



Research Article

The Future of Horticultural Crops: Navigating Climate Uncertainty in the Context of Farmers Perception and Metrological Data

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Abstract | Food security and farmers' livelihood is greatly affected by climate change. It is imperative to design strategies for combating the impacts of climate change and thus minimizing the risk for food security and survival of plants. The study was conducted to investigate farmers' perceptions about climate change based on climatic parameters; temperature, rainfall and snowfall during the last six decades in the temperate zone of Pakistan, whereby the primary data was compared with the metrological data. Based on the metrological data, it was found that the annual average temperature was increased from 13.2 °C (1980) to 15.47 °C (2017) while annual average rainfall was reduced from 131.88 mm/year (1980) to 109.2 mm/year (2017) over the the last 30 years. The farmer's perceptions comply with the metrological data in which 95% of the farmers perceived an increase in temperature while 97.7 % farmers perceived a decrease in the rainfall. Similarly, 97% farmers perceived earlier spring onset and 50.33 % perceived decreasing snowfall intensity and frequency. As far as the farmers' knowledge level is concerned, 70% of the farmers are unaware about climate change while 30% are familiar with it. Newspapers, Radio and Television were found to be the main source of awareness about climate change. According to the results, 90% farmers were of the opinion that horticultural crops (fruits) yield has been reduced while the occurrence of pests and diseases have increased significantly over the last 3 decades. As far as the mitigation strategy is concerned, 40% of the farmers use compost; 29% use crop rotation; 13% use soil conservation, 9% use planting different varieties, 6% farmers leave the land in fallow condition, while 3% farmers use various agroforestry as measures to cope with changing climate. The study results indicate that significant variations occurred in certain climate factors such as temperature and rainfall which have adverse effects on crop productivity. Thus, it is advised to design agriculture policy which should be based on local data and strengthening of farmers capacity and facilitating them for mitigating the impact of future climate change on local farmers' agriculture productivity and food security.

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Introduction

Climate change is a fact and affecting crops in various ways throughout the world. It is a great challenge for us to mitigate its impacts by securing food for the growing world population. Under the current population growth rate, the human population is estimated to be around 9.1 billion by 2050 (Amjath-Babu *et al.* 2016; Lu *et al.*, 2011). There will be 70% more demand for food production and other living requirements from the agriculture sector (Furuya *et al.*, 2009; Habib and Zamin, 2003; Fahad *et al.*, 2016a; Zamin *et al.*, 2019a). Under this scenario 80 million people are forecasted at the risk of hunger by 2028 (Parry *et al.*, 1999; Furuya *et al.*, 2009). Moreover, climate change is influencing biological systems through augmented temperatures, more inconstant precipitation and rising CO₂ in the atmosphere (Zamin *et al.*, 2019b).

Recent climate change simulation models have revealed an increase in temperature, fluctuation in precipitation, water availability and decrease in crop production (Vedwan and Rhoades, 2009; Arshad *et al.*, 2017; Ullah *et al.*, 2015; Nasir *et al.*, 2018). Although, Pakistan is contributing at least to global warming, still the country will be worse hit by climate change and that is why, the country is witnessing a growing pressure on natural resources and the environment. The country has been identified as the 12th most vulnerable country to climate change in the world in a recent report (Fahad and Wang, 2020; Kreft and Eckstein, 2013; Dawn, 2010). Water is likely to decline, which in turns will affect food production (Fahad and Wang, 2018; Ashfaq *et al.*, 2011). The climate change in the country has already cost \$3.57 billion during 18 years according to a World Bank report. It is risking half of the country's population (Dawn, 2009). There has been a growing concern of the impact of climate change in Pakistan (Babar *et al.*, 2014; Shah *et al.* 2019) and in recent first meeting of the Climate Sub-Committee of the national assembly standing committee has warned that the depleting glaciers in the country would deplete water resources. Climate change will also have adverse impacts on crops leading to lower crop productivity, soil erosion, water logging and migration (Dawn, 2010). Climate change is not only contributing to rise in temperature but also shifting rainfall patterns and there is an increase in the heat index in the Khyber Pakhtunkhwa province of Pakistan (Zahid and Rasul, 2010).

As compared to other sectors, climate related risks on crop yield are more likely to be in the agriculture sector (Babar *et al.*, 2014; Ashraf *et al.*, 2016). Horticultural crops are more vulnerable to climate change (Rehman *et al.*, 2015) as climate change might decrease chilling hours and inhibit bloom and fruit set in horticultural crops (Snyder, 2017). Disease and insect occurrence has further declined the production of existing crops. The existing commercial varieties of horticultural crops will perform poorly in an unpredictable manner due to aberration of climate while due to high temperature physiological disorder of horticultural crops will be more pronounced (Datta, 2013). The climate change will also affect farmers cropping pattern, cultivation strategies, (Fahad and Wang, 2018; Denton, 2001; Kikar, 2000). Since farmers have dependency on small scale agriculture in addition to prevalence of poverty, vulnerability, food insecurity, deforestation, variations in rainfall pattern, soil erosion and land sliding, climate change is likely to further aggravate the socioeconomic condition of these communities (Yinhong, 2009; Ayanladea *et al.*, 2017).

