atmosphere

MDPI

Review

A Systematic Review on Farmers' Adaptation Strategies in Pakistan toward Climate Change

Naeem Saddique [1,2,*], Muhammad Jehanzaib [3,4,5,*], Abid Sarwar [1], Ehtesham Ahmed [6], Muhammad Muzammil [1,7], Muhammad Imran Khan [1], Muhammad Faheem [8], Noman Ali Buttar [9], Sikandar Ali [1] and Christian Bernhofer [2]

1 Department of Irrigation and Drainage, University of Agriculture, Faisalabad 38000, Pakistan
2 Institute of Hydrology and Meteorology, Technische Universität Dresden, 01737 Tharandt, Germany
3 Institute of Geophysics, Polish Academy of Science, 01-452 Warsaw, Poland
4 Research Institute of Engineering and Technology, Hanyang University, Ansan 15588, Korea
5 Department of Civil Engineering & Technology, Qurtuba University of Science and Information Tecnology, Dera Ismail Khan 29050, Pakistan
6 Institute of Urban and Industrial Water Management, Technische Universität Dresden, 01069 Dresden, Germany
7 Institute for Landscape Ecology and Resources Management (ILR), Research Centre for Bio Systems, Land Use and Nutrition (IFZ), Justus Liebig University, 35392 Giessen, Germany
8 Department of Farm Machinery and Power, University of Agriculture, Faisalabad 38000, Pakistan
9 Department of Agricultural Engineering, Khawaja Fareed University of Engineering and Information Technology, Rahim Yar Khan 64200, Pakistan
* Correspondence: naeem.saddique@uaf.edu.pk (N.S.); jehanzaib7@hanyang.ac.kr (M.J.); Tel.: +92-300-4392433 (N.S.)

check for updates

Citation: Saddique, N.; Jehanzaib, M.; Sarwar, A.; Ahmed, E.; Muzammil, M.; Khan, M.I.; Faheem, M.; Buttar, N.A.; Ali, S.; Bernhofer, C. A Systematic Review on Farmers' Adaptation Strategies in Pakistan toward Climate Change. *Atmosphere* **2022**, *13*, 1280. https://doi.org/10.3390/atmos13081280

Academic Editor: Tanja Cegnar

Received: 29 June 2022
Accepted: 9 August 2022
Published: 11 August 2022

Abstract: Pakistan is among the countries that are highly vulnerable to climate change. The country has experienced severe floods and droughts during recent decades. The agricultural sector in Pakistan is adversely affected by climate change. This systematic review paper set out to analyze the existing literature on adaptation measures at the farm level toward climate change in Pakistan. Adopting a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method, a total of 62 articles were identified from the Web of Science and Scopus databases. The review paper indicates that the main adaptation strategies adopted by farmers are as follows: changing cropping practices, changing farm management techniques, advanced land use management practices, and nonagriculture livelihood options. Further, this review shows the factors influencing the farmer's adaptation measures to climate change. Influencing factors were examined and classified into three groups: demographic, socioeconomic, and resources and institutional. Barriers hindering farmers' adaptive capacity were identified as lack of access to information and knowledge, lack of access to extension services, lack of access to credit facility, and lack of farm resources.

Keywords: Pakistan; climate variability; adaptation measures; agriculture; cropping practices; socioeconomic; institutional

1. Introduction

Negative impacts of climate change (CC) on natural and human systems are more obvious than positive impacts [1]. In developing regions of the world, projected climate change poses severe threats to agriculture in the 21st century [1]. Despite substantial advancements in technology, an improvement in agriculture production is not possible without suitable weather conditions [2]. Among all the climatic variables, rainfall and temperature could be used for determining crop yields. Crop farming is highly affected by changing climatic conditions with different intensities worldwide.

Nevertheless, in developing countries, crop farming is significantly affected by changes in weather conditions and, thus, the reduction in crop yield. Rural livelihood is also significantly affected by climate change, especially in developing countries, and further increases the vulnerability of the farming community [3]. Additionally, the variation in climate may further cause food insecurity in South Asia as predicted by Parry (2007), indicating about a 30% decline in yield per hectare in cereal crop production and up to a 37% loss of gross per capita water from 2001 to 2059 [4].

Pakistan is one of the top ten countries that are vulnerable to climate events in the world and has been significantly affected by climate change [5]. Pakistan has an agro-based economy, approximately more than 60% of the population live in rural areas, and their livelihood depends on agriculture. The agricultural sector contributes 19.3% of the country's GDP [6] and directly or indirectly employs 42% of its labor force. Pakistan has been influenced by various climatic stresses such as floods, droughts, erratic rainfalls, and heat waves. The agricultural sector in Pakistan has been significantly affected by the most damaging floods of 2010 and 2014 and the droughts that lasted from 1999 to 2003, and in the last twenty years, the productivity of major crops such as wheat, rice, sugarcane, and cotton has also been significantly affected [7]. According to the World Bank and Global Climate Risk Index (GCRI) reports, Pakistan is ranked 8th among the countries facing harsh weather conditions [8]. However, the adaptive capacity of Pakistan toward climate change is significantly low due to a shortage of financial and physical resources [7,9].

Adaptation strategies in agriculture can manage the adverse impacts of climate change but cannot solve the climate change problem alone. According to the Intergovernmental Panel on Climate Change (IPCC), adaptation is referred to as adjustments in the natural and human system in response to current and anticipated climatic change and its consequences that moderate or neutralize the harm or generate potential opportunities against climate change [1]. Additionally, adaptation can be implemented at different levels such as local, regional, subnational, and national levels. Local-level adaptation is more difficult as compared to others as these are the ones that face the harshness of climate change [10]. The developing countries are most affected by climate change because of their low adaptive capacity to negative impacts of climatic conditions [11]. Adaptation in the agricultural sector is more critical as it depends on climatic conditions. Therefore, effective adaptation at the farm level is required to ensure food and the livelihood of the rural community.

Currently, limited or no support is available for climate change adaptation in the agricultural sector of Pakistan, due to a lack of financial resources, low technological capacity, and ineffective climate policy [12]. However, at the national level, an integrated policy is required for climate change adaptation in the agricultural sector [13]. Research shows that farmers planning, investment in new stress-tolerant varieties, crops insurance, social interactions, and food security programs may be some vital aspects of the adaptation policy to climate change [14]. In this regard, adaptation methods selected by farmers are affected by various factors such as socioeconomic and environmental ones [15,16]. This body of knowledge (BOK) will provide the reliability of different strategies and their ability to cope with climate change [17]. Various government and private organizations as well as local farmers' communities can also play their role in climate adaptation [15]. In this regard, researchers have introduced various factors such as lack of access to information and knowledge, lack of access to extension services, lack of access to credit facilities, and lack of farm resources that may be involved as barriers to climate change adaptation.

A systematic review of farmers' climate change adaptation measures has not been carried out so far; however, limited review papers have been published on agricultural adaptation strategies in Pakistan [18,19]. The present study attempts to fill the gap. In doing so, we have characterized the widely chosen climate change adaptation among Pakistani farmers as well as the provinces where we have noted limited observations. In order to achieve the objectives of the study, this systematic literature review addressed the following questions:

What are the key adaptation strategies used by farmers in agriculture?

What are the factors that are involved as barriers to climate change adaptation?

Indeed, this study is vital as Pakistani farmers are likely to experience the adverse impacts of climate change. Additionally, for designing agricultural policies, such prerequisite information is vital.

