frontiers | Frontiers in Environmental Science

ORIGINAL RESEARCH
published: 11 May 2022
doi: 10.3389/fenvs.2022.900193

Determining Farmers' Awareness About Climate Change Mitigation and Wastewater Irrigation: A Pathway Toward Green and Sustainable Development

Muhammad Tayyab Sohail[1], Eslam B. Elkaeed[2], Muhammad Irfan[3]*, Ángel Acevedo-Duque[4] and Sohaib Mustafa[5]**

[1]School of Public Administration, Xiangtan University, Hunan Xiangtan, China, [2]Department of Pharmaceutical Sciences, College of Pharmacy, AlMaarefa University, Riyadh, Saudi Arabia, [3]Faculty of Management Science, Department of Business Administration, ILMA University, Karachi, Pakistan, [4]Public Policy Observatory Faculty of Business and Administration, Universidad Autónoma de Chile, Santiago, Chile, [5]Department of Management, National College of Business Administration and Economics (NCBA&E), Lahore, Pakistan

OPEN ACCESS

Edited by:
Asif Razzaq,
Dalian University of Technology, China

Reviewed by:
Mirza Huzaifa Asif,
North China Electric Power University, China
Muhammad Afaq Haider Jafri,
Beijing University of Technology, China

***Correspondence:**
Muhammad Tayyab Sohail
tayyabsohail@yahoo.com
Muhammad Irfan
irfansahar2010@gmail.com
Sohaib Mustafa
gillsohaib@yahoo.com

Specialty section:
This article was submitted to Environmental Economics and Management, a section of the journal Frontiers in Environmental Science

Received: *20 March 2022*
Accepted: *11 April 2022*
Published: *11 May 2022*

Citation:
Sohail MT, Elkaeed EB, Irfan M, Acevedo-Duque Á and Mustafa S (2022) Determining Farmers' Awareness About Climate Change Mitigation and Wastewater Irrigation: A Pathway Toward Green and Sustainable Development. Front. Environ. Sci. 10:900193. doi: 10.3389/fenvs.2022.900193

The present study was conducted in one of the major agriculture areas to check farmers' awareness of climate change, adaptation measurements, and use of wastewater for irrigation. A semi-structured questionnaire was adopted from the existing literature, it was divided into different parts such as demographic information, use of wastewater for irrigation, farmer's livelihood assets, climate change deciding factors, and adaptation measures, and some statistical tools (correlation and regression) were used to analyze the data. The farmers with enough resources and assets regarded themselves as safer and have enough capacity to bear the negative impacts of climate change. Farmers' assets (FA) with determinants of climate change (DCC) and adaption measures (AM) are highly significant with the correlation values of 0.440 and 0.466, respectively, and DCC with AM (0.269). The correlation values for other variables are: gender with cultivated land 0.202, wastewater use (WWU) 0.419, farmers' assets (FA) 0.766, determinants of climate change (DCC) 0.381, and adaption measures (AM) 0.449. Floods and droughts variables have shown a significant relationship with adaption measures at *p*-value 0.000 and coefficient 0.176 and *p*-value 0.021 and coefficient 0.063, respectively. The study will aid in the implementation of effective monitoring and public policies to promote integrated and sustainable water development.

Keywords: farmers, climate, change, development, green, sustainable and resilient

INTRODUCTION

Climate change is a global environmental challenge (Hao et al., 2021; Huang et al., 2022; Shi et al., 2022), and to minimize its negative impact (Razzaq et al., 2020; 2021; 2022), governments are implementing environmentally friendly technologies worldwide (Tang et al., 2022; Wen et al., 2022; Xiang et al., 2022). Many developing countries are affected by climate change due to lack of effective policies or insufficient capacity to deal with it (Elavarasan et al., 2021; Abbasi et al., 2022; Ahmad et al., 2022). Pakistan is the most affected country in this region by climate change (Irfan et al., 2019,

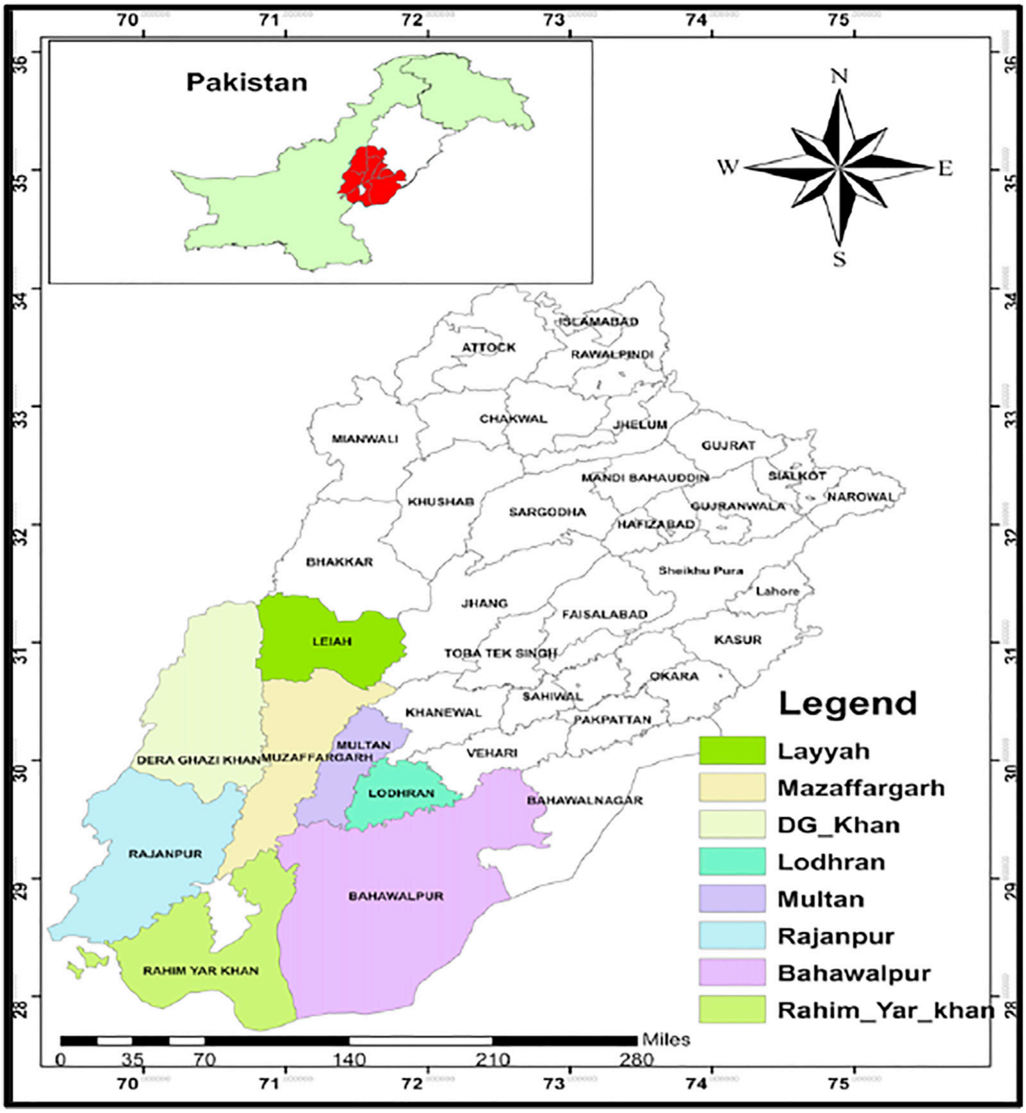

FIGURE 1 | Study area.

2020; Ali et al., 2021; Tanveer et al., 2021), and high temperatures can have negative effects on agriculture (Ali et al., 2021; Chandio et al., 2021; Irfan et al., 2021). Pakistan's contribution toward global warming is very low, but the impact of climate change has grown day by day (Fahad et al., 2018). Floods, droughts, and storms are all too common in Pakistan these days as a result of the high temperature, which is linked to climate change (Mueller et al., 2014; Khan et al., 2020). Many scholars acknowledged that farmers use various ways to adapt climate change vulnerability (Bryant et al., 2000; Bryan et al., 2009) and stated that climate change vulnerability and risk perception adaptability at the household level are critical to minimize climate change impacts on agriculture (Abid et al., 2016; Srivastava, 2020). Pakistan is a developing country, and the situation in terms of adaptation and vulnerability is unsatisfactory (Hussain and Mudasser, 2007; Sohail et al., 2014; Sohail et al., 2019a). Adger and Kelly (1999) claim that good adaptation can mitigate the harmful effects of climate change (Sohail et al., 2021a). Climate change has been shown in numerous studies to have a significant impact on people living in rural areas connected to the farming sector (O'Brien and Leichenko, 2000). Because there is a significant link between climate change and agriculture, those who work in agriculture are more likely to be affected by the effects of climate change (Field et al., 2012). Climate change is a serious threat to many countries' agricultural sectors, and implementing adaptation strategies is thus vital to protect future agricultural production and farmers' livelihoods (Chandra et al., 2017; Amir et al., 2020). Pakistan is mainly an agricultural country (Sohail et al., 2015; Fiaz et al., 2016), and agriculture depends on irrigation (Lee et al., 2020). It is very common in many countries to use wastewater for agriculture purposes, and it is a good way of disposing wastewater with advantages such as a lot of nutrients, which make the crop yields rise without using fertilizer, but apart from some positive impacts,

TABLE 1 | Survey participants.