In addition to the prediction of climate simulation models, local farmers understandings and perceptions of climate variability are of critical policy significance (Ayanladea *et al.*, 2017; Ashraf *et al.*, 2016). These perceptions have also helped to increase understanding of climate change and its impact on agriculture (Lobell and Burke, 2010; Vedwan and Rhoades, 2001; Ayanladea *et al.*, 2017; Amadou *et al.*, 2015) which can lead to adaptation strategies to climate change (Howden *et al.*, 2007). There is a vast literature on the assessment of farmers' perceptions and climate change. However, there are few studies on the comparison of climate data and its coincidence with farmers perceptions and recent findings from temperate forest zones of Pakistan (Fahad *et al.*, 2020). Therefore, new empirical insights are needed to guide environmental and agriculture policy of the government. Climate change will impact different geographical zones differently (Vedwan and Rhoades, 2009; Shah *et al.*, 2019). Therefore, this study was conducted to analyze the trend in variables such as temperature and how these changes coincides with farmers' perceptions about climate change.

Materials and Methods

Study area

Farmers were surveyed in different geographical areas

in district Dir in the province of Khyber Pakhtunkhwa, Pakistan in summer 2021-22. District Dir can be geographically grouped into upper-Dir and Lower Dir. Topographically, the areas are dominated by high mountains. Historically Dir District was merged with Pakistan in 1969. Before the merger, it was a state and the ruler of the area was called Nawab. The Dir was given the status of administrative District in 1970. Districts Upper Dir and Lower Dir are surrounded by Chitral district and Afghanistan to its Northwest, Swat District on the East while Malakand at South and Bajaur Agency at south west (Figure 1). There are five (5) tehsils in the District Upper Dir namely; Dir, Barawal, Kalkot, Wari and Khal with total area 3699 square kilometers.

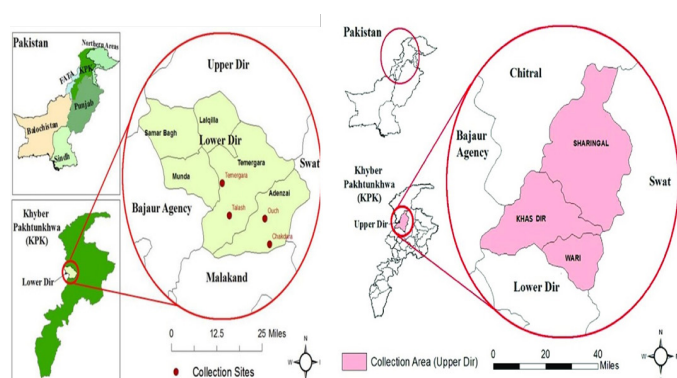


Figure 1: Lower Dir (left) and Upper Dir (right).

The upper Dir area is a mountainous region and is characterized by a moderate and warm summer where there is high temperature in June and July (the maximum and minimum temperature in June is about 33 and 16 degrees centigrade, respectively). In November on the advent of winter, temperature begins to fall and during December, January, and February, temperature normally falls below freezing point. The mean maximum and minimum temperature in January is 11 and -2 degrees centigrade respectively (PPAF, 2014).

The lower part of District Dir is known as Lower Dir. Topographically the area consists mainly of mountains and hills. These are ranges of Southern Hindukush with its highest peaks in the northern part of Dir. The area consists of valleys named Timergara, Jandool Maidan, Samarbagh, and Asban.

The total area of lower Dir is approximately 1582 square kilometers. There are two tehsils in the district. The weather remains hot in the summer while the winter is extremely cold. The temperature in the area

rises in May to June. July and August are hot while the temperature decreases in September. The weather turns cold from the month of October onwards. The months of December and January are the coldest months (PPAF, 2015).

Sampling and data collection

For sampling and data collection, multistage sampling techniques were used. In the first stage, purposive sampling techniques were used to select the Upper and Lower Districts of Dir. Names of villages were received from local government authorities. Then the random number Tables technique was used for village selection.

Primary data

Interviews were taken from 300 farmers in all the villages of each district. The interviews were conducted at their farms during the year 2021/22. The relevant information pertaining to farmers socioeconomic and demographic condition, yield of crop, pest and diseases on crops, drought occurrence, knowledge of climate change and their perceptions regarding changes in temperature and precipitation during the last 30 years were included in the computer generated questionnaire. Before starting the actual survey on site, the questionnaire was pre-tested to rectify any ambiguity and irrelevance of the questions. Similarly, information regarding sources of climate change awareness and their mitigation measures were collected on a 4-point Likert scale. For this purpose, community meetings were held with experienced farmers and other Key informants in the village on different aspects of climate change.

Secondary data

The metrological data, called secondary data, were collected from the head office of the Pakistan metrological department. A formal request was sent to the department and after a few meetings, the data was provided for the research purpose. So, the time series data were gathered on rainfall, temperature, snowfall for the period 1970 to 2017. Thus, a real time trend of climatic variables such as temperature, rainfall and snowfall over a long period of time was generated. The secondary data on annual rainfall, temperature, snowfall was compared with farmers responses.

Results and Discussion

Temperature

The mean data on temperature reveal an overall

increase in the average temperature. As indicated in Figure 2 the temperature increased after the 1980s. The average temperature has shifted from 13 °C to 15.47 °C in a single decade. Similarly, from the 1990s to 2011-17 the temperature has shifted from 15.95 °C to 15.44 °C. Thus an increase in the mean annual temperature was found over the years. Similar findings were found by Giannakopoulos *et al.* (2005) and Dash *et al.* (2007). Zahid and Rasul (2010) also reported similar results in temperature change in the same province of Khyber Pakhtunkhwa. The impact of high temperature in summer includes water shortage and aggravating pest and disease occurrence while in winter, insufficient chilling is leading to changes in flowering phenology such as delay in flower bud bursting, early flowering, flower drop, poor fruit set, changes in quality. The increasing trend in temperature from 1985 till 2009 was also recorded by Sen *et al.* (2015) while evaluating the impact of climatic variables on temperature fruits.