The rest of the paper is organized as follows. The next section briefly describes the methodology used to perform the systematic review. Section 3 focuses on adaptation measures practiced by farmers in the agricultural sector. In Section 4, we discuss the existing barriers in climate change adaptation and the last section concludes the study.

2. Materials and Methods

Databases and Search Criteria

Web of Science and Scopus were the two databases selected to search for relevant articles. Table 1 shows the keywords used in the two databases to search for papers. Based on previous studies and a thesaurus, keywords similar and related to the farming community, agriculture adaptations, and constraints were used. Inclusion and exclusion criteria were determined for systematic review. First, concerning literature type, only those articles that had empirical data were selected, while book chapters, review articles, and conference proceedings were excluded. Secondly, the period from 2007 to August 2021 was selected for searching articles in databases. Thirdly, in order to avoid difficulty in translating and understanding, non-English papers were excluded. Lastly, only articles that focused on Pakistani farmers were selected.

The Preferred Items for Systematic Review Recommendations (PRISMA) method consists of the following four steps: identification, screening, eligibility, and inclusion (Figure 1) [20]. The first stage identified the keywords used in the search process. By using the keywords given in Table 1, the database search resulted in 320 articles from Web of Science and 120 articles from Scopus. At this stage, 26 duplicate articles were removed from the entire pool. The screening was the second stage. At this stage, inclusion and exclusion criteria (removed due to review articles, published in non-English, published before 2007, and global studies) were employed to further exclude the articles (Table 2). In doing so, 49 articles were removed and the remaining 365 articles were selected for the next stage. At the eligibility stage, the title and abstract were carefully examined and 285 articles were removed as flowing words were not found in the title and/or abstract such as agriculture or crops or farmer's climate change adaptations. After this, we reviewed the full text of 80 articles, and 62 articles met the criteria and were included in the final review process.

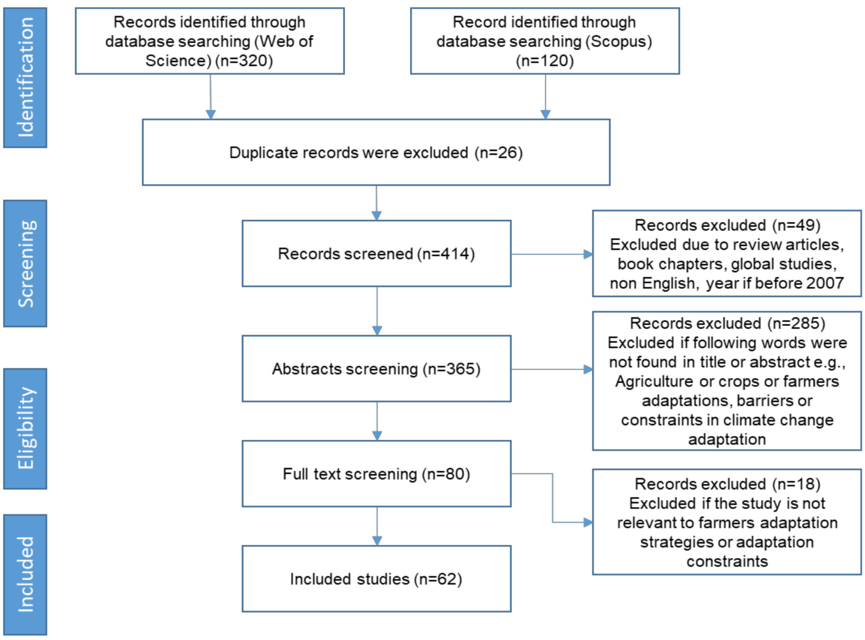

Figure 1. Systematic review process.

Table 1. Databases and keywords used.

Databases	Keywords Used
Web of Science and Scopus	"Climate change adaptation", OR "adaptations measures", OR "coping strategies", OR "Climate-smart agriculture", OR "sustainable agriculture", OR "farm-level adaptation measures", OR "rain-fed farming system", AND "determinants" OR "barriers" OR "constraints", AND "smallholder farmers", OR "agriculture", OR "farm level" AND "Pakistan"

Table 2. Inclusion and exclusion criteria.

Criteria	Eligibility	Exclusion
Literature type	Journal (research articles)	Review papers, conference proceedings, book chapters, book series
Language	English	Non-English
Timeline	Between 2007 to Aug-2021	<2007
Country	Pakistan	Non-Pakistan
Title and abstract	Focused on adaptation strategies in agriculture	Not focused on adaptation strategies in agriculture

3. Results and Discussion

Sixty-two identified papers were analyzed conferring to the following three topics: (1) climate change adaptation strategies, (2) factors influencing adaptation measures, and (3) climate change adaptation constraints.

The administrative structure of Pakistan presently comprises four provinces, namely Punjab, KPK, Balochistan, and Sindh. Figure 2 demonstrates the province-wise percentage of articles published. It can be seen that around 54% of articles have taken study sites in Punjab, followed by KPK (24%), Sindh (12%), and Balochistan (10%).

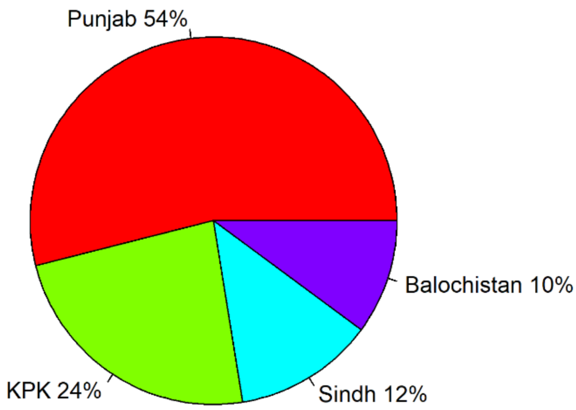

Figure 2. Province-wise distribution of reviewed articles.

Figure 3 shows the year-wise distribution of reviewed articles focusing on the climate change adaptation measures by farmers in agriculture and factors affecting climate change adaptation. The first study on climate adaptation in agriculture was published in 2012, indicating that climate change adaptation is a new topic of exploration in Pakistan.

Notably, in recent years from 2018 to Aug-2021, almost 81% of the total number of reviewed papers have been published. Not a single article was published in 2013 and 2014, but there was a peak of 18 articles, only 6 years later in 2020. The recent growth in the number of studies shows the increased interest in climate change adaptation in agriculture.

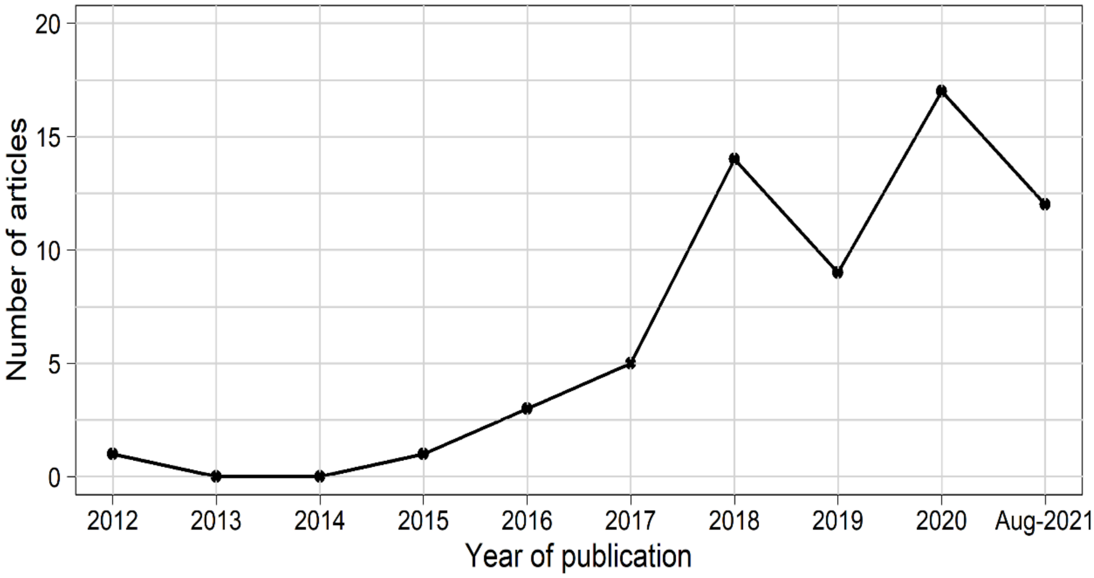

Figure 3. Year-wise number of papers published.