Province	District	No. of interviewed farmers
Punjab	Layyah	130
	Muzaffargarh	140
	DG Khan	145
	Lodhran	160
	Multan	140
	Rajanpur	155
	Bahawalpur	150
	Rahim_Yar_Khan	180
	Total	1,200

it contains organic compounds, heavy metals, and a wide spectrum of enteric pathogens which can harm human health, the environment, and agricultural productivity (Sohail et al., 2019b; Mahfooz et al., 2019; Sohail et al., 2020). Usually, farmers depend on canal water and wastewater for agriculture purposes, and wastewater is considered to have a positive impact on crops (Yamin et al., 2015). Sometimes wastewater cannot be fit for agriculture and can have negative impact on crops, soils, vegetables, environments, and human health (Holt, 2000; Hassan et al., 2013; Ullah et al., 2013; Mustafa et al., 2022). Furthermore, sometimes some farmers do not have access to canal water or suffer from shortage of allocated canal water due to lack of canal water supply. Therefore, if they have easy access to wastewater pumping stations, they will use wastewater as an alternate source of irrigation (Anwar et al., 2010). It is estimated that about 200 million farmers irrigate 20 million hectares of land with wastewater globally (Raschid-Sally and Jayakody, 2009). All these have severe impact on the production of different crops in Pakistan (Lobell and Gourdji, 2012). But still, there are missing comprehensive policies to deal with such natural disasters (Shah et al., 2020; Yen et al., 2021; Liu et al., 2022). The sustainable livelihoods approach (SLA) was used in this research, to check how livelihood assets help to achieve farmers' well-being. In this research, we build SLA by mixing household adoption techniques and costly adaptation strategies, along with consequences for livelihood outcomes (Shinbrot et al., 2019). The objectives of this study were: 1) farmers' awareness of climate change and adaption of different techniques to deal with climate change. 2) Farmer's awareness about the impact of reuse of wastewater on crops. 3) Farmer's livelihood assets and life status in South Punjab, Pakistan. This study will aid policymakers in assisting farmers in their daily lives and farming operations. Without the intervention of the government, it is impossible to provide assistance and support to vulnerable farmers for the adaptation and implementation of good practices (Udmale et al., 2014).

MATERIALS AND METHODS

Study Area

Punjab is the most populous and second-largest province of Pakistan. It encompasses 25.8% of Pakistan's total land area. The weather in Punjab province varies throughout the year. By mid-February, the temperature starts to rise, and the spring weather lasts until mid-April when the summer heat hits, and June and July are the hottest months of the year. Temperatures in the Punjab region range from 2 to 45°C but can reach 50°C (122°F) in the summer. Punjab has three distinct seasons in terms of climate. Punjab has a total land area of 20.63 million hectares, with 59 percent of that area under cultivation. The province accounts for 53% of the country's overall agricultural GDP and 74% of its cereal production (Abid et al., 2015; 34.; Ahmad and Afzal, 2020). Due to the importance of this agricultural area, Farmers' perceptions toward climate change and adaptation measures were studied in this study (**Figure 1**).

Data Sources and Data Preparation

This study was based on farmers' experience with climate change, the use of wastewater for irrigation, and their adaption techniques toward climate change (Fahad and Wang, 2018; Sohail et al., 2021c). A semi-structured questionnaire was adopted from the existing literature and modified as per the study area requirement to collect data from eight districts of South Punjab, Pakistan (Layyah, Muzaffargarh, DG Khan, Lodhran, Multan, Rajanpur, Bahawalpur, and Rahim_Yar_Khan) (Fahad and Wang, 2018; Fahad et al., 2020). Basic research ethics were considered while defining the objectives of the research and collecting data from farmers, and the objective of the research was clearly explained to farmers (Bogner et al., 2009; Rasool et al., 2017), and it was informed to farmers that these data will be used only for research purposes and there is no compulsion for them to answer these questions (McCusker and Gunaydin, 2015). A survey team consisting of five researchers (Ph.D., Master, and Postdoc) was sent to collect data from farmers of South Punjab, Pakistan. Farmers were informed about the purpose of the research; the first portion was about demographic information of participants, and the rest of the questionnaire was about the use of wastewater for irrigation purposes (Mojid et al., 2010), farmer's livelihood assets, determining factor of climate change, and adaption measures. In this study, 1,200 completely filled questionnaires were collected from the study area, and a pre-test was carried out to check the reliability of data and to avoid any discrepancies. After data collection, data were fed into SPSS 24 for further analyses. A confidence level of 95% was used with a 7% margin error. Some other researchers also used the same margin error of 7% (Hussain and Thapa, 2012; Fahad et al., 2018, 2020). Some statistical tools (correlation and regression) were used to analyze the data.

RESULTS AND DISCUSSION

Table 1 shows the number of farmers interviewed in the present study; a total number of 1,200 farmers were interviewed from Punjab Province of Pakistan (Layyah 130, Muzaffargarh 140, DG Khan 145, Lodhran 160, Multan 140, Rajanpur 155, Bahawalpur 150, and Rahim_Yar_Khan 180) **Table 1**. There are some internal possible factors such as personal characteristics, individual circumstances, and farming practices which are additionally

TABLE 2 | Demographic information of participants.

Characteristic	Category	Districts of Punjab (%)							
		Layyah	Muzaffargarh	DG Khan	Lodhran	Multan	Rajanpur	Bahawalpur	Rahim_Yar_Khan
Gender	Male	85.4	81.4	73.8	75.0	77.1	71.6	74.0	72.2
	Female	14.6	18.6	26.2	25.0	22.9	28.4	26.0	22.8
Age (years)	18–25	17.7	13.6	13.8	15.0	19.3	23.2	22.7	20.6
	26–35	37.7	20.7	37.2	33.1	32.9	34.8	33.3	26.7
	36–45	28.5	43.6	26.2	40.6	32.1	28.4	32.7	41.1
	Above 45	16.2	22.1	22.8	11.3	15.7	13.5	11.3	11.7
Education (years)	0	31.1	23.6	25.5	45.6	52.1	49.0	39.3	30.6
	1–5	43.1	50.0	54.5	40.6	39.3	41.3	34.7	38.9
	6–10	14.6	15.7	11.0	9.4	5.0	7.7	18.7	21.1
	11-above	9.2	10.7	9.0	4.4	3.6	1.9	7.3	9.4
Family size (numbers)	1–2	16.2	25.7	18.6	11.9	19.3	21.9	16.7	11.7
	3–5	43.8	32.9	44.8	39.4	44.3	44.5	48.7	43.9
	6-above	40.0	41.4	36.6	48.8	36.4	33.5	34.7	44.4
Farming present land (years)	1–5	26.2	35.0	46.2	45.0	53.6	49.0	54.0	61.7
	6–10	50.0	32.9	28.3	31.9	20.7	36.1	28.7	28.9
	11–15	10.0	21.4	18.6	15.6	22.1	9.0	12.7	5.6
	16-above	13.8	10.7	6.9	7.5	3.6	5.8	4.7	3.9
Land preparation (use)	Tractor	76.2	55.7	73.8	76.3	53.6	78.1	73.3	63.3
	Bullocks	18.5	35.7	20.0	18.8	42.1	21.3	25.3	34.4
	Both	5.4	8.6	6.2	5.0	4.3	0.6	1.3	2.2
Plowing per year	Once	16.9	3.6	4.1	6.9	8.6	5.8	8.0	5.0
	Twice	70.0	78.6	80.7	61.3	63.6	56.8	45.3	45.0
	Three-more	31.1	17.9	15.2	31.9	27.9	37.4	46.7	50.0
Information sources	Media	25.4	30.7	24.0	18.1	18.6	16.8	14.0	7.8
	Other farmers	31.1	35.0	35.2	31.9	35.7	40.0	36.0	33.3
	Own view	29.2	29.3	29.0	40.0	31.4	32.9	44.0	50.0
	Do not know	12.3	5.0	11.7	10.0	14.3	10.3	6.0	8.9
Are you aware of climate change	Yes	78.5	87.9	82.8	83.1	87.1	74.8	79.3	85.6
	No	21.5	12.1	17.2	16.9	12.9	25.2	20.7	14.4

defined as individual farmers' response and adaption capacity (Udmale et al., 2014).