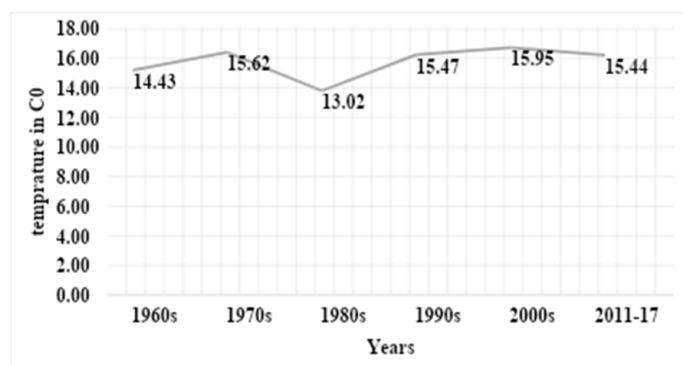


Figure 2: Trend in temperature during 1960-2017 in district Dir, Khyber Pakhtunkhwa (Source: Pakistan Metrological department).

Rainfall

The mean data pertaining to rainfall indicate an extreme fluctuation in the rainfall pattern in the study area (Figure 3). The total annual rainfall shifted from 112.93 millimetre to 131.88 millimetres. The rainfall has declined between the years 1990-2000. However, an increasing trend was observed in 2000 to 2017. The extreme pattern of rainfall in many areas has led to severe flooding in 1990 and 2010. Studies such as Guhathakurta *et al.* (2011) also reported an increase in rainfall in India, and decrease in other parts of the country leading to flood risk and extreme rainfall. These changes in the pattern of the rain fall and frequency has implications for the local farmers because the extreme changes in the rainfall causes flooding (Bacha *et al.*, 2021; Ashraf *et al.*, 2016; Arnbjerg-Nielsen *et al.*, 2013). The flood in 2010 in the study area devastated large acres of land in the

plain and in the mountains leading to huge losses to horticultural crops and a good deal of economic losses to the farmers. Rainfall is affecting water availability in springs and providing a permanent source of water to groundwater reservoirs. As a result the ground water level is lowering and leading to droughts and water scarcity even for drinking water for farming communities (Shakoor *et al.*, 2011; Ullah *et al.*, 2015).

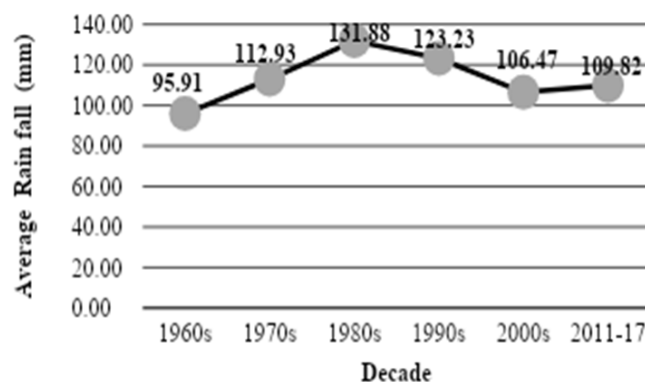


Figure 3: Trend of average rainfall in Dir District, Khyber Pakhtunkhwa (Source: Pakistan Metrological department).

Snowfall

The mean data on snow fall obtained from Pakistan Metrological Department for the period 2004 to 2016 show that there was variability in snowfall for different years. Furthermore, a heavy snowfall has been observed during the year 2008 to 2013. More than 70 inches of annual snowfall was found in the study area followed by an abrupt reduction (Figure 4). These variations and abrupt shifts in snowfall patterns are actually caused by changing climate at regional and global level and which are leading to local impacts in the form of harsh weather and snow storms. The year 2013 is found to be a drier year with respect to snow fall in which an annual mean snowfall of less than 10 inches was recorded. In 2014 an annual mean snowfall of more than 20 inches was recorded and again in 2016 less than 10 inches annual mean snowfall was found. These figures indicate significant variability in weather in the study area. Similar results were found by Ullah *et al.* (2015) who also recorded a decreasing trend of snowfall and elevated rate of glaciers melting in district Dir. These changes and variation in weather parameters are attributed to changes in climate at the regional and global levels causing local repercussions including unfavourable weather conditions and snow storms.

Farmer's socio economics condition

The information regarding farmers socioeconomic

status and farming condition is recorded in Table 1. The farmers age is >50 years and they are not highly educated, however, they are well experienced in farming practices. They are living in a joint family system with a large household size. Due to small land holdings, they are engaged in mixed farming and along with the fruit crop and vegetable cultivation, they are also engaged in livestock farming. Livestock production is also used as a source of organic fertilizers for the crops.

Farmers knowledge of climate change

Climate change when taken in the global context is a widely known phenomenon. However, it is little known for the farmers in the remote area who are not well aware about the risk and existence of climate change. Therefore, the respondents were asked about their knowledge of climate change. Analysis of the data show 71 % farmers in the study area are unaware of climate change. Since both the districts have diversified climatic conditions, therefore, variations were found in farmers awareness about climate change at the district level. Interestingly, in Dir (Lower) more than 50% of the farmers were found to be unaware of the climate change while the farmers awareness level is higher in District Dir (upper) with 52% farmers. These may be attributed to the fact that in areas where the impact of climate change is more visible to farmers in terms of impact on farming, they are likely to indicate their awareness level about the climate change. Farmers awareness has a positive effect on farmers decisions to adapt mitigation measures. The relationship of farmer awareness with mitigation

measure was also found in previous research studies (Lorenzoni *et al.*, 2007; Bord *et al.*, 2000; O'Connor *et al.*, 2002; Prokopy *et al.*, 2008; Semenza *et al.*, 2008; reality (Hyland *et al.*, 2016).

