b (false)	25 (a) 105 (b)	81
60)	Power operated winnower is better than traditional method of knowing? a (yes) b (no)	108 (a) 32 (b)	83

It is evident from Table 2, farmers possessed high knowledge on puddler, mould board plough, rotavator, harrow, combine harvester and paddy drum seeder. The reason for the above trend might be interesting, the majority of rice farmers held a positive opinion about custom hiring centers, which provide mechanization services to the farming community on a rental basis with reasonable hiring charges. This indicates a favorable perception of such services among farmers, which showcases the potential for increased adoption of farm machinery and implements in the agricultural practices of rice farming. However, their knowledge on cono weeder, thresher, paddy transplanter, straw baler and paddy reaper appeared to be relatively limited. The reason for the above trend might be that some agricultural machinery, such as the cono weeder, cage wheels, thresher, paddy transplanter, straw baler, and paddy reaper might be more intricate and require specialized knowledge to operate effectively and lack of training and experience in handling such machinery was another reason for the above trend.

Further, the rice farmers might not have much exposure to these specific types of agricultural equipment. As a result, they might not be familiar with their functions, features and operation. In some cases, certain agricultural equipment might not be commonly used in a particular region. This kind of lack of exposure could lead to limited understanding and knowledge about this machinery. Hussain *et al.* (2005) provided a similar type of survey about wheat growers having cropping patterns and rotation of rice crop in kharif season. They also found low technical and mechanical knowledge in wheat growers. Khan (2002) wrote some issues of limited rice production. Water harvesting should be enhanced by adopting mechanized rice cultivation, reduced tillage operations, laser leveling etc. Mechanized rice planting, direct planting seed of rice and direct seed sowing without puddling measures might be checked in different agro-climatic conditions of Pakistan to cope with climate change scenarios.

The percentages regarding knowledge of the respondents indicated that rice farmers had a limited understanding of the above-mentioned agricultural equipment. This observation could have implications for the adoption and effective utilization of these machines in agricultural practices by the rice farmers. Further education, training and awareness-building efforts might be needed to improve their understanding and knowledge level which encourages the adoption of these technologies in their agricultural activities.

Farm Tools in Rice Production

Nearly half of the respondents had medium extension contact and extension participation which forced them towards the usage of some basic implements (Figure 2) due to lack of information on improved farm machinery and implements. As the cost of paddy transplanter is very high i.e., more than 8 lakhs and it is difficult for small farmers to use it. Further many farmers were not known about implements like cono-weeder, as majority of rice transplantation done by manually where there is no scope for row spacing.

Hence, it is not possible to use cono-weeder in these situations with reference to machine transplanted paddies. In case of many paddy growing areas, apart from the rice farmers of this study region also not having knowledge on its mode of operation, the method of preparation of seedling trays (80 trays/acre) and age of seedlings (14-15 days) to be transplanted.

Figure 2: *Farms tools used in mechanical rice production and assessed in questionnaires described in Table 2.*

Hence, all these circumstances could be enhanced by increasing the awareness and knowledge of the rice farmers on farm mechanization through conducting demonstrations, organizing training programs, exposure visits to successful farm mechanization farms, presentation of success stories, promoting informal communication on farm mechanization through local opinion leaders. Hussain and Khan (2004) studied farmer's approach towards adoption of crop production technology in Dera Ismail Khan and suggested mechanized and corporate farming to enhance crop production in said area. Sandip (2020) described the factors involved in farm mechanization in India and predicted high production of crops with adoption of mechanized farming. Similar knowledge level of rice production was studied by Ravishankar *et al*. (2018).

Conclusions and Recommendations

The findings revealed that majority of the rice farmers were found to have a medium to high level of knowledge on various farm machinery and implements used in rice cultivation, in climate change scenario and possessed high knowledge on puddler, mould board plough, rotavator, harrow, combine harvester and paddy drum seeder. Rice growers have some awareness about changing climates and adopting strategies to cope with this challenge. However, their knowledge on cono weeder, thresher, paddy transplanter, straw baler and paddy reaper appeared to be relatively limited. The probable reason for the above trend might be due to their experience in farming and paddy being labor intensive crop demands more labor which forced them to look for other alternatives. Majority of rice farmers had an education level ranging from intermediate to graduation. This education level enabled farmers to access mass media and ICT tools, which in turn allowed them to gain knowledge about various farm mechanization implements.

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Novelty Statement

There is a need and awareness of knowledge level determination about agriculture mechanization and climate change adaptation among the farmers for extension work. Knowledge obtained from this study will be helpful for agronomist, farmers and policy makers in adaptation of agricultural mechanization especially in rice cultivation.

Author's Contribution

Iqtidar Hussain: Principal and project investigator, write-up and corresponding author.
Muhammad Saleem: Co-principal project investigator
Hamayoon Khan: Helped in proofreading and editing
Hadia Gul: Data analysis
Ehtesham Ul-Haq: Collection of review of literature
Muhammad Jawad Nazir: Helped in data collection
Faheem Abbass: Survey conduction
Muhammad Naeem: Survey designing

Generative AI and AI-assisted technology statement
The author(s) declare that no Generative AI was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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