Table 2 explains the demographic information of all respondents in these eight districts of Punjab province: Layyah 85.4% male and 7% female, Muzaffargarh 81.4% male and 18.6% female, DG Khan 73.8% male and 26.2% female, Lodhran 75% male and 25% female, Multan 77.1% male and 22.9% female, Rajanpur 71.6% male and 28.4% female, Bahawalpur 74% male and 26% female, and Rahim_Yar_Khan 72.2% male and 22.8% female. In all selected districts of Punjab province, the age of most farmers was between 26 and 45 years, which showed that most of them are young, experienced, and active in farming. In most of the districts, farmers' education level was not high, most of them have primary-level education, and some of them have had more than 6 years of education level. The majority of farmers were experienced, and some of them have about five to 10 years of farming experience. Deressa et al. (2009) described that the awareness of the farmer is positively related to farming experience and education. The family size in all districts was a little high; almost all families have more than two children, while most of them have more than five as well, and they consider it labor force in farming. In all eight districts, the majority of the respondents used tractors for plowing land, and some of them used bullocks as well. The percentages of farmers plowing using tractors in all districts are Layyah 76.2%, Muzaffargarh 55.7%, DG Khan 73.8%, Lodhran 76.3%, Multan 53.6%, Rajanpur 78.1%, Bahawalpur 73.3%, and Rahim_Yar_Khan 63.3%. The majority of farmers were plowing twice a year, and the number of people plowing three times a year was not less as well. It is very considerable from where farmers get information for their farming; most of the people said they got information from their co-farmers and particularly old farmers in the same area. To check the farmer's awareness, there was another question "are you aware of climate change," and the response to this question was very satisfactory with Layyah 78.5%, Muzaffargarh 87.9%, DG Khan 82.8%, Lodhran 83.1%, Multan 87.1%, Rajanpur 74.8%, Bahawalpur 79.3% and Rahim_Yar_Khan 85.6% who were well aware of climate change (**Table 2**). The existing literature informed us that farmers' perception of climate change and its impact emphasizes that awareness of climatic risks is mediated by farmland features and farmers' demographic assets (Singh et al., 2017). Knowledge, information sharing, and communication are always beneficial for farmers in decision-making, and it helps them with proper adoption measurement for climate change and associated factors (Drafor and Agyepong, 2005). It is also approved by the existing literature that climate change adaptation techniques used at their farmhouses are concerned by the significance of demographic characteristics and socioeconomics of farmers.

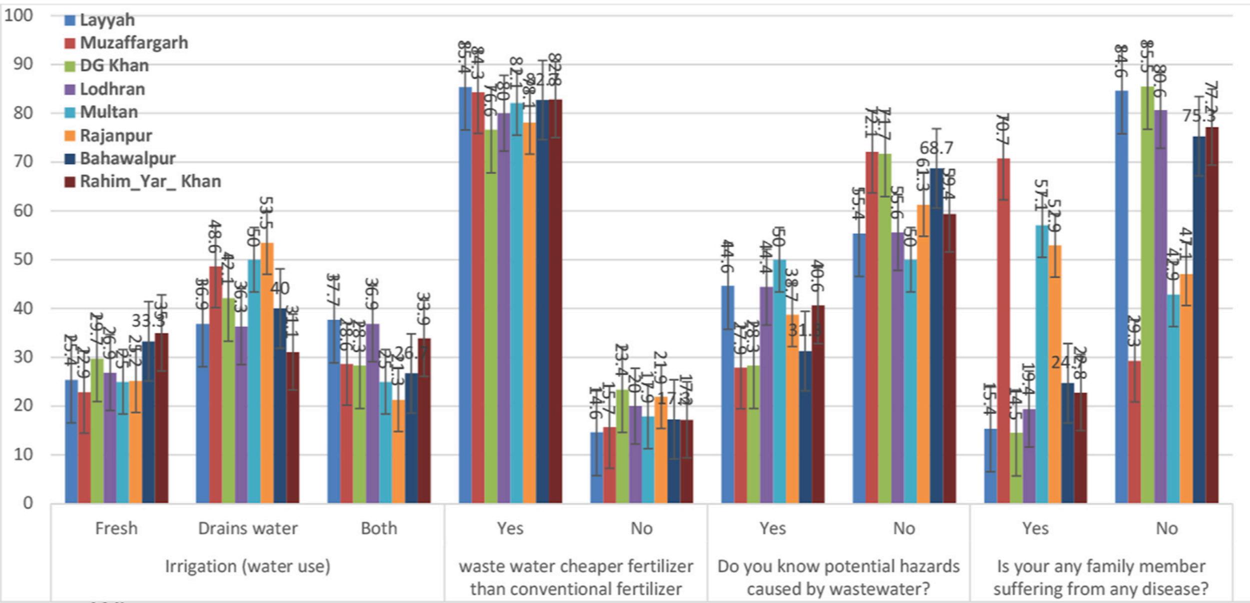

FIGURE 2 | Wastewater use for irrigation (%).

There is not a satisfactory infrastructure for wastewater collection and treatment in Pakistan at any level, especially in South Punjab, Pakistan (Kanwal et al., 2020). Major industries are throwing their wastewater directly into nearby water bodies or cultivated land (Shahid et al., 2020). The climate of Pakistan fluctuates in different parts of the country, and freshwater is very scarce, especially in Sindh and southern Punjab provinces of the country, it is scarce due to the semiarid to arid climate (Shah et al., 2019), the reason why farmers are using canal water, groundwater, and wastewater for crop irrigation. Groundwater for irrigation is expensive and unreliable in Pakistan due to energy crises (Murtaza et al., 2019). Moreover, groundwater is mostly of poor quality in these areas of Pakistan due to enhanced concentrations of soluble salts and toxic metal contents (Murtaza et al., 2019). Due to these reasons, wastewater is commonly used for irrigation in some areas, and considering the current situation, there are many chances that the application of wastewater may increase in the coming years (Shahid et al., 2020). **Figure 2** elaborates on the situation of water used for irrigation purposes. The results of this survey showed that people used drains or both drain and freshwater for irrigation purposes which was average to high in this study area. Some researchers explained that the use of low-quality water for irrigation can have an impact on soil and groundwater quality and can have a bad impact on human health (Bruvold and Crook, 1981). As the usage drains the water, for to know the reasons, there was another question, which was "wastewater is cheaper fertilizer than conventional fertilizer." Most of the responses were in favor of "yes" and accounted for Layyah 85.4%, Muzaffargarh 84.3%, DG Khan 76.6%, Lodhran 80.0%, Multan 82.1%, Rajanpur 78.1%, Bahawalpur 82.7%, and Rahim_Yar_Khan 82.8%. Most farmers added that there are some main reasons for using drain water which were: 1) lower water price, 2) lower cost of the fertilizer, and 3) increase crop production (Mojid et al., 2010). Most of the farmers were unaware of the possible hazards of using drain water which accounted for Layyah 55.4%, Muzaffargarh 72.1%, DG Khan 71.7%, Lodhran 56.6%, Multan 50.0%, Rajanpur 61.3%, Bahawalpur 68.7%, and Rahim_Yar_Khan 59.4, while some districts farmers were aware of possible hazards which accounted for Multan 50.0%, Layyah 44.6%, Lodhran 44.4%, and Rahim_Yar_Khan 40.6% (Carr et al., 2011). If wastewater is easily available for irrigations farmers, they will prefer to use it due to economic benefits; usually, they do not consider human health or environmental risks due to wastewater (Mahfooz et al., 2020; Shahid et al., 2020; Sohail et al., 2021b). Many farmers like to use wastewater due to its positive impact and existence of nutrients for crops, although nutrients level in wastewater are not explored fully (Khalid et al., 2020), and studies have outlined the possible hazards related to the toxic metal buildup in wastewater-irrigated topsoil and on human health (Kanwal et al., 2020, Shahid et al., 2020). Many farmers said that no one in their family suffered from any diseases, while some farmers said that they have some people; but, in three districts, some people were infected with minor to major diseases which accounted for Muzaffargarh 70.7%, Multan 57.1%, and Rajanpur 52.9% (Shahid et al., 2020) (**Figure 2**).

Table 3 describes farmers' lifestyles and assets, for example, motorbikes, tractors/plow, bicycles, spraying device, children going to school, tube well, electric generator, air conditioners, gas generator, car, and pets (Jezeer et al., 2019). In these eight districts of South Punjab province, Pakistan, the majority of farmers have all the aforementioned assets related to their farming and daily life. Some farmers owned tractors for land preparation, but many of them used bullocks, and sometimes rented a tractor for their land preparation.

TABLE 3 | Farmer's livelihood assets.

Characteristic		Punjab (districts)							
		Layyah	Muzaffargarh	DG khan	Lodhran	Multan	Rajanpur	Bahawalpur	Rahim_Yar_Khan
Motorbike	No	48.5	22.1	24.8	30.6	27.9	30.3	36.0	36.7
	Yes	51.5	77.9	75.2	69.4	72.1	69.7	64.0	63.3
Bicycle	No	65.4	77.1	72.4	75.6	68.6	65.2	66.0	60.0
	Yes	34.6	22.9	27.6	24.4	31.4	34.8	34.0	40.0
Tractor/plow	No	41.5	52.0	47.6	25.5	75.7	67.7	68.0	68.3
	Yes	58.5	47.9	52.4	47.5	24.3	32.3	32.0	31.7
Spraying device	No	80.0	78.6	69.7	74.4	76.4	72.9	74.0	63.3
	Yes	20.0	21.4	30.3	25.6	23.6	27.1	26.0	36.7
Tube well	No	47.7	84.3	79.6	80.0	53.6	78.1	82.7	82.8
	Yes	52.3	15.1	24.4	20.0	46.4	21.9	17.3	17.2
Children going to school	No	29.2	26.4	56.6	28.7	35.0	33.5	26.0	20.0
	Yes	70.8	73.6	43.4	71.3	65.0	66.5	74.0	80.0
Electric generator	No	85.4	84.3	75.5	73.8	87.1	78.1	82.7	81.7
	Yes	14.6	15.7	25.5	26.3	12.9	21.9	17.3	18.3
Gas generator	No	79.2	83.6	71.0	70.6	79.3	73.5	77.3	78.3
	Yes	20.8	16.4	29.0	29.4	20.7	26.5	22.7	21.7
Air conditioner	No	71.5	71.4	64.8	65.0	66.4	62.6	72.7	72.8
	Yes	28.5	28.6	35.2	35.0	33.6	37.4	27.3	27.2
Car	No	85.4	82.9	69.0	78.1	77.9	74.2	76.0	77.2
	Yes	14.6	17.1	31.0	21.9	22.1	25.8	24.0	22.8
Pets (dog and horse, etc.)	No	61.5	62.9	45.5	60.6	70.7	58.7	65.3	59.4
	Yes	38.5	37.1	54.5	39.4	29.3	41.3	34.7	40.6

TABLE 4 | Correlation of selected variables.