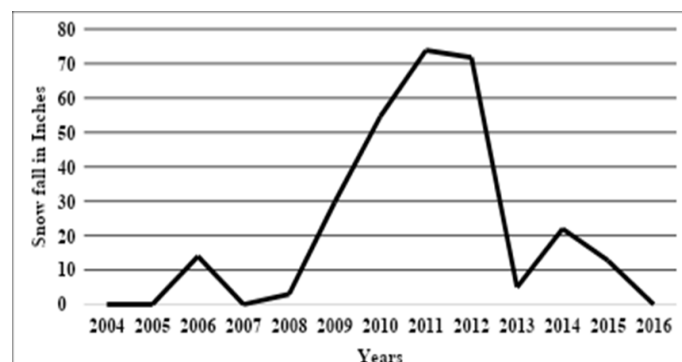


Figure 4: Snowfall variability in the study area (Source: Pakistan Metrological department)

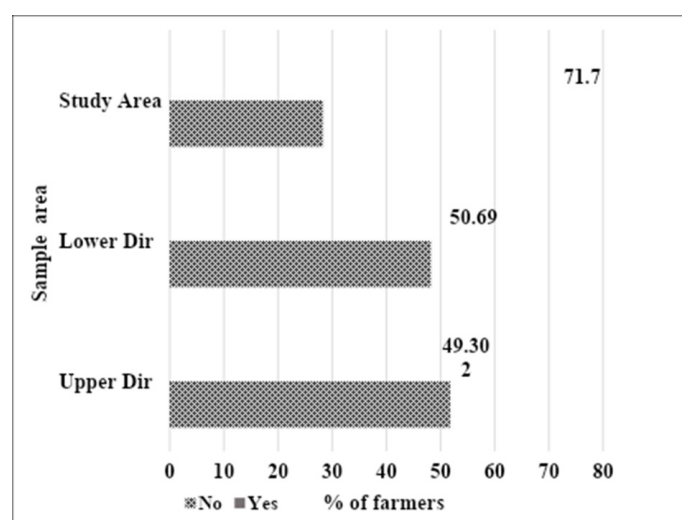


Figure 5: Farmers' knowledge about the climate change.

Table 1: Descriptive statistics of the farmer's Socioeconomic condition.

Variable	Description	Mean
Farmer age	Farmers age in years	54.99(11.94)
Farmer education	Years of school attended	3.5 (7.35)
Farming experience	Years of farming experience	31.83 (9.19)
Farming type	Subsistence/Commercial	3.53 (2.56)
Household size	number of members in the household	10.47(2.69)
Adult males	number adult males in the household	3.49 (1.73)
Male children	number of < 16 years male children	3.34 (1.92)
Female	number of < 16 years female children	2.73(1.86)
Land ownership status	Dummy (1= own land, 0= otherwise)	1.14(0.46)
Farm size	Size of farmers farm in acres	3.63 (2.09)
Livestock ownership	Dummy (1=own livestock, 0=otherwise)	0.91(0.27)
Livestock monetary benefits	Total annual monetary benefits in Pakistani Rupees	30705.33(25671.98)
Ownership of heavy machinery	Dummy (1= yes 0= otherwise)	0.07(0.261)
Sample size Total		300

Farmers source of awareness about climate change

From where the farmers obtain the knowledge and awareness is a question. The results from the questionnaire show that the most influential source of awareness was found to be the mass media such as newspapers, radio and television. More than 22% farmers marked the reading newspapers, listening to radio and watching TV as their awareness channels. Similarly, the second most influencing source of awareness about climate change is fellow farmers (19.2%) in the study area, followed by internet and social media with a 12.7% response rate (Figure 6). However, the public extension agencies and private companies dealing in pesticides and fertilizers businesses had less influencing role in climate change awareness among the farmers. These findings are evidence of the fact that mass media has a positive role in creating awareness among the farmers about climate change. On the other hand, the public extension department which is the stakeholder had only a passive role (1%) in awareness creation with non-significant contribution. Therefore, it is clear that the social networks such as friends, relatives and fellow farmers played a major role in awareness pertaining to climate change among the farming community. It is advised to connect the public sector agriculture extension department with social media for better results in creating awareness in farmers to mitigate the impacts of climate change on crops and ultimately on farmers livelihood. The existing small landholdings coupled with below average productivity is attributed to the fact that farmers cannot afford to buy modern tools and to access modern agriculture technology. They also lack the financial means to purchase tractors and other farm machinery. However, different media sources have aided farmers in raising awareness about climate change and they are taking the necessary measures according to their capacity.

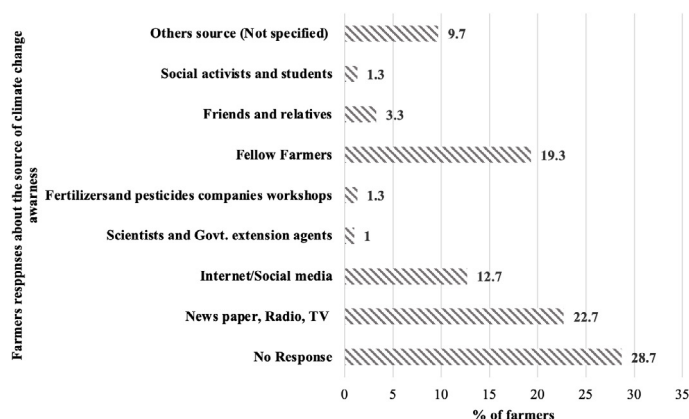


Figure 6: Farmers sources of awareness about the climate change.