3.1. Climate Change Adaptation Strategies

This section demonstrates the main adaptation strategies adopted by farmers in Pakistan such as changing cropping practices, changing farm management techniques, advanced land use management practices, and nonagriculture livelihood options (Table 3).

Table 3. The studied climate change adaptation strategies.

	Changing Crop Practices					Changing Crop Management Techniques				Advanced Land Use Management Practices			Nonagriculture Input Options			
Authors	**CCT**	**CCV**	**CSD**	**CD**	**CPD**	**CF**	**CP**	**CI**	**CS**	**PST**	**SC**	**WC**	**RLK**	**RL**	**MG**	**OFG**
Mahmood et al., 2012 [21]		Y				Y					Y					
Abid et al., 2015 [7]	Y	Y	Y	Y		Y		Y		Y	Y			Y	Y	
Abid et al., 2016a [22]	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y		Y	Y	
Abid et al., 2016b [23]		Y	Y			Y		Y		Y	Y					
Ahmad et al., 2016 [24]			Y													
Abid et al., 2017 [25]	Y	Y	Y			Y				Y						
Ahamd et al., 2017 [26]		Y	Y													
Ali and Erenstein, 2017 [27]	Y	Y	Y													
Arshad et al., 2017a [28]	Y	Y	Y	Y				Y			Y	Y				
Arshad et al., 2017b [29]		Y	Y													
Amin et al., 2018 [30]						Y										
Arshad et al., 2018 [31]						Y		Y			Y					
Awais et al., 2018 [32]				Y	Y			Y								
Bacha et al., 2018 [33]		Y		Y				Y	Y			Y				
Bhatti et al., 2018 [34]			Y													
Gorst et al., 2018 [35]	Y	Y	Y			Y		Y		Y	Y					
Hussain et al., 2018 [36]		Y	Y		Y	Y					Y					
Imran et al., 2018 [37]		Y														
Nasir et al., 2018 [38]		Y	Y				Y	Y								
Rahman et al., 2018 [39]		Y			Y	Y										
Salman et al., 2018 [40]	Y		Y		Y		Y		Y							
Tariq et al., 2018 [41]		Y	Y													
Ullah et al., 2018 [42]	Y	Y				Y	Y	Y		Y		Y				
Abid et al., 2019 [3]	Y	Y	Y	Y		Y	Y			Y	Y					
Ali et al., 2019 [43]		Y						Y								
Bakhsh and Kamran, 2019 [44]		Y											Y		Y	
Bhatti et al., 2019 [45]		Y	Y	Y				Y								
Gul et al., 2019 [46]			Y		Y	Y										
Imran et al., 2019 [47]								Y								
Mahmood et al., 2019 [48]					Y	Y	Y									
Shah et al., 2019 [49]				Y						Y						
Ullah et al., 2019 [50]		Y	Y	Y		Y	Y	Y	Y			Y	Y	Y	Y	
Ahmad et al., 2020 [51]		Y	Y			Y										

Table 3. *Cont.*

	Changing Crop Practices					Changing Crop Management Techniques				Advanced Land Use Management Practices			Nonagriculture Input Options			
Authors	**CCT**	**CCV**	**CSD**	**CD**	**CPD**	**CF**	**CP**	**CI**	**CS**	**PST**	**SC**	**WC**	**RLK**	**RL**	**MG**	**OFG**
Ahmad and Afzal, 2020 [52]	Y	Y	Y		Y		Y		Y	Y						
Ali et al., 2020a [53]			Y					Y		Y		Y				Y
Ali et al., 2020b [54]		Y						Y								
Amir et al., 2020a [55]	Y	Y	Y												Y	Y
Amir et al., 2020b [56]	Y	Y	Y					Y					Y	Y		
Khalid et al., 2020 [57]		Y			Y	Y										
Fahad et al., 2020 [58]	Y	Y						Y	Y		Y	Y				Y
Hussain et al., 2020 [59]																Y
Jabbar et al., 2020 [60]				Y		Y										
Javed et al., 2020 [61]		Y	Y			Y				Y						
Khan et al., 2020 [62]		Y	Y	Y		Y										
Mahmood et al., 2020 [63]		Y	Y			Y				Y						
Nasir et al., 2020 [64]			Y		Y	Y		Y								
Shabbir et al., 2020 [65]		Y	Y	Y	Y	Y		Y								
Shah et al., 2020 [66]		Y	Y			Y	Y	Y				Y				
Aftab et al., 2021 [67]		Y	Y													
Ali and Rose, 2021 [68]	Y	Y				Y	Y	Y			Y	Y				Y
Arshad et al., 2021 [69]			Y													
Ashraf et al., 2021 [70]		Y		Y		Y	Y	Y		Y		Y			Y	Y
Ayub et al., 2021 [71]		Y														
Jamil et al., 2021a [72]			Y					Y			Y					
Jamil et al., 2021b [73]						Y		Y			Y					
Khan et al., 2021 [74]		Y	Y	Y		Y		Y								
Sardar et al., 2021 [75]		Y	Y			Y						Y				
Shahid et al., 2021 [76]	Y	Y	Y			Y		Y		Y	Y		Y			
Qazlbash et al., 2021 [77]		Y								Y		Y	Y			
No. of Papers	15	42	36	14		30	11	27	5	15	14	12	5	4	6	6
Changing crop practices	Changing crop management techniques						Advanced land use management practices					Nonagriculture input options				
CCT = Change crop type CCV = Change crop variety CSD = Change sowing dates CD = Crop diversification CPD = Change plant density	CF = Change fertilizer CP = Change pesticide CI = Change irrigation CS = Change seed quality						PST = Planting shaded trees SC = Soil conservation WC = Water conservation					RLK = Rearing livestock RL = Rent out land MG = Migration OFJ = Off farm job				

3.1.1. Changing Cropping Practices

Changing cropping practices including changing crop type, changing crop varieties, changes in sowing and harvesting dates, crop rotation, and intercropping were the most effective and widely used adaptation strategies to cope with climate change. Changes in crop type were mentioned in fifteen articles. Changing crop types were adopted by farmers to deal with pest and insect attacks, soil problems, extreme weather events, and water shortage [22,27]. Changing crop varieties and adopting advanced varieties are largely employed by farmers in Pakistan, and this adaptation measure is reported in 42 articles. Farmers cultivated modern improved varieties to maintain their farm production and these varieties have a genetically good response to pest attacks or extreme temperatures, which negatively affect the growth of old varieties [37,42,74]. For instance, farmers in Punjab change the traditional cotton variety with genetically modified cotton varieties due to heavy pest attacks on traditional cotton varieties. Similarly, farmers employed heat-tolerant wheat varieties to cope with extreme temperature events [22].