	Gender	Age group	Education level	Cultivated land	Source of information	Wastewater use (WWU)	Farmers' assets (FA)	Determinants of climate change (DCC)	Adaption measures (AM)
Gender	1								
Age group	0.022	1							
Education level	0.165**	0.052	1						
Cultivated land	**0.202****	0.035	0.047	1					
Source of information	0.011	**0.340****	-0.033	-0.030	1				
Wastewater use (WWU)	**0.419****	0.155**	0.154**	0.118**	0.133**	1			
Farmers' assets (FA)	**0.766****	0.014	0.174**	0.180**	0.021	**0.435****	1		
Determinants of climate change (DCC)	**0.381****	0.034	0.128**	0.072*	0.034	**0.239****	**0.440****	1	
Adaption measures (AM)	**0.449****	0.030	0.128**	0.126**	0.038	**0.284****	**0.466****	**0.269****	1

***Correlation is significant at the 0.01 level (two-tailed).*
**Correlation is significant at the 0.05 level (two-tailed).*

Many other secondary kinds of luxuries, for example, cars, air conditioners, generators, and tube wells in the study area were not available to all farmers, which approved their less luxurious life, showing the compulsions of climate change (Ullah et al., 2013). They are supposed to access the latest technology for farming, and agricultural assets stimulate progress in agriculture and help to lessen poverty (Fahad, et al., 2018). Some researchers indicated that the farmers who were eager to reduce the risk associated with indeterminate climate change had enough resources and had more capacity to adapt (Deressa et al., 2009). The farmers with enough resources and assets regarded themselves as safer and have enough capacity to bear the negative impacts of climate change; additionally, small farmers are always at risk due to natural disasters such as heavy precipitation, droughts, and floods (Qasim et al., 2015; Zhao et al., 2019).

Table 4 and **Figures 3A,B** elaborate on the perception of farmers toward climate change in South Punjab, Pakistan. No doubt impacts of climatic change have become gradually apparent over the past few decades (Patt and Schröter, 2008). The main indicators which were encompassed to check perception were flood, irrigation, droughts, agriculture, drinking water in agriculture areas, soil issues, communication, transportation to the agricultural land, animal diseases, and crop pests. As per response from farmers, the flood rate in Muzaffargarh is 48.6%, DG Khan is 75.9%, and Rajanpur is 70.3% which is high while the rest of the tehsils put it at more moderate or lower rate than that of the study area, but till they were under severe pressure of floods. It means food can be the main threat to the farmers in those areas due to the Indus River. The literature provided sufficient evidence of the impact of high

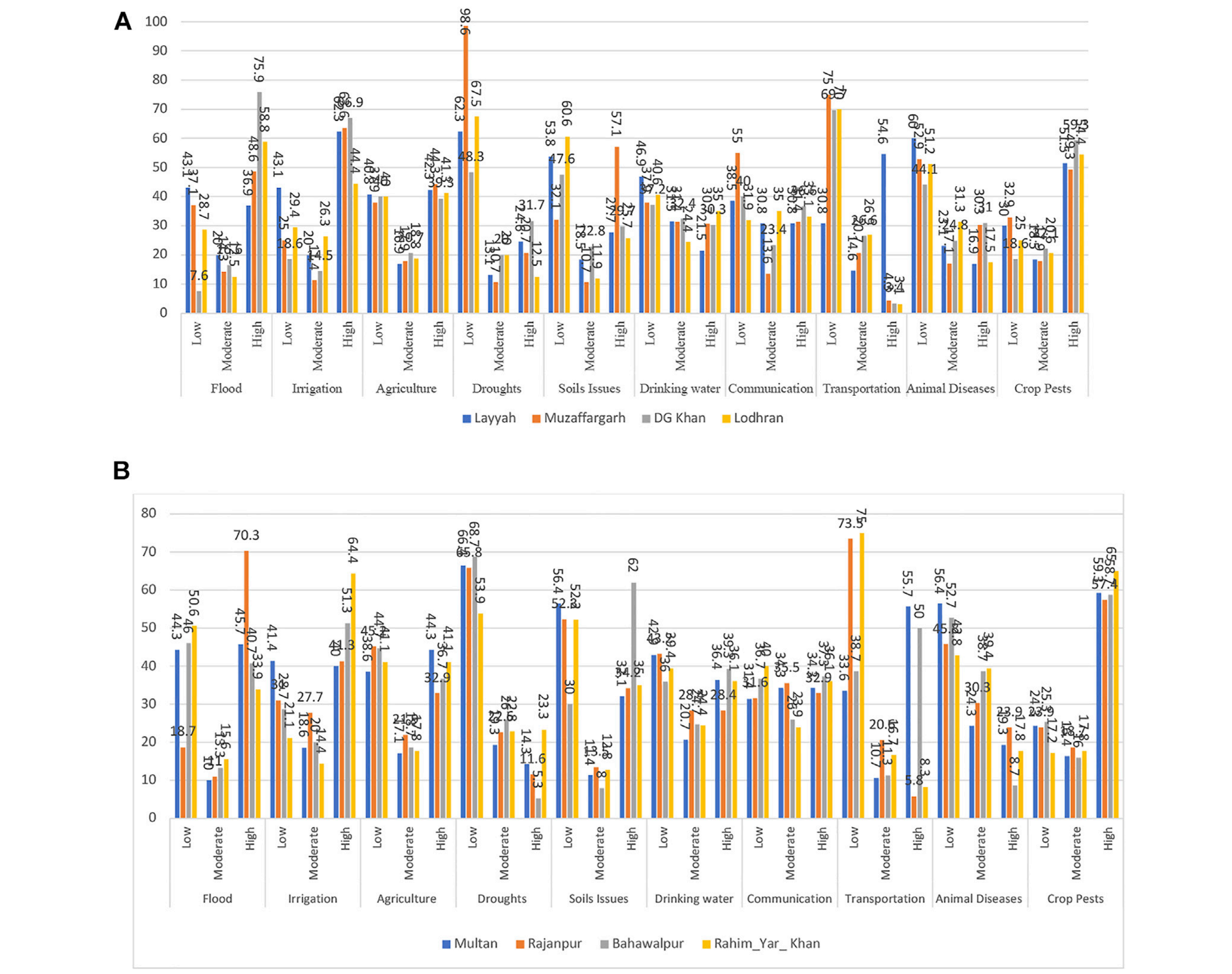

FIGURE 3 | Determining factors of Climate Change (%) in South Punjab Pakistan.

temperatures and floods on farmers' life (Maheen and Hoban, 2017). Pakistan is a developing country and trying to make progress in many sectors, but still like many other developing countries major portion of the population is living under unsatisfactory conditions, particularly farmers who are living in rural disaster areas (Fahad, et al., 2018). There have been many destructive floods in the history of Pakistan in different areas (Hoanh et al., 2006) such as 2010, 2011, and 2014 which caused forestry, damage to livestock, fisheries, infrastructure, fertilizers, animal sheds, and loss of approximately 250,000 farm households, and one million cultivated lands were devastated (NDMA, 2014). Such disasters can be reasons for crop failure, poor yields, and livestock mortality (Harvey. 2014). Soil issues are another main issue for many farmers in South Punjab, Pakistan (Maqbool et al., 2021). As per responses from farmers, soil issues in this study area were low to moderate, but still, some farmers face soil issues which accounted for Layyah 27.7%, Muzaffargarh 57.1%, DG Khan 29.7%, Lodhran 25.7%, Multan 32.1%, Rajanpur 34.2%, Bahawalpur 60.0%, and Rahim_Yar_Khan 35.0% (Javed et al., 2020). Animals are always an important asset for farmers in the whole world, and animal diseases can be another challenge for them (Musungu, 2020). As per the response from farmers, there are some farmers who were facing animal disease problem in South Punjab, Pakistan. Crop pets are going to be severe in South Punjab for some years (Khan et al., 2020). The responses from farmers about crop pets in this study area were high, which accounted for Layyah 51.5%, Muzaffargarh 49.3%, DG Khan 59.3%, Lodhran 54.4%, Multan 59.3%, Rajanpur 57.4%, Bahawalpur 58.7%, and Rahim_Yar_Khan 65.0%.