Farmers perception on annual temperature

Temperature fluctuation is a major factor related to climate change. It has many consequences on crops. The designed questionnaire had questions about the shift in the temperature during the summer and winter times. The results in Figure 7 show that according to farmers' perceptions both the summer and winter temperature have increased at local level. 95% of the farmers in the study area claimed an increase in summer temperature. They further discovered that summer has become more intense and winter has become warmer than 30 years back. The secondary data taken from farmers are in line with the metrological data whereby an increase in temperature has been recorded. Temperature is the main factor affecting water availability, disease and pest occurrence, crop yield in terms of influencing chilling requirements of crops, flowering phenology and changes in quality. The increasing trend in temperature from 1985 till 2009 was also recorded by Sen *et al.* (2015) while evaluating the impact of climatic variables on temperate fruits (Chmielewski, 1992).

Farmers perception of rainfall occurrence

The farmers were asked about the increase and decrease in the occurrence of rainfall in the study area. The analysis in Figure 8 showed that the majority of farmers (97.7%) perceived a decrease in the rainfall occurrence. The study reveals that the occurrence of rains are less frequent than 30 years back. According to the farming community the rains have become less frequent but are more intense which sometimes lead to flooding and hailstorms. Such weather variability in the study area has led to devastating impact on crops such as damages to flowers and fruits in the standing orchards in the study area. The damaged fruits in the orchards or high rate of flowers drop due to these conditions are adversely affecting the financial conditions of farmers in addition to post harvest losses (Fahad *et al.*, 2020). The results of the study indicate that secondary data and the perceptions of the farmers in district Dir (upper and lower), Pakistan clearly confirm that there is extreme variability in the rainfall pattern during the last few decades. It was found that intense rain falls are frequent which causes flooding in the study area and thus a lot of fertile land is lost and agriculture crops affected which directly affects farmers' incomes. Rainfall has long been considered the most important climate variable influencing human activity (Vogel, 2005). Reduced frequency

of rains resulting in decrease in underground water depletion as perceived by the farmers are another implication of the climate variability in the area. The experienced farmers during consultations disclosed that as the rainfall declines, it causes drought and drying of water wells due to declining water table. These changes have impacted the water availability, which in turn affect the water consumption for households needs vis-à-vis production of agriculture crops (Sen *et al.*, 2015).

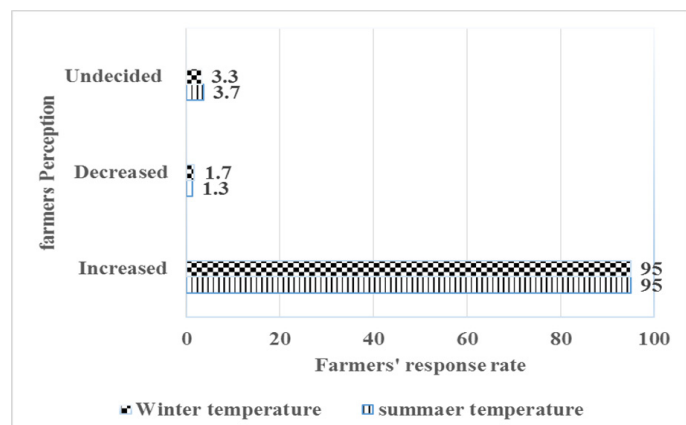


Figure 7: Farmers perception of the change in summer and winter temperature.

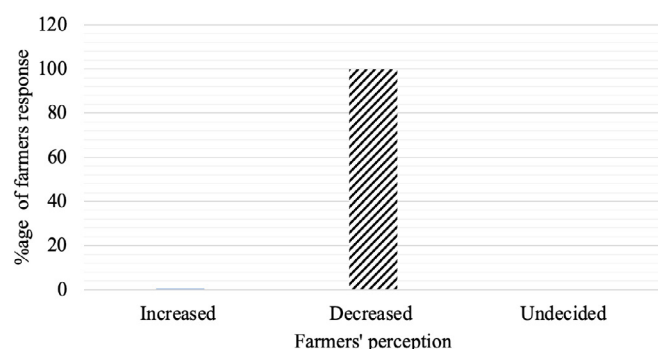


Figure 8: Farmers perception of Rainfall occurrence.

Farmers perception of spring onset

The farmers perception regarding spring onset was recorded in Table 2. The results obtained from face to face interviews with the local farmers indicated that the spring commenced earlier than 30 years back. The highest number (97.7%) of farmers stated that the onset of spring is earlier than before in the study area. The impact of global climate change has a greater influence on regional weather which is evident from the farmers disclosure of early spring arrival as compared to 30 years back in the area. Majority of the sample farmers indicated that the earlier beginning of spring has implications for crop productivity since some fruit trees cultivated under local climate conditions require longer chilling to

reach maturity, which may be hampered by the shorter chilling period. This could have a negative impact on the crop production in the end (Nasir *et al.*, 2018). Summer has been more intense, and winter has become warmer than it was 30 years ago (Ullah *et al.*, 2018). The temperature in the research area has been rising over the last two decades. These clear differences in winter and summer temperatures show local weather variability. Similar results received in other districts of Khyber Pakhtunkhwa supported our findings (Fahad *et al.*, 2020). Farmers' perceptions of temperature change is matching with study of Imran (2018) conducted in the Punjab province.

Table 2: Farmers perceptions of the spring onset in the study area.

Farmers perception of Spring onset	% of sampled farmers
Spring on set earlier than 30 years back	97.7
Spring onset later than 30 years back	1
No change in spring onset	1
Undecided	0.3
Total	100

Source: Field survey, 2021.