Changes in sowing dates were identified in 36 papers. The results showed that almost half of the studies considered the sowing or planting dates adjustment, making it the second most adopted measure against climate change because it is simple to implement and less input cost is required [3,39,55,61]. Khan et al. [62] reported that the farmers in the rice-growing zone are changing the rice cultivation dates due to fluctuations in temperature and precipitation. Evaluation of different adaptation options revealed that the planting of sunflower crop 21 days earlier (as compared to the current sowing date) with an increased plant population (83,333 plants ha^{-1}) could reduce the yield losses due to climate change [32]. Similarly, a study conducted by Shabbir et al. [65] found that the early transplanting of rice crops will enhance the yield by about 8.7% under RCP8.5 by the middle of the 21st century. Crop diversification is reported in several studies [14] as an adaptation measure to minimize the losses incurred by the failure of a single crop due to extreme weather conditions [44,45,52,66]. Aftab et al. [67] pointed out that the farm household in flood-prone areas of KPK has created a tree-lined shelterbelt along the perimeter of the agriculture field as an adaptation measure against flood events. Intercropping is an effective measure that increases crop yield as well as enhances water use efficiency and soil fertility. According to Shah et al. [49], the farmers in Mansehra, KPK are using legumes in maize as an intercropping strategy. Similarly, limited farmers in Thatta and Gujranwala are using an intercropping strategy, mainly intercropping of legumes in rice.

3.1.2. Changing Farm Management Techniques

Changes in farm management techniques, including changing the fertilizer, pesticide, irrigation, and seed quality, are also employed by farmers to minimize the negative impacts of climate change. Changing the fertilizer was identified in 30 articles. Changing the fertilizer was adopted by farmers to enhance soil fertility and improve plant health [30,57,68,76]. Ullah et al. [50] found that the respondents in KPK applied more fertilizer to their crops in response to the loss of fertile soil by floods in 2010. Likewise, farmers in Punjab observed a reduction in crop productivity due to the loss of fertile soil by heavy monsoon rainfall, and in response, they use more micro-nutrients and fertilizers to maintain the soil fertility [23]. Similarly, farm households reported the use of more pesticides in order to protect the crops from pest attacks. Changes in irrigation application were reported in 27 research articles. This practice is very common among farmers to cope with climate variability [40,64]. For example, in the case of extreme temperature events or droughts, farmers were reported using more irrigation for their crops especially at the sowing stage. Similarly, farmers have changed irrigation application time and frequency to protect crops from climate variability and change [70,76]. In the mountainous area of KPK, Ali et al. [53] reported that farmers were using the terracing method for irrigation. Some farmers in Punjab are using groundwater as an alternative water resource to cope with water scarcity and climate change [22]. The advanced irrigation system instead of accelerating farmers' agricultural processes is able to assist farmers in their adaptation strategy. Abid et al. [23] found that adapters produced 0.14 t/ha more wheat than nonadapters. Further, adaptation generates PKR 5142 (USD 51) per hectare more returns for adapters. Gorst et al. [35] reported that farmers who adopted the adaptation measures produced 21 percent more rice as compared to nonadapters, given an average rice yield of 22.67 maunds per acre.

3.1.3. Advanced Land Use Management Measures

Advanced land use management measures were taken as effective strategies to respond to climate variability. Farmers reported tree plantations for protection against rising temperature, floods, and winds [77]. Smallholder farmers are growing more trees on agricultural land, which may be due to institutional support and awareness. Tree plantation was less reported in commercial agricultural land, where farmers expect a yield loss due to the plantation of shady trees [49]. Soil conservation was reported in 14 articles. As per the previous studies, the adopted soil conservation measures are mulching, zero tillage, organic manure, terrace fields, contour planting, grassy field margin, laser land leveling, and enhancing the height of field bunds, etc. [23,52]. Farmers in Punjab reported a higher use of organic manure as an adaptation strategy to preserve soil quality, which was reduced due to heavy monsoon rainfall in 2010. Water conservation is also used as an adaptation measure in all provinces of Pakistan to protect the crops from extreme weather conditions [33,75]. Rainwater harvesting is adopted at the farm level to store the water during the rainy season and to later use this water in the dry season. However, the majority of smallholder farmers are not able to install the water harvesting system, due to the lack of financial resources and knowledge [53]. Farmers in mountainous areas reported that they capture the rainwater by constructing large embankments around the field. This captured water infiltrates the soil and is used for growing crops in the next season [77].

3.1.4. Nonagriculture Livelihood Options

Nonagriculture livelihood options are performed at both farm and outside the farm such as forestation, trade, migration, and government vs. private jobs by some family members to minimize the risks associated with climate variability and extreme weather events [55]. Hussain et al. [59] reported that the farmers purchased agricultural machinery and good-quality seeds from nonagriculture income to cope with different environmental shocks and to recover their livelihood. The negative effects of climate change have enhanced the rural–rural and rural–urban migration in Pakistan [33,77]. According to Amir et al. [56], respondents migrate to urban areas to gain socioeconomic sustainability. Similarly, farm households in Gujrat, Punjab reported partial migration in response to loss in agricultural income due to drought-like conditions attributed to less rainfall [22]. These types of climate-induced relocations are stressing the social, economic, and ecological infrastructures in urban areas of Pakistan [56]. Nevertheless, only six articles were reported on migration. Renting out cropland was found in four papers. Some farmers partially rented out their land in order to minimize the economic risks related to climate variability [22]. Farmers adopt this practice in Punjab and KPK [25,50].

3.2. Factors Influencing Adaptation Measures

This section depicts the factors influencing the farmers' choice of climate change adaptation measures. Influencing factors were examined and classified into three groups: demographic, socioeconomic, and resources and institutional.

3.2.1. Demographic Factors

Age is a vital element that characteristically determines the inclination toward new technology and methods for agriculture. A total of thirty-one papers focused on the age of farmers as a factor affecting the adaptation to climate change. Studies conducted by Khan et al. [62] and Shahid et al. [76] suggest that the age of the farmer had a positive link with adaptation to climate change. Aged farmers have better knowledge and experience of the local climate and its induced hazards; hence, they are expected to be more adaptive to potential risks of climate variability. On the other hand, Ali and Erenstein [27] and Jamil et al. [73] concluded that farmer age turned out to be negatively associated with adaptations to climate change. Younger farmers are more likely to adopt new technologies and advanced agriculture methods by using their knowledge and determination, while aged farmers are not aware of recent technologies in agriculture and/or are reluctant to new farming practices. However, Ali et al. [53] and Ali and Rose [68] found that household head age has a mixed association with adaptation measures. For instance, an increase in farmer age would decrease the probability of adopting new crop varieties, efficient irrigation methods, and migration to urban areas and private business while increasing the likelihood of adapting sowing dates and mulching.

Household size plays a vital role in climate adaptation. Most studies found a positive and significant relationship between family size and adaptation measures [59]. Farmers with large household size are more likely to adapt labor-consuming adaptation strategies such as crop diversification, water harvesting, deep ploughing, and terrace farming [53]. Similarly, Abid et al. [7] found that increasing one individual in an average household would increase the likelihood of choosing soil conservation and planting shaded trees as adaptation measures [7].