The present study also included adaption techniques against climate change (**Figure 4**). It is very common among many farmers to choose crop variety, fertilizer adjustment, water, agrotechnical support, and agricultural finance and to deal with livelihood risks (Kuang et al., 2020). It is reported that similar kinds of adaptation measures such as changing planting dates, crop types, changing varieties, and changing input mix are adopted by farmers in Pakistan (Gorst et al., 2015). Sometimes farmers faced problem-

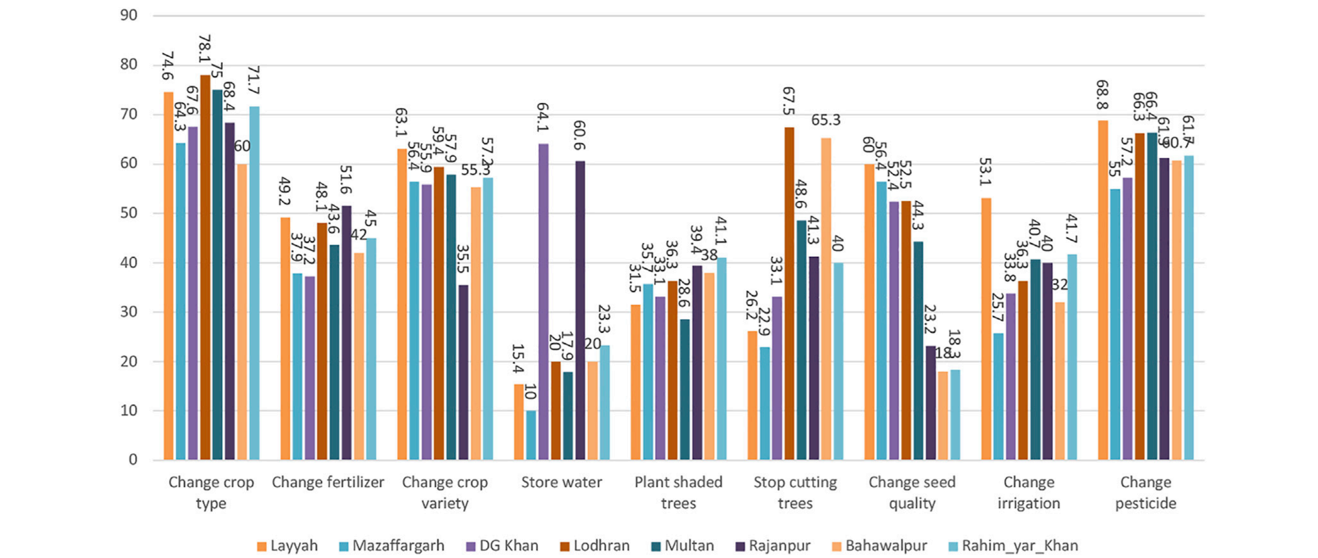

FIGURE 4 | Adaption strategies/measures (%) by farmers in South Punjab, Pakistan.

TABLE 5 | Linear regression table of selected variables.

Variable	Coefficient: Unstandardized coefficient		Standardized coefficient	t	Sig
	B	**Std. error**	**Beta**		
Animal diseases	0.021	0.008	0.073	2.695	0.007***
Soil issues	0.021	0.006	0.087	3.206	0.001***
Droughts	0.050	0.008	0.176	6.552	0.000***
Flood	0.015	0.007	0.063	2.303	0.021**
Crop pests	0.005	0.007	0.018	0.659	0.510
Store water	0.086	0.013	0.178	6.574	0.000***
Transportation to agriculture land	0.036	0.007	0.134	4.948	0.000***
Drinking water in agriculture areas	0.015	0.007	0.058	2.172	0.030**
Possible potential hazards caused by wastewater	0.070	0.012	0.154	5.662	0.000***

[a]*Dependent variable: adaption measures (AM); significance levels: *= P ≤ 0.10; **= P ≤ 0.05 and; ***= P ≤ 0.01.*

related attacks of pests on crops which is comparatively high in South Punjab for many years, and it may affect production so in different time zones, and they use different techniques to reduce risk (Ishtiaq et al., 2020). It is also stated that in recent times crop production reduction can be due to different plant diseases, climate change, poverty, or irrigation issues (Fahad et al., 2018). The literature showed that small farmers were relatively more vulnerable to adopting climate changes than big farmers (Jamshidi et al., 2019), and the impact of climatic risks on farmer's income, family food, and security was significantly hypothetically stronger by low-resource-endowed being farmers (Shukla et al., 2019), and as per another study in Africa, they indicated it as the first step to the adoption process toward climate change (Trinh et al., 2018). The existing literature described the impact of climate changes on crop production (Hay and Mamura, 2010). Pakistan is an agricultural country, and a major portion of its GDP comes from agriculture, but unfortunately Pakistan recently is dropping its crop production due to climate issues (Tingju et al., 2014). Farmers must learn about climate risks and adoption measures, which can help them to reduce risk rates and can help to increase crop production (Fahad et al., 2018). Meanwhile, physical assets and natural and social assets have positive effects on farmers' adaptation strategies (Kuang et al., 2020).

Table 4 shows the results of descriptive statistics and correlation coefficient of these selected variables (gender, age, education, farming experience, source of information, wastewater use (WWU), farmer's assets (FA), determination of climate change (DCC), and adaption measures (AM)). Correlation is a tool to check the relation between two or more variables. The values of correlation are between +1.00 and -1.00. The strength of the correlation is determined by the magnitude of the number with one being the maximum. In the current study, correlation values of selected variables are significant among all variables, and there is a medium to strong correlation among different variables. Farmers' assets

(FA) with determinants of climate change (DCC) and adaption measures (AM) are highly significant with the correlation values 0.440 and 0.466, respectively, and DCC with AM (0.269). The correlation values for other variables are: gender with cultivated land 0.202, waste water use (WWU) 0.419, farmers' assets (FA) 0.766, determinants of climate change (DCC) 0.381, and adaption measures (AM) 0.449. All variables were found significant with a week to moderate correlation among all selected variables (**Table 4**).

Table 5 shows the results of linear regression among selected variables of the present study. Among explanatory determinants, animal diseases showed significance (p-value of 0.01 and coefficient of 0.073). For instance, as the farmers adopt sufficient measures, they can control diseases among animals, and animals are always basic assets of farmers (Musungu, 2020). In other words, farmers always adopt some measures in different regions to control animal diseases, and there is a significant relationship between farmers' adoption strategies and animal diseases. The variable soil issues is highly significant (with a p-value of 0.001 and coefficient of 0.087). This means that with enough resources and measurement soil issues can be handled. Flood and drought variables have shown a significant relationship with adaption measures [(p-value 0.000 and coefficient 0.176) and (p-value 0.021 and coefficient 0.063), respectively] indicating that adoption measures can be helpful for droughts and floods. Crop pet variable has shown an insignificant relationship (p-value 0.510 and coefficient 0.018). It showed that sometimes farmers are adopting different measures to control crop pets but they are unable to do it; as from last few years, there are a huge number of pets appeared every year, especially in South Punjab, Pakistan. Stored water showed statistical significance with the dependent variable at p-value 0.000 and positive coefficient 0.178 with farm households' adoption measure strategies. The transportation to agriculture and drinking water in agriculture variables have shown a significant relationship with adoption measure at p-value 0.000 and coefficient of 0.134 and p-value 0.030 and coefficient of 0.058, respectively. The variable possible potential hazards caused by wastewater has indicated a significant relationship with the dependent variable at p-value 0.000 and coefficient 0.154; in other words, more good adoption measures and access to information related to hazards of wastewater use can help to reduce the impact of wastewater on human health.

CONCLUSION

Farmers of the study area described that drought, temperature, floods, and variation are the major risks linked with climate change, and it is adversely affecting agriculture in this study area; farmers used some techniques against climate change such as irrigation, seeds, fertilizer, and crops. Pakistan is an agricultural country, and a major portion of GDP comes from this sector, and the majority of the population belongs to farming. Most of the farmers were unaware of the possible hazards of using drain water. Many statistical tools were used to check the relationship among different variables, wastewater use, and any family member suffering from any disease, which showed a significant relation. The farmers with enough resources and assets regarded themselves as safer and have enough capacity to bear the negative impact of change in the climate. In the current study, correlation values of selected variables are significant among all variables, and there is a medium to strong correlation among different variables. This study was limited to one province of Pakistan. But, main results of this research can be implemented in other places as well where the climate change adaptations are still ineffective. The study will help to support the implementation of proper monitoring and public policies to ensure integration and sustainability, and it will aid policymakers to provide support to farmers in their daily life and farming practices.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

MTS: conceptualization, methodology, software, and writing—original draft. EBE: supervision and final draft approval. MI: data collection and analyzing. AA-D: editing and data collection. SM: visualization, and investigation. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

The authors extend their appreciation to the Research Center at AlMaarefa University for funding this work.