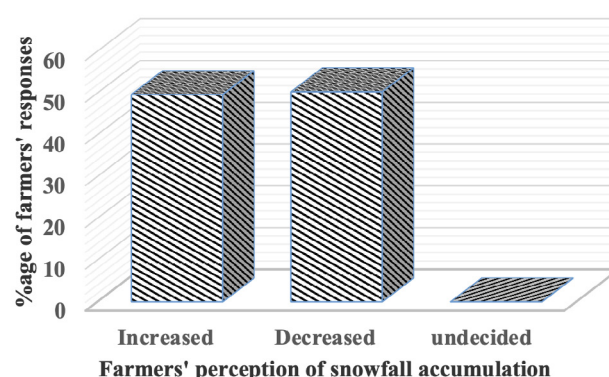


Figure 9: Farmers perception of snow fall accumulation compared to 30 years back.

Farmers perception of snowfall accumulation

Since snowfall plays a significant role in providing water source for the field crops throughout the year, therefore, farmers were questioned about the snowfall accumulation as compared to 30 years back. According to the analysis snowfall accumulation was adversely affected during the last 30 years. Maximum (50.33%) farmers perceived decreased snowfall accumulation as compared to 30 years back (Figure 9). The variation in farmers perceptions might be due to the reason that different areas have different microclimate thus having different snowfall accumulation. Farmers with

increased snowfall accumulation might be referred to the empirical evidence (Figure 4) during the year 2008-2013 where an increasing trend was found in snow fall while in the rest of years decrease in snow fall is observed (Nasir *et al.*, 2018). During 2013 onward, the trend in snowfall has declined. While very recently in January 2022 unexpectedly, increased snowfall accumulation was observed in parts of the Khyber Pakhtunkhwa including the study area (Swat and Dir) while in some parts it assumed the shape of a snow storm. These variations in pattern and snow fall intensity is evidence of the climate change at the local level.

Crop yield (fruit)

Since there is limited land for agronomic crops in Dir, so mostly fruit trees are grown as orchards or on marginal land to get partial livelihood for their family. The weather variability in the area has led to frequent drought occurrence, limiting crop heat or chilling requirements and other physiological disorders (Liu *et al.*, 2010; Challinor *et al.*, 2014). In the study area, 90% farmers perceived an increase in drought occurrence and attributed it to the fact of less frequent rains in the study area (Table 3). During the field survey discussion, it was revealed that drought is directly related to rainfall. The farmers perceived that drought years are the worst years for crops particularly for the areas where water distribution channels are not available. Farmers in the study area were of the opinion that cash crops such as fruit and vegetable crops cannot be grown in the areas with frequent drought occurrence (Farhan *et al.*, 2019).

Pests and diseases occurrence

Climate change has not only an adverse effect on water availability but led to an increase in pest and disease occurrence. 90% farmers stated that due to climate change the insect and disease spread have been increased while 50% were of the opinion that the pest problem is reduced (Table 3). Most of the farmers with

less pest perception belonged to the areas where only marginal land was cultivated. However, the pest and disease infestation have been increased in the areas where crops are grown on commercial and large scale. Irregular and heavy rainfalls, humid environment and warmer temperature promote the spread of different types of insects and diseases which can lead to low yield of crops (Ullah *et al.*, 2015; Ishaya and Abaje, 2008). Similarly, drought conditions reduce the crop capabilities to tolerate the prevailing insect and disease infestation and thus leading to reduction in crop yield.

Farmers adaptation strategies

Based on the knowledge about climate change, the farmers adjust the farming practices and strategies to cope with climate change impacts which is technically called (IPCC, 2001). The farmers response was recorded as shown in Figure 9. Farmers are involved in practicing various adaptation practices. The most common strategy was using compost. More than 40 % of the sampled respondents reported using the use of compost to mitigate the impact of changing climate. Other farmers (30%) adopted the practice of crop rotation as a strategy to cope with climate change impact on their farming. Similarly, 10% of the sampled farmers reported the use of changing planting dates. Changing varieties was also used as mitigation strategy by farmers and stated that during the last couple of years the change of different plant varieties has increased due to the local climatic variability such

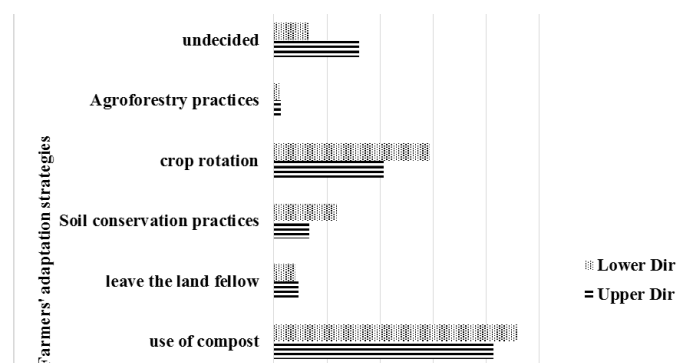


Figure 10: Farmers' adaptation strategies.

Table 3: Farmers' perceptions of crop yield and pest and disease occurrence in the study area.