Thirty-five papers have shown the importance of education in adaptation. Educated farmers have more information of advanced agriculture technologies and improved varieties compared to farmers with little or no education. The probability of adaptation to climate change increases with an increase in the year [52,78]. They are more flexible in deciding on different management practices in order to obtain the maximum benefit from limited resources. If these farmers are heads of households, the adaptation ability of other family members could be increased. In contrast, farmers with low education levels are dependent on neighboring farmers in choosing adaptation measures.

3.2.2. Socioeconomic Factors

Landholding size represents the total land cultivated by a farmer and may be considered a proxy for farm household wealth [27]. Larger landholding size has a positive and significant influence on the probability of adaptation strategies such as changing crop types, crop varieties, irrigation methods, and shifting from crops to livestock. These farmers can invest in high-cost measures and tend to respond earlier to certain climate hazards [7,75,79].

Off-farm income is an important factor associated with climate change adaptation in agriculture and is discussed in twenty papers. According to Shahid et al. [76], the off-farm income and adaptation index has a significant-positive relationship. Farmers who are involved in off-farm activities have minimized their financial constraints and enhance crops productivity by using more inputs. High off-farm income enhances the likelihood of strategies such as farm mechanization, changing crop varieties, and high-efficiency irrigation methods. Conversely, Khan et al. [62] and Mahmood et al. [63] reported the negative impact of off-farm income on climate change adaptation. Farmers who depend on farm earnings are more likely to adapt than those with off-farm income.

Farm experience has a positive and significant association with adaptation strategies. Results from studies conducted by Ashraf et al. [70] and Jabbar et al. [60] suggest that farm experience plays a vital role in adaptation. Farmers with more years of farming experience are more likely to be aware of previous extreme climate events and to be a better judge to respond to these events. Further, farm households that have experienced past environmental damage are better prepared [7].

Eighteen papers have shown the importance of nonland assets in adaptation. Tube well ownership plays an important role in climate change adaptation in agriculture as this ensures the supply of groundwater for irrigation at the farm level in response to changing climatic conditions. Possession of tube wells also improves farmers' fertilizer management ability [7,62]. Similarly, livestock and car ownership are positively associated with farmers' adaptive capacity and the number of adaptation measures [27]. Tractor ownership also significantly affects adaptation measures as it helps farmers in various agronomic practices such as seed drilling, zero tillage operation, early planting, and crop diversification [63,73]. Having more assets enables the farmers to adopt advanced technology-related measures such as changing crop types, sowing improved varieties, crop diversification, soil conservation practices, and water harvesting [27].

3.2.3. Resources and Institutional Factors

Access to extension services was identified in twenty papers. These reveal that access to extension services enhanced the availability of climate information and adaptation options. Farmers' selection of adaptation strategies was found to be significantly affected by access to extension services [58,67,80]. Research conducted by Ali and Rose [68] reported that access to extension services positively and significantly affected farmers' decision-making about sowing time, irrigation, mulching, crops to livestock, and water-efficient methods. However, access to extension services was found to increase the probability of changing crop variety while decreasing the probability of changing crop type, which may be due to farmers obtaining poor information about climate change and crop production or information being outdated [7]. According to Amir et al. [55], the Agriculture Extension Department is underperforming in rainfed areas as farmers who have access to extension services also borrowed money, and compromised food intake and education during financial stress.

Access to credit is identified as a key contributing factor that can increase farmers' adaptive capacity against climate change. This service is especially important for developing countries where poverty is the major reason behind lower adaptation capacity [68]. Access to credit was found positively and significantly associated with adaptation measures such as tree plantation, irrigation, planting of different varieties, crop diversification, and fertilizer management [53]. Khan et al. [62] and Shahid et al. [76] reported that the ease of access to financial resources enhances farm households' adaptive capacity and decision-making in choosing various measures against climate variability.

Access to information on weather and climate is a key factor that enhances farmers' adaptation capacity and is discussed in fifteen articles. Farmers with better knowledge of the climate and weather forecasts are more likely to adopt various adaptation measures [58]. According to Abid et al. [7], access to timely seasonal and daily information on climate has a significant-positive effect on the likelihood of adaptation measures such as changing irrigation, fertilizer management, adjusting sowing dates, and other land management practices. In addition, access to weather forecast information is positively and significantly related to adopting different climate-smart agriculture (CSA) practices [75].

3.3. Climate Change Adaptation Constraints

Lack of access to information was found as an important constraint in adaptation. This barrier was reported in twenty-eight papers [53,56]. Farmers do not have adequate weather information or knowledge regarding advanced land management practices and optimum use of agriculture inputs. Most of the studies reported simple measures adopted by farmers and did not focus on advanced adaptations. The main reason behind this lack of adoption of advanced farming practices was the lack of knowledge and information [22,42].

The lack of access to farm credit services has identified another constraint to adaptation in Pakistan. This lack of access to credit facilities was reported by Ullah et al. [42], Ali et al. [53], and Shahid et al. [76]. Abid et al. [22] reported that even some farmers have access to credit services, but they were reluctant to use them due to high interest rates [22]. In addition, this credit was not used for climate change adaptation measures. Instead, it was used for other activities such as purchasing household items and for wedding events.

Another constraint to adaptations is the lack of access to extension services [55,62]. Only a few farmers have access to extension officers, while others rely on relatives, the community, or themselves for information and guidelines regarding agriculture. In most of the cases, the services of the agriculture extension officers were biased toward influential and wealthier farmers [22].

Five papers reported resource limitation as a barrier to adaptation measures [48,56,76]. Water scarcity was a major constraint in most of the studies. According to farmers' perception, water availability from canals and rainfall is not enough to fulfill the crop requirement and maximize the crop productivity. Thus, farmers are dependent on groundwater but most of the farmers have small landholdings with limited funds, and they are not able to cultivate all the lands, due to high groundwater pumping costs. In addition, small landholder farmers do not have access to good-quality inputs such as fertilizer, pesticides, and seeds, due to their shortage or absence [22].

4. Conclusions

Climate change adaptation in the agricultural sector is considered a noteworthy tactic to cope with the impacts of climate change. The systematic review paper highlighted the four major themes of adaptation strategies in agriculture toward climate change in Pakistan. These themes included changing cropping practices, changing farm management techniques, advanced land use management measures, and nonagriculture livelihood options. These themes were further extended to 16 subthemes (such as changing crop type, crop variety, sowing dates, fertilizer, and irrigation) as a result of the analysis. From the review, the factors that influence farmers' adaptation strategies in Pakistan were age, education, farming experience, landholding, access to climate information, access to credit facilities, and access to extension services. A number of constraints were identified at the farm level that concern the adaptive capacity of the farm households including the lack of access to information and knowledge, lack of access to extension services, lack of access to credit, and lack of farm resources.

Investments toward capacity-building are required to achieve benefits from adaptation in agriculture. In order to reduce the farm level vulnerability to climate change and enhance the adaptive capacity of farmers, the outreach and extent of institutional services, especially the advisory services related to climate change adaptation, need to be enhanced. There is a significant gap between the services provided by local institutions and what is needed at the farm level. There is also a dire need for a close observation network to track the outcomes of adaptations. In addition, an integrated and more in-depth assessment of farmers' adaptations and outcomes is necessary for better policy targets for achieving long-term food security and farmers' wellbeing. This study had some limitations; first, investigating both internal (such as normative and cognitive dimensions) and external (such as socio-politico-economic) elements impacting adaptation is crucial to better understand farmers' adaptation. However, studies lacked evidence for how internal factors can affect farmers' adaptation measures. Second, the reviewed studies did not show the extent to which the implemented adaptations were successful. The associated maladaptive outcomes are still under-researched. The reviewed adaptation strategies could be adopted in other countries with similar climate, cropping pattern, and socioeconomic system such as India and Bangladesh.