REFERENCES

Abbasi, K. R., Shahbaz, M., Zhang, J., Irfan, M., and Alvarado, R. (2022). Analyze the Environmental Sustainability Factors of China: The Role of Fossil Fuel Energy and Renewable Energy. *Renew. Energ.* 187, 390–402. doi:10.1016/j.renene.2022.01.066

Abid, M., Scheffran, J., Schneider, U. A., and Ashfaq, M. (2016). Climate Change Vulnerability, Adaptation, and Risk Perceptions at Farm Level in Punjab, Pakistan. *Sci. Total Environ.* 547, 447–460. doi:10.1016/j.scitotenv.2015.11.125

Abid, M., Scheffran, J., Schneider, U. A., and Ashfaq, M. (2015). Farmers' Perceptions of and Adaptation Strategies to Climate Change and Their Determinants: the Case of Punjab Province, Pakistan. *Earth Syst. Dynam.* 6 (1), 225–243. doi:10.5194/esd-6-225-2015

Adger, W. N., and Kelly, P. M. (1999). Social Vulnerability to Climate Change and the Architecture of Entitlements. *Mitigation adaptation Strateg. Glob. Change* 4 (3-4), 253–266. doi:10.1023/a:1009601904210

Ahmad, B., Irfan, M., Salem, S., and Asif, M. H. (2022). Energy Efficiency in the Post-COVID-19 Era: Exploring the Determinants of Energy-Saving Intentions and Behaviors. *Front. Energ. Res.* 9, 824318. doi:10.3389/fenrg.2021.824318

Ahmad, D., and Afzal, M. (2020). Climate Change Adaptation Impact on Cash Crop Productivity and Income in Punjab Province of Pakistan. *Environ. Sci. Pollut. Res. Int.* 27, 30767–30777. doi:10.1007/s11356-020-09368-x

Ali, S., Yan, Q., Sajjad Hussain, M., Irfan, M., Ahmad, M., Razzaq, A., Dagar, V., and Işık, C. (2021). Evaluating Green Technology Strategies for the Sustainable Development of Solar Power Projects: Evidence from Pakistan. *Sustainability* 13 (23), 12997. doi:10.3390/su132312997

Amir, S., Saqib, Z., Khan, M. I., Khan, M. A., Bokhari, S. A., Zaman-ul-Haq, M., et al. (2020). Farmers 'perceptions and Adaptation Practices to Climate Change in Rain-Fed Area: a Case Study from District Chakwal, Pakistan. *Pakistan J. Agric. Sci.* 57 (2), 465–475. doi:10.21162/PAKJAS/19.9030

Anwar, H. N., Nosheen, F., Hussain, S., and Nawaz, W. (2010). Socio-economics Consequences of Reusing Wastewater in Agriculture in Faisalabad. *Pakistan J. Life Soc. Sci.* 8 (2), 102–105.

Bogner, A., Littig, B., and Menz, W. (2009). *Interviewing Experts*. Springer.

Bruvold, W., and Crook, J. (1981). What the Public Thinks: Reclaiming and Reusing Wastewater. *Water Eng. Manage.* 128 (4), 65–71.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., and Ringler, C. (2009). Adaptation to Climate Change in Ethiopia and South Africa: Options and Constraints. *Environ. Sci. Pol.* 12, 413–426. doi:10.1016/j.envsci.2008.11.002

Bryant, C. R., Smit, B., Brklacich, M., Johnston, T. R., Smithers, J., Chiotti, Q., et al. (2000). "Adaptation in Canadian Agriculture to Climatic Variability and Change," in *Societal Adaptation to Climate Variability and Change* (Dordrecht: Springer), 181–201. doi:10.1007/978-94-017-3010-5_10

Carr, G., Potter, R. B., and Nortcliff, S. (2011). Water Reuse for Irrigation in Jordan: Perceptions of Water Quality Among Farmers. *Agric. Water Manag.* 98 (5), 847–854. doi:10.1016/j.agwat.2010.12.011

Chandio, A. A., Jiang, Y., Akram, W., Adeel, S., Irfan, M., and Jan, I. (2021). Addressing the Effect of Climate Change in the Framework of Financial and Technological Development on Cereal Production in Pakistan. *J. Clean. Prod.* 288, 125637.

Chandra, A., McNamara, K. E., Dargusch, P., Caspe, A. M., and Dalabajan, D. (2017). Gendered Vulnerabilities of Smallholder Farmers to Climate Change in Conflict-Prone Areas: A Case Study from Mindanao, Philippines. *J. Rural Stud.* 50, 45–59. doi:10.1016/j.jrurstud.2016.12.011

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., and Yesuf, M. (2009). Determinants of Farmers' Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia. *Glob. Environ. Change* 19 (2), 248–255. doi:10.1016/j.gloenvcha.2009.01.002

Drafor, I., and Agyepong, K. A. (2005). Local Information Systems for Community Development in Ghana. *Improving Inf. flows Rural Community* 5, 73–77.

Fahad, S., Inayat, T., Wang, J., Dong, L., Hu, G., Khan, S., et al. (2020). Farmers' Awareness Level and Their Perceptions of Climate Change: A Case of Khyber Pakhtunkhwa Province, Pakistan. *Land Use Policy* 96, 104669. doi:10.1016/j.landusepol.2020.104669

Fahad, S., and Wang, J. (2018a). Farmers' Risk Perception, Vulnerability, and Adaptation to Climate Change in Rural Pakistan. *Land use policy* 79, 301–309. doi:10.1016/j.landusepol.2018.08.018

Fahad, S., Wang, J., Hu, G. Y., Wang, H., Yang, X. Y., Shah, A. A., et al. (2018). Empirical Analysis of Factors Influencing Farmers Crop Insurance Decisions in Pakistan: Evidence from Khyber Pakhtunkhwa Province. *Land Use Policy* 75, 459–467. doi:10.1016/j.landusepol.2018.04.016

Fiaz, S., Mobeen, N., Noor, M., Muddassir, M., and Mubushar, M. (2016). Implications of Irrigation Water Crisis on Socio-Economic Condition of Farmers in Faisalabad District, Punjab, Pakistan. *Ajaees* 10 (1), 1–7. doi:10.9734/ajaees/2016/22883

Field, C. B., Barros, V., Stocker, T. F., and Dahe, Q. (2012). *Managing the Risks of Extreme Events and Disasters to advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Gorst, C., Kwok, C. S., Aslam, S., Buchan, I., Kontopantelis, E., Myint, P. K., et al. (2015). Long-term Glycemic Variability and Risk of Adverse Outcomes: a Systematic Review and Meta-Analysis. *Diabetes Care* 38 (12), 2354–2369. doi:10.2337/dc15-1188

Hao, Y., Gai, Z., Yan, G., Wu, H., and Irfan, M. (2021). The Spatial Spillover Effect and Nonlinear Relationship Analysis between Environmental Decentralization, Government Corruption and Air Pollution: Evidence from China. *Sci. Total Environ.* 763, 144183. doi:10.1016/j.scitotenv.2020.144183

Harvey, D. (2014). *Seventeen Contradictions and the End of Capitalism*. USA: Oxford University Press.

Hassan, N. U., Mahmood, Q., Waseem, A., Irshad, M., and Pervez, A. (2013). Assessment of Heavy Metals in Wheat Plants Irrigated with Contaminated Wastewater. *Polish J. Environ. Stud.* 22 (1), 115–123.

Hay, J., and Mimura, N. (2010). The Changing Nature of Extreme Weather and Climate Events: Risks to Sustainable Development. *Geomatics, Nat. Hazards Risk* 1 (1), 3–18. doi:10.1080/19475701003643433

Holt, M. S., Tuong, T. P., and John, W. G. (2006). Sources of Chemical Contaminants and Routes into the Freshwater Environment. *Food Chem. Toxicol.* 38, S21–S27. doi:10.1016/s0278-6915(99)00136-2

Holt, W. V. (2000). Basic Aspects of Frozen Storage of Semen. *Anim. Reprod. Sci.* 62 (1–3), 3–22.

Huang, W., Saydaliev, H. B., Iqbal, W., and Irfan, M. (2022). Measuring the Impact of Economic Policies on Co2 Emissions: Ways to Achieve green Economic Recovery in the post-covid-19 Era. *Clim. Change Econ.*, 2240010. doi:10.1142/S2010007822400103

Hussain, A., and Thapa, G. B. (2012). Smallholders' Access to Agricultural Credit in Pakistan. *Food Sec.* 4, 73–85. doi:10.1007/s12571-012-0167-2

Hussain, S. S., and Mudasser, M. (2007). Prospects for Wheat Production under Changing Climate in Mountain Areas of Pakistan - an Econometric Analysis. *Agric. Syst.* 94 (2), 494–501. doi:10.1016/j.agsy.2006.12.001

Irfan, M., Hao, Y., Ikram, M., Wu, H., Akram, R., and Rauf, A. (2021). Assessment of the Public Acceptance and Utilization of Renewable Energy in Pakistan. *Sustainable Prod. Consumption* 27, 312–324. doi:10.1016/j.spc.2020.10.031

Irfan, M., Hao, Y., Panjwani, M. K., Khan, D., Chandio, A. A., and Li, H. (2020). Competitive Assessment of South Asia's Wind Power Industry: SWOT Analysis and Value Chain Combined Model. *Energ. Strategy Rev.* 32, 100540. doi:10.1016/j.esr.2020.100540

Irfan, M., Zhao, Z. Y., Mukeshimana, M. C., and Ahmad, M. (2019). "Wind Energy Development in South Asia: Status, Potential and Policies," in 2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET), Sukkur, Pakistan, 30-31 Jan. 2019 (IEEE), 1–6. doi:10.1109/icomet.2019.8673484