Farmers perception of crop yield			% of sampled farmers	Farmers perception of pest and disease occurrence		% of sampled farmers
Horticultural yield increased	Crop	(fruit)	10	Pest and disease occurrence increased		90
Horticultural yield decreased	Crop	(fruit)	90	Pest and disease occurrence decreased		5
No change in yield			0	No change in yield		1
Undecided			0	Undecided		4
Total			100			100

Source: Field survey, 2021.

as change in the temperature and season duration among others such as using low chill varieties in the areas where the temperature has increased and the chilling requirement of crops cannot be fulfilled. In Lower Dir, the use of Apple variety Anna is reported, which is a low chill apple variety and gives better performance in warmer areas. Some farmers (6%) were leaving the land, others practiced soil conservation practices (13%) and agroforestry (3%) as mitigation strategies. The use of adaptation practices exists; however, such practices are not affordable for the majority of the farmers. Those farmers who are not able to cope with the changing climatic conditions are adversely affected in terms of crop yield and quality of the agriculture produce (Adger *et al.*, 2005). In response to the changing weather pattern and change in the local climate conditions, local farmers are adapting different strategies as mitigation strategies (Usman and Reason, 2004; Adger *et al.*, 2005). However, the small farmers are constrained by various socioeconomic and institutional factors (Mortimore and Adams, 2001).

Conclusions and Recommendations

Based on the study findings, it is concluded that during the decades under investigation the temperature has shown a rising trend especially between the year 1980 and 2017 while a declining trend was found in rainfall. Similarly, a decreasing trend for snowfall was observed during the year 2014 to 2017. Farmers awareness level is low in the study area and social media (mass media) has a significant role in awareness as compared to government extension departments. Due to an increasing trend of temperature the winter season reduced resulting in decrease in crop yield and increase in pest and disease spread. In the light of prevailing awareness, the farmers are using various cultural practices such as using compost, crop rotation, new varieties etc. However, in spite of these strategies, it recommended public policy and government interventions to strengthen the farmer's awareness campaigns about climate change mitigation measures to enhance the resilience to climate change. The knowledge and regional impact may be thoroughly investigated and incorporated into the agriculture planning and policy. Therefore keeping into account the adverse impact of climate change on horticultural crops, a long term mitigation strategy should be designed.

Acknowledgements

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Novelty Statement

In the view of challenges to food security under the changing climatic conditions, the mitigation measures on the basis of farmers experience in the local context will play a major role in policy designing for climate resilient strategies.

Author's Contribution

Muhammad Zamin: Contributed in data processing and interpretation of results and organized over all manuscript development.

Fazli Rabbi: Helped in analysis and discussion of results.

Hamayoon Khan: Assisted in review of literature.

Muhammad Zahid: Helped in site data collection.

Raheel Saqib: Helped in proofreading and format setting.

Shafiullah: Helped in discussion of results.

Muhammad Shakur: Helped in manuscript review.

Conflict of interest

The authors have declared no conflict of interest.

References

- Adger, W.N., N.W. Arnell and E.L. Tompkins. 2005. Adapting to climate change: Perspectives across scales. *Glob. Environ. Change*, 15(2): 75-76. <https://doi.org/10.1016/j.gloenvcha.2005.03.001>
- Amadou, M.L., G.B. Villamor, E.M. Attua and S.B. Traoré. 2015. Comparing farmers perception of climate change and variability with historical climate data in the Upper East Region of Ghana. *Ghana J. Geogr.*, 7(1): 47-74.
- Amjath-Babu, T.S., T.J. Krupnik, S. Aravindakshan, M. Arshad and H. Kaechele. 2016. Climate change and indicators of probable shifts in the consumption portfolios of dryland farmers in Sub-Saharan Africa: Implications for policy. *Ecol. Indic.*, 67: 830-838. <https://doi.org/10.1016/j.ecolind.2016.03.030>
- Arnbjerg-Nielsen, K., P. Willems, J. Olsson, S.