Author Contributions: Conceptualization, N.S., M.J. and C.B.; Methodology, N.S.; Validation, N.S. and M.J.; Formal Analysis, N.S., M.M. and A.S.; Data Curation, N.S., E.A. and M.J.; Writing—Original Draft Preparation, N.S., M.J., N.A.B. and M.I.K.; Visualization, M.F., A.S. and E.A., Resources, M.J., Writing—Review and Editing, N.S., M.F., S.A. and C.B.; Supervision, C.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IPCC. Climate change 2014: Impacts, adaptation, and vulnerability. Part a: Global and sectoral aspects. In *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; p. 1048.
2. Jha, P.K.; Viśvavidyālaya, T. Proceedings of the international Conference on Biodiversity, Livelihood and Climate Change in the Himalayas. Central Department of Botany, Tribhuvan University. 2015. Available online: http://pi.lib.uchicago.edu/1001/cat/bib/11343348 (accessed on 30 August 2021).
3. Abid, M.; Scheffran, J.; Schneider, U.A.; Elahi, E. Farmer Perceptions of Climate Change, Observed Trends and Adaptation of Agriculture in Pakistan. *Environ. Manag.* **2019**, *63*, 110–123. [CrossRef]
4. Parry, M.L. Climate Change (2007): Impacts, adaptation and vulnerability. In *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2007.
5. Kreft, S.; Eckstein, D.; Melchior, I. Global climate risk index. In *Who Suffers Most from Extreme Weather Events?* Germanwatch e.V. Office Bonn: Bonn, Germany, 2017; Volume 10.
6. GOP. Economic Survey. In *Economic Affairs Division*; Government of Pakistan: Islamabad, Pakistan, 2016.
7. Abid, M.; Scheffran, J.; Schneider, U.A.; Ashfaq, M. Farmers' perceptions of and adaptation strategies to climate change and their determinants: The case of Punjab province, Pakistan. *Earth Syst. Dyn.* **2015**, *6*, 225–243. [CrossRef]
8. Eckstein, D.; Künzel, V.; Schäfer, L. Global climate risk index 2018. *J. Ger. Bonn* **2017**, *9*, 36.
9. Adger, W.N.; Arnell, N.W.; Tompkins, E.L. Successful adaptation to climate change across scales. *Glob. Environ. Chang.* **2005**, *15*, 282–292. [CrossRef]
10. UNFCCC. Report of the Conference of the Parties on its Fifteenth Session. In Proceedings of the Part Two: Decisions Adopted by the Conference of the Parties, Copenhagen, Denmark, 7–19 December 2009.
11. IFAD. *Rural Poverty Report 2011*; IFAD: Rome, Italy, 2010.
12. OECD. *The Economics of Adapting Fisheries to Climate Change*; OECD Publishing: Paris, France, 2011. [CrossRef]
13. Farooqi, A.B.; Khan, A.H.; Mir, H. Climate change perspective in Pakistan. *Pak. J. Meteorol.* **2005**, *2*, 11–21. Available online: http://www.pmd.gov.pk/rnd/rnd_files/vol2_Issue3/2 (accessed on 30 August 2021).
14. Schlenker, W.; Lobell, D.B. Robust negative impacts of climate change on African agriculture. *Environ. Res. Lett.* **2010**, *5*, 014010. [CrossRef]
15. Bryan, E.; Ringler, C.; Okoba, B.; Roncoli, C.; Silvestri, S.; Herrero, M. Adapting agriculture to climate change in Kenya: Household strategies and determinants. *J. Environ. Manag.* **2013**, *114*, 26–35. [CrossRef]
16. Deressa, T.T. *Measuring the Economic Impact of Climate Change on Ethiopian Agriculture: Ricardian Approach. Policy Research Working Paper; No. 4342*; World Bank: Washington, DC, USA, 2007; Available online: https://openknowledge.worldbank.org/handle/10986/7290 (accessed on 30 August 2021).
17. Deressa, T.T.; Hassan, R.M.; Ringler, C.; Alemu, T.; Yesuf, M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Glob. Environ. Chang.* **2009**, *19*, 248–255. [CrossRef]
18. Hussain, M.; Butt, A.R.; Uzma, F.; Ahmed, R.; Irshad, S.; Rehman, A.; Yousaf, B. A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. *Environ. Monit. Assess.* **2020**, *192*, 48. [CrossRef]
19. Fahad, S.; Wang, J. Climate change, vulnerability, and its impacts in rural Pakistan: A review. *Environ. Sci. Pollut. Res.* **2020**, *27*, 1334–1338. [CrossRef]
20. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Group, P. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* **2009**, *6*, e1000097. [CrossRef]
21. Mahmood, N.; Ahmad, B.; Hassan, S.; Bakhsh, K. Impact of temperature ADN precipitation on rice productivity in rice-wheat cropping system of Punjab province. *J. Anim. Plant Sci.* **2012**, *22*, 993–997.
22. Abid, M.; Schilling, J.; Scheffran, J.; Zulfiqar, F. Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. *Sci. Total Environ.* **2016**, *547*, 447–460. [CrossRef]
23. Abid, M.; Schneider, U.A.; Scheffran, J. Adaptation to climate change and its impacts on food productivity and crop income: Perspectives of farmers in rural Pakistan. *J. Rural. Stud.* **2016**, *47*, 254–266. [CrossRef]
24. Ahmad, S.; Nadeem, M.; Abbas, G.; Fatima, Z.; Khan, R.J.Z.; Ahmed, M.; Khan, M.A. Quantification of the effects of climate warming and crop management on sugarcane phenology. *Clim. Res.* **2016**, *71*, 47–61. [CrossRef]
25. Abid, M.; Ngaruiya, G.; Scheffran, J.; Zulfiqar, F. The role of social networks in agricultural adaptation to climate change: Implications for sustainable agriculture in Pakistan. *Climate* **2017**, *5*, 85. [CrossRef]
26. Ahmad, S.; Abbas, G.; Fatima, Z.; Khan, R.J.; Anjum, M.A.; Ahmed, M.; Khan, M.A.; Porter, C.H.; Hoogenboom, G. Quantification of the impacts of climate warming and crop management on canola phenology in Punjab, Pakistan. *J. Agron. Crop. Sci.* **2017**, *203*, 442–452. [CrossRef]
27. Ali, A.; Erenstein, O. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Clim. Risk Manag.* **2017**, *16*, 183–194. [CrossRef]
28. Arshad, M.; Amjath-Babu, T.S.; Krupnik, T.J.; Aravindakshan, S.; Abbas, A.; Kächele, H.; Müller, K. Climate variability and yield risk in South Asia's rice–wheat systems: Emerging evidence from Pakistan. *Paddy Water Environ.* **2017**, *15*, 249–261. [CrossRef]