Ishtiaq, M., Sadique, M., Faried, N., Naeem-Ullah, U., and Hamza, M. A. (2020). First Record of Tomato Leaf Miner, Tuta Absolute (Meyrick 1917) (Lepidoptera: Gelechiidae) from Southern Part of Punjab, Pakistan. *J. Anim. Plant Sciences-Japs* 30 (6), 1604–1611. doi:10.36899/JAPS.2020.6.0181

Jamshidi, O., Asadi, A., Kalantari, K., Azadi, H., and Scheffran, J. (2019). Vulnerability to Climate Change of Smallholder Farmers in the Hamadan Province, Iran. *Clim. Risk Manag.* 23, 146–159. doi:10.1016/j.crm.2018.06.002

Javed, A., Farooqi, A., Baig, Z. U., Ellis, T., and van Geen, A. (2020). Soil Arsenic but Not rice Arsenic Increasing with Arsenic in Irrigation Water in the Punjab plains of Pakistan. *Plant Soil* 450, 601–611. doi:10.1007/s11104-020-04518-z

Jezeer, R. E., Verweij, P. A., Boot, R. G. A., Junginger, M., and Santos, M. J. (2019). Influence of Livelihood Assets, Experienced Shocks and Perceived Risks on Smallholder Coffee Farming Practices in Peru. *J. Environ. Manag.* 242, 496–506. doi:10.1016/j.jenvman.2019.04.101

Kanwal, S., Sajjad, M., Gabriel, H. F., and Hussain, E. (2020). Towards Sustainable Wastewater Management: A Spatial Multi-Criteria Framework to Site the Land-FILTER System in a Complex Urban Environment. *J. Clean. Prod.* 266, 121987. doi:10.1016/j.jclepro.2020.121987

Khalid, S., Shahid, M., NatashaShah, A. H., Saeed, F., Ali, M., Dumat, C., et al. (2020). Heavy Metal Contamination and Exposure Risk Assessment via Drinking Groundwater in Vehari, Pakistan. *Environ. Sci. Pollut. Res. Int.* 27, 39852–39864. doi:10.1007/s11356-020-10106-6

Khan, N. A., Gao, Q., and Abid, M. (2020). Public Institutions' Capacities Regarding Climate Change Adaptation and Risk Management Support in Agriculture: the Case of Punjab Province, Pakistan. *Sci. Rep.* 10 (1), 14111–14112. doi:10.1038/s41598-020-71011-z

Kuang, F., Jin, J., He, R., Ning, J., and Wan, X. (2020). Farmers' Livelihood Risks, Livelihood Assets and Adaptation Strategies in Rugao City, China. *J. Environ. Manage.* 264, 110463. doi:10.1016/j.jenvman.2020.110463

Lee, S.-H., Choi, J.-Y., Hur, S.-O., Taniguchi, M., Masuhara, N., Kim, K. S., et al. (2020). Food-centric Interlinkages in Agricultural Food-Energy-Water Nexus under Climate Change and Irrigation Management.

Resour. Conservation Recycling 163, 105099. doi:10.1016/j.resconrec.2020.105099

Liu, Y., Sohail, M. T., Khan, A., and Majeed, M. T. (2022). Environmental Benefit of Clean Energy Consumption: Can BRICS Economies Achieve Environmental Sustainability through Human Capital? *Environ. Sci. Pollut. Res.* 29 (5), 6766–6776. doi:10.1007/s11356-021-16167-5

Lobell, D. B., and Gourdji, S. M. (2012). The Influence of Climate Change on Global Crop Productivity. *Plant Physiol.* 160, 1686–1697. doi:10.1104/pp.112.208298

Madurai Elavarasan, R., Leoponraj, S., Dheeraj, A., Irfan, M., Gangaram Sundar, G., and Mahesh, G. K. (2021). PV-Diesel-Hydrogen Fuel Cell Based Grid Connected Configurations for an Institutional Building Using BWM Framework and Cost Optimization Algorithm. *Sustainable Energ. Tech. Assessments* 43, 100934. doi:10.1016/j.seta.2020.100934

Maheen, H., and Hoban, E. (2017). Rural Women's Experience of Living and Giving Birth in Relief Camps in Pakistan. *Plos Curr.* 9, ecurrents.dis.7285361a16eefbeddacc8599f326a1dd. doi:10.1371/currents.dis.7285361a16eefbeddacc8599f326a1dd

Mahfooz, Y., Yasar, A., Guijian, L., Yousaf, B., Sohail, M. T., Khan, S., et al. (2020). An Assessment of Wastewater Pollution, Treatment Efficiency and Management in a Semi-arid Urban Area of Pakistan. *Dwt* 177, 167–175. doi:10.5004/dwt.2020.24949

Mahfooz, Y., Yasar, A., Sohail, M. T., Tabinda, A. B., Rasheed, R., Irshad, S., et al. (2019). Investigating the Drinking and Surface Water Quality and Associated Health Risks in a Semi-arid Multi-Industrial metropolis (Faisalabad), Pakistan. *Environ. Sci. Pollut. Res.* 26 (20), 20853–20865. doi:10.1007/s11356-019-05367-9

Maqbool, A., Ashraf, M. A., Khaliq, A., Wang, H., and Saeed, M. (2021). Efficient Water Allocation Strategy to Overcoming Water Inequity Crisis for Sustainability of Agricultural Land: A Case of Southern Punjab, Pakistan. *Stoch. Environ. Res. Risk Assess.* 35, 245–254. doi:10.1007/s00477-020-01903-z

McCusker, K., and Gunaydin, S. (2015). Research Using Qualitative, Quantitative or Mixed Methods and Choice Based on the Research. *Perfusion* 30 (7), 537–542. doi:10.1177/0267659114559116

Mojid, M. A., Wyseure, G. C. L., Biswas, S. K., and Hossain, A. B. M. Z. (2010). Farmers' Perceptions and Knowledge in Using Wastewater for Irrigation at Twelve Peri-Urban Areas and Two Sugar Mill Areas in Bangladesh. *Agric. Water Manag.* 98 (1), 79–86. doi:10.1016/j.agwat.2010.07.015

Mueller, V., Gray, C., and Kosec, K. (2014). Heat Stress Increases Long-Term Human Migration in Rural Pakistan. *Nat. Clim. Chang.* 4 (3), 182–185. doi:10.1038/nclimate2103

Murtaza, G., Zia-ur-Rehman, M., Rashid, I., and Qadir, M. (2019). Use of Poor-Quality Water for Agricultural Production. *Res. Dev. saline Agric.*, 769–783. doi:10.1007/978-981-13-5832-6_26

Mustafa, S., Zhang, W., Shehzad, M. U., Anwar, A., and Rubakula, G. (2022). Does Health Consciousness Matter to Adopt New Technology? an Integrated Model of UTAUT2 with SEM-fsQCA Approach. *Front. Psychol.* 13, 836194. doi:10.3389/fpsyg.2022.836194

Musungu, A. L. (2020). *Assessment of Livestock Farmers' Preferences for Integration of Community-Owned Resource Persons and Interrelationships in Animal Trypanosomiasis Management Methods in Kwale County*. Kenya: University of Nairobi. Doctoral dissertation.

NDMA (2014). *Pakistan Floods 2014: Recovery Needs Assessment and Action Framework 2014-16*. Islamabad: NDMA. AvaliableAt: http://www.ndma.gov.pk/BooksPublications.php November 21, 2015).

O'Brien, K. L., and Leichenko, R. M. (2000). Double Exposure: Assessing the Impacts of Climate Change within the Context of Economic Globalization. *Glob. Environ. Change* 10 (3), 221–232. doi:10.1016/s0959-3780(00)00021-2

Patt, A., and Schroter, D. (2008). Perceptions of Climate Risk in Mozambique: Implications for the success of Adaptation Strategies. *Glob. Environ. Change* 18 (3), 458–467. doi:10.1016/j.gloenvcha.2008.04.002

Qasim, S., Khan, A. N., Shrestha, R. P., and Qasim, M. (2015). Risk Perception of the People in the Flood Prone Khyber Pakhtunkhwa Province of Pakistan. *Int. J. Disaster Risk Reduct* 14, 373–378. doi:10.1016/j.ijdrr.2015.09.001

Raschid-Sally, L., and Jayakody, P. (2009). *Drivers and Characteristics of Wastewater Agriculture in Developing Countries: Results from a Global Assessment*. International Water Management Institute, Vol. 127.