29. Arshad, M.; Kächele, H.; Krupnik, T.J.; Amjath-Babu, T.S.; Aravindakshan, S.; Abbas, A.; Mehmood, Y.; Müller, K. Climate variability, farmland value, and farmers' perceptions of climate change: Implications for adaptation in rural Pakistan. *Int. J. Sustain. Dev. World Ecol.* **2017**, *24*, 532–544. [CrossRef]
30. Amin, A.; Nasim, W.; Mubeen, M.; Ahmad, A.; Nadeem, M.; Urich, P.; Fahad, S.; Ahmad, S.; Wajid, A.; Tabassum, F.; et al. Simulated CSM-CROPGRO-cotton yield under projected future climate by SimCLIM for southern Punjab, Pakistan. *Agric. Syst.* **2018**, *167*, 213–222. [CrossRef]
31. Arshad, M.; Amjath-Babu, T.S.; Aravindakshan, S.; Krupnik, T.J.; Toussaint, V.; Kächele, H.; Müller, K. Climatic variability and thermal stress in Pakistan's rice and wheat systems: A stochastic frontier and quantile regression analysis of economic efficiency. *Ecol. Indic.* **2018**, *89*, 496–506. [CrossRef]
32. Awais, M.; Wajid, A.; Saleem, M.F.; Nasim, W.; Ahmad, A.; Raza, M.A.; Bashir, M.U.; Mubeen, M.; Hammad, H.M.; Ur Rahman, H.M.; et al. Potential impacts of climate change and adaptation strategies for sunflower in Pakistan. *Environ. Sci. Pollut. Res.* **2018**, *25*, 13719–13730. [CrossRef]
33. Bacha, M.S.; Nafees, M.; Adnan, S. Farmers' perceptions about climate change vulnerabilities and their adaptation measures in District Swat. *Sarhad J. Agric.* **2018**, *34*, 311–326. [CrossRef]
34. Bhatti, M.T.; Balkhair, K.S.; Masood, A.; Sarwar, S. Optimized shifts in sowing times of field crops to the projected climate changes in an agro-climatic zone ofPakistann. *Exp. Agric.* **2018**, *54*, 201–213. [CrossRef]
35. Gorst, A.; Dehlavi, A.; Groom, B. Crop productivity and adaptation to climate change in Pakistan. *Environ. Dev. Econ.* **2018**, *23*, 679–701. [CrossRef]
36. Hussain, J.; Khaliq, T.; Ahmad, A.; Akhter, J.; Asseng, S. Wheat Responses to Climate Change and Its Adaptations: A Focus on Arid and Semi-arid Environment. *Int. J. Environ. Res.* **2018**, *12*, 117–126. [CrossRef]
37. Imran, M.A.; Ali, A.; Ashfaq, M.; Hassan, S.; Culas, R.; Ma, C. Impact of Climate Smart Agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab, Pakistan. *Sustainability* **2018**, *10*, 2101. [CrossRef]
38. Nasir, M.J.; Khan, A.S.; Alam, S. Climate change and agriculture: An overview of farmers perception and adaptations in Balambat Tehsil, District Dir Lower, Pakistan. *Sarhad J. Agric.* **2018**, *34*, 85–92. [CrossRef]
39. Habib ur Rahman, M.; Ahmad, A.; Wang, X.; Wajid, A.; Nasim, W.; Hussain, M.; Ahmad, B.; Ahmad, I.; Ali, Z.; Ishaque, W.; et al. Multi-model projections of future climate and climate change impacts uncertainty assessment for cotton production in Pakistan. *Agric. For. Meteorol.* **2018**, *253-254*, 94–113. [CrossRef]
40. Salman, A.; Husnain MI ul Jan, I.; Ashfaq, M.; Rashid, M.; Shakoor, U. Farmers' adaptation to climate change in Pakistan: Perceptions, options and constraints. *Sarhad J. Agric.* **2018**, *34*, 963–972. [CrossRef]
41. Tariq, M.; Ahmad, S.; Fahad, S.; Abbas, G.; Hussain, S.; Fatima, Z.; Nasim, W.; Mubeen, M.; Habib ur Rehman, M.; Khan, M.A.; et al. The impact of climate warming and crop management on phenology of sunflower-based cropping systems in Punjab, Pakistan. *Agric. For. Meteorol.* **2018**, *256-257*, 270–282. [CrossRef]
42. Ullah, W.; Nihei, T.; Nafees, M.; Zaman, R.; Ali, M. Understanding climate change vulnerability, adaptation and risk perceptions at household level in Khyber Pakhtunkhwa, Pakistan. *Int. J. Clim. Chang. Strateg. Manag.* **2018**, *10*, 359–378. [CrossRef]
43. Ali, S.; Gucheng, L.; Ying, L.; Ishaq, M.; Shah, T. The relationship between carbon dioxide emissions, economic growth and agricultural production in Pakistan: An autoregressive distributed lag analysis. *Energies* **2019**, *12*, 4644. [CrossRef]
44. Bakhsh, K.; Kamran, M.A. Adaptation to climate change in rain-fed farming system in Punjab, Pakistan. *Int. J. Commons* **2019**, *13*, 833–847. [CrossRef]
45. Bhatti, M.T.; Ahmad, W.; Shah, M.A.; Khattak, M.S. Climate change evidence and community level autonomous adaptation measures in a canal irrigated agriculture system of Pakistan. *Clim. Dev.* **2019**, *11*, 203–211. [CrossRef]
46. Gul, F.; Jan, D.; Ashfaq, M. Assessing the impact of climate change adaptation strategies on poverty rates of wheat farmers in Khyber Pakhtunkhwa, Pakistan. *Sarhad J. Agric.* **2019**, *35*, 442–448. [CrossRef]
47. Imran, M.A.; Ali, A.; Ashfaq, M.; Hassan, S.; Culas, R.; Ma, C. Impact of climate smart agriculture (CSA) through sustainable irrigation management on Resource use efficiency: A sustainable production alternative for cotton. *Land Use Policy* **2019**, *88*, 104113. [CrossRef]
48. Mahmood Nasir Arshad, M.; Kächele, H.; Ma, H.; Ullah, A.; Müller, K. Wheat yield response to input and socioeconomic factors under changing climate: Evidence from rainfed environments of Pakistan. *Sci. Total Environ.* **2019**, *688*, 1275–1285. [CrossRef]
49. Shah, S.I.A.; Zhou, J.; Shah, A.A. Ecosystem-based Adaptation (EbA) practices in smallholder agriculture; emerging evidence from rural Pakistan. *J. Clean. Prod.* **2019**, *218*, 673–684. [CrossRef]
50. Ullah, W.; Nafees, M.; Khurshid, M.; Nihei, T. Assessing farmers' perspectives on climate change for effective farm-level adaptation measures in Khyber Pakhtunkhwa, Pakistan. *Environ. Monit. Assess.* **2019**, *191*. [CrossRef]
51. Ahmad, I.; Ahmad, B.; Boote, K.; Hoogenboom, G. Adaptation strategies for maize production under climate change for semi-arid environments. *Eur. J. Agron.* **2020**, *115*, 126040. [CrossRef]
52. Ahmad, D.; Afzal, M. Climate change adaptation impact on cash crop productivity and income in Punjab province of Pakistan. *Environ. Sci. Pollut. Res.* **2020**, *27*, 30767–30777. [CrossRef]
53. Ali, M.F.; Ashfaq, M.; Hassan, S.; Ullah, R. Assessing indigenous knowledge through farmers' perception and adaptation to climate change in Pakistan. *Pol. J. Environ. Stud.* **2020**, *29*, 525–532. [CrossRef]

54. Ali, S.; Liu, Y.; Nazir, A.; Ishaq, M.; Khan, S.B.; Abdullah; Shah, T. Does technical progress mitigate climate effect on crops yield in Pakistan? *J. Anim. Plant Sci.* **2020**, *30*, 663–676. [CrossRef]
55. Amir, S.; Saqib, Z.; Khan, M.I.; Ali, A.; Khan, M.A.; Bokhari, S.A.; Ul-Haq, Z. Determinants of farmers' adaptation to climate change in rain-fed agriculture of Pakistan. *Arab. J. Geosci.* **2020**, *13*, 1–19. [CrossRef]
56. Amir, S.; Saqib, Z.; Khan, M.I.; Khan, M.A.; Bokhari, S.A.; Zaman-Ul-haq, M.; Majid, A. Farmers' perceptions and adaptation practices to climate change in rain-fed area: A case study from district chakwal, Pakistan. *Pak. J. Agric. Sci.* **2020**, *57*, 465–475. [CrossRef]
57. Khalid, A.M.; Hina, T.; Hameed, S.; Hamid Nasir, M.; Ahmad, I.; Ur Rehman Naseer, M.A. Modeling adaptation strategies against climate change impacts in integrated rice-wheat agricultural production system of Pakistan. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2522. [CrossRef]
58. Fahad, S.; Inayat, T.; Wang, J.; Dong, L.; Hu, G.; Khan, S.; Khan, A. Farmers' awareness level and their perceptions of climate change: A case of Khyber Pakhtunkhwa province, Pakistan. *Land Use Policy* **2020**, *96*, 104669. [CrossRef]
59. Hussain, A.; Memon, J.A.; Hanif, S. Weather shocks, coping strategies and farmers' income: A case of rural areas of district Multan, Punjab. *Weather Clim. Extrem.* **2020**, *30*, 100288. [CrossRef]
60. Jabbar, A.; Wu, Q.; Peng, J.; Zhang, J.; Imran, A.; Yao, L. Synergies and determinants of sustainable intensification practices in Pakistani agriculture. *Land* **2020**, *9*, 110. [CrossRef]
61. Javed, S.A.; Haider, A.; Nawaz, M. How agricultural practices managing market risk get attributed to climate change? Quasi-experiment evidence. *J. Rural. Stud.* **2020**, *73*, 46–55. [CrossRef]
62. Khan, I.; Lei, H.; Shah, I.A.; Ali, I.; Khan, I.; Muhammad, I.; Huo, X.; Javed, T. Farm households' risk perception, attitude and adaptation strategies in dealing with climate change: Promise and perils from rural Pakistan. *Land Use Policy* **2020**, *91*, 104395. [CrossRef]
63. Mahmood, N.; Arshad, M.; Kaechele, H.; Shahzad, M.F.; Ullah, A.; Mueller, K. Fatalism, climate resiliency training and farmers' adaptation responses: Implications for sustainable rainfed-wheat production in Pakistan. *Sustainability* **2020**, *12*, 1650. [CrossRef]
64. Nasir, I.R.; Rasul, F.; Ahmad, A.; Asghar, H.N.; Hoogenboom, G. Climate change impacts and adaptations for fine, coarse, and hybrid rice using CERES-Rice. *Environ. Sci. Pollut. Res.* **2020**, *27*, 9454–9464. [CrossRef]
65. Shabbir, G.; Khaliq, T.; Ahmad, A.; Saqib, M. Assessing the climate change impacts and adaptation strategies for rice production in Punjab, Pakistan. *Environ. Sci. Pollut. Res.* **2020**, *27*, 22568–22578. [CrossRef]
66. Shah, H.; Siderius, C.; Hellegers, P. Cost and effectiveness of in-season strategies for coping with weather variability in Pakistan's agriculture. *Agric. Syst.* **2020**, *178*, 102746. [CrossRef]
67. Aftab, A.; Ahmed, A.; Scarpa, R. Farm households' perception of weather change and flood adaptations in northern Pakistan. *Ecol. Econ.* **2021**, *182*, 106882. [CrossRef]
68. Ali, M.F.; Rose, S. Farmers' perception and adaptations to climate change: Findings from three agro-ecological zones of Punjab, Pakistan. *Environ. Sci. Pollut. Res.* **2021**, *28*, 14844–14853. [CrossRef]
69. Arshad, A.; Raza, M.A.; Zhang, Y.; Zhang, L.; Wang, X.; Ahmed, M.; Habib-Ur-rehman, M. Impact of climate warming on cotton growth and yields in China and Pakistan: A regional perspective. *Agriculture* **2021**, *11*, 97. [CrossRef]
70. Ashraf, M.; Arshad, A.; Patel, P.M.; Khan, A.; Qamar, H.; Siti-Sundari, R.; Ghani, M.U.; Amin, A.; Babar, J.R. Quantifying climate-induced drought risk to livelihood and mitigation actions in Balochistan. *Nat. Hazards* **2021**, *109*, 2127–2151. [CrossRef]
71. Ayub, M.; Ashraf, M.Y.; Kausar, A.; Saleem, S.; Anwar, S.; Altay, V.; Ozturk, M. Growth and physio-biochemical responses of maize (Zea mays L.) to drought and heat stresses. *Plant Biosyst.* **2021**, *155*, 535–542. [CrossRef]
72. Jamil, I.; Jun, W.; Mughal, B.; Raza, M.H.; Imran, M.A.; Waheed, A. Does the adaptation of climate-smart agricultural practices increase farmers' resilience to climate change? *Environ. Sci. Pollut. Res.* **2021**, *28*, 27238–27249. [CrossRef] [PubMed]
73. Jamil, I.; Jun, W.; Mughal, B.; Wheed, J.; Hussain, H.; Waseem, M. Agricultural Innovation: A comparative analysis of economic benefits gained by farmers under climate resilient and conventional agricultural practices. *Land Use Policy* **2021**, *108*, 105581. [CrossRef]
74. Khan, N.A.; Qiao, J.; Abid, M.; Gao, Q. Understanding farm-level cognition of and autonomous adaptation to climate variability and associated factors: Evidence from the rice-growing zone of Pakistan. *Land Use Policy* **2021**, *105*, 105427. [CrossRef]
75. Sardar, A.; Kiani, A.K.; Kuslu, Y. Does adoption of climate-smart agriculture (CSA) practices improve farmers' crop income? Assessing the determinants and its impacts in Punjab province, Pakistan. *Environ. Dev. Sustain.* **2021**, *23*, 10119–10140. [CrossRef]
76. Shahid, R.; Shijie, L.; Shahid, S.; Altaf, M.A.; Shahid, H. Determinants of reactive adaptations to climate change in semi-arid region of Pakistan. *J. Arid. Environ.* **2021**, *193*, 104580. [CrossRef]
77. Qazlbash, S.K.; Zubair, M.; Manzoor, S.A.; ul Haq, A.; Baloch, M.S. Socioeconomic determinants of climate change adaptations in the flood-prone rural community of Indus Basin, Pakistan. *Environ. Dev.* **2021**, *37*, 100603. [CrossRef]
78. Mahmood, N.; Arshad, M.; Mehmood, Y.; Faisal Shahzad, M.; Kächele, H. Farmers' perceptions and role of institutional arrangements in climate change adaptation: Insights from rainfed Pakistan. *Clim. Risk Manag.* **2021**, *32*, 100288. [CrossRef]
79. Khan, N.A.; Gao, Q.; Iqbal, M.A.; Abid, M. Modeling food growers' perceptions and behavior towards environmental changes and its induced risks: Evidence from Pakistan. *Environ. Sci. Pollut. Res.* **2020**, *27*, 20292–20308. [CrossRef]
80. Akhtar, S.; Li, G.; Ullah, R.; Nazir, A.; Iqbal, M.A.; Raza, M.H.; Iqbalc, H.; Faisal, M. Factors influencing hybrid maize farmers' risk attitudes and their perceptions in Punjab Province, Pakistan. *J. Integr. Agric.* **2018**, *17*, 1454–1462. [CrossRef]