Rasool, A., Jundong, H., and Sohail, M. T. (2017). Relationship of Intrinsic and Extrinsic Rewards on Job Motivation and Job Satisfaction of Expatriates in China. *J. Appl. Sci.* 17 (3), 116–125. doi:10.3923/jas.2017.116.125

Razzaq, A., Ajaz, T., Li, J. C., Irfan, M., and Suksatan, W. (2021). Investigating the Asymmetric Linkages between Infrastructure Development, green Innovation, and Consumption-Based Material Footprint: Novel Empirical Estimations from Highly Resource-Consuming Economies. *Resour. Pol.* 74, 102302. doi:10.1016/j.resourpol.2021.102302

Razzaq, A., Cui, Y., Irfan, M., Maneengam, A., and Acevedo-Duque, Á. (2022). Asymmetric Effects of fine Particulate Matter and Stringency Policy on COVID-19 Intensity. *Int. J. Environ. Health Res.*, 1–13. doi:10.1080/09603123.2022.2059452

Razzaq, A., Sharif, A., Aziz, N., Irfan, M., and Jermsittiparsert, K. (2020). Asymmetric Link between Environmental Pollution and COVID-19 in the Top Ten Affected States of US: A Novel Estimations from Quantile-On-Quantile Approach. *Environ. Res.* 191, 110189. doi:10.1016/j.envres.2020.110189

Shah, A. A., Gong, Z., Pal, I., Sun, R., Ullah, W., and Wani, G. F. (2020). Disaster Risk Management Insight on School Emergency Preparedness - A Case Study of Khyber Pakhtunkhwa, Pakistan. *Int. J. Disaster Risk Reduction* 51, 101805. doi:10.1016/j.ijdrr.2020.101805

Shah, S. I. A., Zhou, J., and Shah, A. A. (2019). Ecosystem-based Adaptation (EbA) Practices in Smallholder Agriculture; Emerging Evidence from Rural Pakistan. *J. Clean. Prod.* 218, 673–684. doi:10.1016/j.jclepro.2019.02.028

Shahid, M., Khalid, S., Murtaza, B., Anwar, H., Shah, A. H., Sardar, A., et al. (2020). A Critical Analysis of Wastewater Use in Agriculture and Associated Health Risks in Pakistan. *Environ. Geochem. Health*, 1–20. doi:10.1007/s10653-020-00702-3

Shi, R., Irfan, M., Liu, G., Yang, X., and Su, X. (2022). Analysis of the Impact of Livestock Structure on Carbon Emissions of Animal Husbandry: A Sustainable Way to Improving Public Health and green Environment. *Front. Public Health* 10, 835210. doi:10.3389/fpubh.2022.835210

Shinbrot, X. A., Jones, K. W., Rivera-Castañeda, A., López-Báez, W., and Ojima, D. S. (2019). *Smallholder Farmer Adoption of Climate-Related Adaptation Strategies: The Importance of Vulnerability Context, Livelihood Assets, and Climate Perceptions*. Environmental management, 1–13.

Shukla, R., Agarwal, A., Sachdeva, K., Kurths, J., and Joshi, P. K. (2019). Climate Change Perception: an Analysis of Climate Change and Risk Perceptions Among Farmer Types of Indian Western Himalayas. *Climatic Change* 152 (1), 103–119. doi:10.1007/s10584-018-2314-z

Singh, R. K., Zander, K. K., Kumar, S., Singh, A., Sheoran, P., Kumar, A., et al. (2017). Perceptions of Climate Variability and Livelihood Adaptations Relating to Gender and Wealth Among the Adi Community of the Eastern Indian Himalayas. *Appl. Geogr.* 86, 41–52. doi:10.1016/j.apgeog.2017.06.018

Sohail, M. T., Xiuyuan, Y., Usman, A., Majeed, M. T., and Ullah, S. (2021a). Renewable Energy and Non-renewable Energy Consumption: Assessing the Asymmetric Role of Monetary Policy Uncertainty in Energy Consumption. *Environ. Sci. Pollut. Res. Int.* 28 (24), 31575–31584. doi:10.1007/s11356-021-12867-0

Sohail, M. T., Aftab, R., Mahfooz, Y., Yasar, A., Yen, Y., Shaikh, S. A., et al. (2019a). Estimation of Water Quality, Management and Risk Assessment in Khyber-Pakhtunkhwa and Gilgit Baltistan Pakistan. *Dwt* 171, 105–114. doi:10.5004/dwt.2019.24925

Sohail, M. T., Delin, H., Siddiq, A., Idrees, F., and Arshad, S. (2015). Evaluation of Historic Indo-Pak Relations, Water Resource Issues and its Impact on Contemporary Bilateral Affairs. *Asia Pac. J. Multidisciplinary Res.* 3, 1.

Sohail, M. T., Delin, H., Talib, M. A., Xiaoqing, X., and Akhtar, M. M. (2014). An Analysis of Environmental Law in Pakistan-Policy and Conditions of Implementation. *Res. J. Appl. Sci. Eng. Technol.* 8 (5), 644–653. doi:10.19026/rjaset.8.1017

Sohail, M. T., Lin, X., Lizhi, L., Rizwanullah, M., Nasrullah, M., Xiuyuan, Y., et al. (2021c). Farmers' Awareness about Impacts of Reusing Wastewater, Risk Perception and Adaptation to Climate Change in Faisalabad District, Pakistan. *Pol. J. Environ. Stud.* 30, 4663–4675. doi:10.15244/pjoes/134292

Sohail, M. T., Mahfooz, Y., Aftab, R., Yen, Y., Talib, M. A., and Rasool, A. (2020). Water Quality and Health Risk of Public Drinking Water Sources: a Study of Filtration Plants Installed in Rawalpindi and Islamabad, Pakistan. *Dwt* 181, 239–250. doi:10.5004/dwt.2020.25119

Sohail, M. T., Mahfooz, Y., Azam, K., Yat, Y., Genfu, L., and Fahad, S. (2019b). Impacts of Urbanization and Land Cover Dynamics on Underground Water in Islamabad, Pakistan. *Dwt* 159, 402–411. doi:10.5004/dwt.2019.24156

Sohail, M. T., Majeed, M. T., Shaikh, P. A., and Andlib, Z. (2021b). Environmental Costs of Political Instability in Pakistan: Policy Options for Clean Energy Consumption and Environment. *Environ. Sci. Pollut. Res.* 29, 1–10. doi:10.1007/s11356-021-17646-5

Srivastava, R. K. (2020). *Managing Urbanization, Climate Change and Disasters in South Asia*. Springer Nature.

Tang, C., Irfan, M., Razzaq, A., and Dagar, V. (2022). Natural Resources and Financial Development: Role of Business Regulations in Testing the Resource-Curse Hypothesis in ASEAN Countries. *Resour. Pol.* 76, 102612. doi:10.1016/j.resourpol.2022.102612

Tanveer, A., Zeng, S., Irfan, M., and Peng, R. (2021). Do perceived Risk, Perception of Self-Efficacy, and Openness to Technology Matter for Solar PV Adoption? an Application of the Extended Theory of Planned Behavior. *Energies* 14 (16), 5008. doi:10.3390/en14165008

Tingju, Z., Xie, H., Waqas, A., Ringler, C., Iqbal, M. M., Goheer, M. A., et al. (2014). *Climate Change and Extreme Events, Impacts on Pakistan's Agriculture*. International Food Policy Research Institute.

Trinh, T. Q., Rañola, R. F., Jr, Camacho, L. D., and Simelton, E. (2018). Determinants of Farmers' Adaptation to Climate Change in Agricultural Production in the central Region of Vietnam. *Land Use Policy* 70, 224–231. doi:10.1016/j.landusepol.2017.10.023

Udmale, P., Ichikawa, Y., Manandhar, S., Ishidaira, H., and Kiem, A. S. (2014). Farmers′ Perception of Drought Impacts, Local Adaptation and Administrative Mitigation Measures in Maharashtra State, India. *Int. J. Disaster Risk Reduction* 10, 250–269. doi:10.1016/j.ijdrr.2014.09.011

Ullah, Z., Khan, H., Waseem, A., Mahmood, Q., and Farooq, U. (2013). Water Quality Assessment of the River Kabul at Peshawar, Pakistan: Industrial and Urban Wastewater Impacts. *J. Water Chem. Technol.* 35, 170–176. doi:10.3103/s1063455x1304005x

Wen, C., Akram, R., Irfan, M., Iqbal, W., Dagar, V., Acevedo-Duqued, Á., et al. (2022). The Asymmetric Nexus between Air Pollution and COVID-19: Evidence from a Non-linear Panel Autoregressive Distributed Lag Model. *Environ. Res.* 209, 112848. doi:10.1016/j.envres.2022.112848

Xiang, H., Chau, K. Y., Iqbal, W., Irfan, M., and Dagar, V. (2022). Determinants of Social Commerce Usage and Online Impulse Purchase: Implications for Business and Digital Revolution. *Front. Psychol.* 13, 837042. doi:10.3389/fpsyg.2022.837042

Yamin, M., Nasir, A., Sultan, M., Ismail, W. I. W., Shamshiri, R., and Akhbar, F. N. (2015). Impact of Sewage and Industrial Effluents on Water Quality in Faisalabad, Pakistan. *Adv. Environ. Biol.* 9 (18), 53–58.

Yen, Y., Zhao, P., and Sohail, M. T. (2021). The Morphology and Circuity of Walkable, Bikeable, and Drivable Street Networks in Phnom Penh, Cambodia. *Environ. Plann. B: Urban Analytics City Sci.* 48 (1), 169–185. doi:10.1177/2399808319857726

Zhao, P., Yen, Y., Bailey, E., and Sohail, M. (2019). Analysis of Urban Drivable and Walkable Street Networks of the ASEAN Smart Cities Network. *Ijgi* 8 (10), 459. doi:10.3390/ijgi8100459

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.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.