- Beecham, A. Pathirana, I. Bülow Gregersen and V.T.V. Nguyen. 2013. Impacts of climate change on rainfall extremes and urban drainage systems: A review. *Water Sci. Technol.*, 68(1): 16. <https://doi.org/10.2166/wst.2013.251>
- Arshad, M., T.S. Amjath-Babu, T.J. Krupnik, S. Aravindakshan, A. Abbas, H. Kächele and K. Müller. 2017. Climate variability and yield risk in South Asia's rice-wheat systems: emerging evidence from Pakistan. *Paddy Water Environ.*, 15(2): 249-261. <https://doi.org/10.1007/s10333-016-0544-0>
- Ashfaq, M., F. Zulfiqar, I. Sarwar, M.A. Quddus and I.A. Baig. 2011. Impact of climate change on wheat productivity in mixed cropping system of Punjab. *Soil Environ.*, 30(2).
- Ashraf, U., H. Ali, M.N. Chaudry, I. Ashraf, A. Batool and Z. Saqib. 2016. Predicting the potential distribution of *Olea ferruginea* in Pakistan incorporating climate change by using Maxent model. *Sustainability*, 8(8): 722. <https://doi.org/10.3390/su8080722>
- Ayanlade, A., M. Radeny and J.F. Morton. 2017. Comparing smallholder farmers perception of climate change with meteorological data: A case study from southwestern Nigeria. *Weather Clim. Extrem.*, 15: 24-33. <https://doi.org/10.1016/j.wace.2016.12.001>
- Babar, S., N. Rehman and A. Amin. 2014. Climate change Impact on Rabi and kharif crops of Khyber-Pakhtunkhwa. *PUTA J. Hum. Soc. Sci.*, 21(1).
- Bacha, M.S., M. Muhammad, Z. Kılıç and M. Nafees. 2021. The dynamics of public perceptions and climate change in Swat Valley, Khyber Pakhtunkhwa, Pakistan. *Sustainability*, 13(8): 446. <https://doi.org/10.3390/su13084464>
- Bord, R.J., R.E. O'Connor and A. Fisher. 2000. In what sense does the public need to understand global climate change? *Publ. Understand. Sci.*, 9(3): 205. <https://doi.org/10.1088/0963-6625/9/3/301>
- Challinor, A.J., J. Watson, D.B. Lobell, S.M. Howden, D.R. Smith and N. Chhetri. 2014. A meta-analysis of crop yield under climate change and adaptation. *Nat. Clim. Change*, 4(4): 287-291. <https://doi.org/10.1038/nclimate2153>
- Chmielewski, F.M., 1992. Impact of climate changes on crop yields of winter rye in Halle (southeastern Germany), 1901 to 1980. *Clim. Res.*, 2(1): 23-33. <https://doi.org/10.3354/cr002023>
- Dash, S.K., R.K. Jenamani, S.R. Kalsi and S.K. Panda. 2007. Some evidence of climate change in twentieth-century India. *Clim. Change*, 85(3): 299-321. <https://doi.org/10.1007/s10584-007-9305-9>
- Datta, S., 2013. Impact of climate change in Indian horticulture. A review. *Int. J. Environ. Sci. Technol.*, 2(4): 661-671.
- Dawn, 2009. Climate change cost Pakistan \$ 3.57 billion in 18years. February, 05, 2009. www.dawn.com/wps/wcm/connect/dawn-content.
- Dawn. 2010. Pakistan most vulnerable to climate change. Daily dawn. February, 05, 2010. www.dawn.com/wps/wcm/connect/dawn-content
- Denton, F., 2001. Climate change impacts: Can Africa cope with the challenges? *Clim. Policy*, 1: 117-123. <https://doi.org/10.3763/cpol.2001.0110>
- Fahad, S., S. Hussain, S. Saud, S. Hassan, B.S. Chauhan, F. Khan (*et al.* Please give all names). 2016a. Responses of rapid viscoanalyzer profile and other rice grain qualities to exogenously applied plant growth regulators under high day and high night temperatures PLoS One, 11(7): e0159590. <https://doi.org/10.1371/journal.pone.0159590>
- Fahad, S. and J. Wang. 2018. Farmers risk perception, vulnerability, and adaptation to climate change in rural Pakistan. *Land Use Policy*, 79: 301-309. <https://doi.org/10.1016/j.landusepol.2018.08.018>
- Fahad, S. and J. Wang. 2020. Climate change, vulnerability, and its impacts in rural Pakistan: A review. *Environ. Sci. Pollut. Res.*, 27(2): 1334-1338. <https://doi.org/10.1007/s11356-019-06878-1>
- Fahad, S., T. Inayat, J. Wang, L. Dong, G. Hu, S. Khan and A. Khan. 2020. Farmers' awareness level and their perceptions of climate change: A case of Khyber Pakhtunkhwa province, Pakistan. *Land Use Policy*, 96: 104669. <https://doi.org/10.1016/j.landusepol.2020.104669>
- Farhan, I.A. and J. Al-Bakri. 2019. Detection of a real time remote sensing indices and soil moisture for drought monitoring and assessment in Jordan. *Open J. Geol.*, 9(13): 1048-1068. <https://doi.org/10.4236/ojg.2019.913105>

- Furuya, J., S. Kobayashi and S.D. Meyer. 2009. Impacts of global warming on the world food market according to SRES scenarios. *World Acad. Sci. Eng. Technol.*, 57: 24-29.
- Giannakopoulos, C., M. Bindi, M. Moriondo, P. Lesager and T. Tin. 2005. Climate change impacts in the Mediterranean resulting from a 2 C global temperature rise.
- Guhathakurta, P., O.P. Sreejith and P.A. Menon. 2011. Impact of climate change on extreme rainfall events and flood risk in India. *J. Earth Syst. Sci.*, 120(3): 359. <https://doi.org/10.1007/s12040-011-0082-5>
- Habib, N. and M. Zamin. 2003. Off-season pea cultivation in Dir Kohistan valley. *Asian J. Plant Sci.*, 2(3): 283-285. <https://doi.org/10.3923/ajps.2003.283.285>
- Howden, S., J. Soussana, F. Tubiello, N. Chhetri, M. Dunlop and H. Meinke. 2007. Adapting agriculture to climate change. *Proc. Natl. Acad. Sci. U.S.A.*, 104: 19691– 19696. <https://doi.org/10.1073/pnas.0701890104>
- Hyland, J.J., D.L. Jones, K.A. Parkhill, A.P. Barnes and A.P. Williams. 2016. Farmers' perceptions of climate change: Identifying types. *Agric. Hum. Values*, 33: 323-339. <https://doi.org/10.1007/s10460-015-9608-9>
- Imran, A., 2018. Global impact of climate change on water, soil resources and threat towards food security: Evidence from Pakistan. *Adv. Plants Agric. Res.*, 8(5): 350-355. <https://doi.org/10.15406/apar.2018.08.00349>
- IPCC, 2001. Climate change: Impacts, adaptation, and vulnerability: Contribution of working group II to the third assessment report of the intergovernmental panel on environment. *Clim. Res.*, 1: 63–79.
- Ishaya, S. and I.B. Abaje. 2008. Indigenous people's perception on climate change and adaptation strategies in Jema'a local government area of Kaduna state, Nigeria. *J. Geog. Reg. Plan.*, 1: 138-143.
- Kikar, G.A., 2000. Synthesis report for the vulnerability and adaptation assessment section: South African country study on climate change. In: *Proceedings of the Presentation at the Workshop on Measuring the Impacts of Climate Change on Indian and Brazilian Agriculture*. World Bank, Washington DC, 5–7 May.
- Kreft, S. and D. Eckstein. 2013. Global climate risk index 2014—who suffers most from extreme weather events? Weather-related loss events in 2012 and 1993 to 2012.
- Liu, S., X. Mo, Z. Lin, Y. Xu, J. Ji, G. Wen and J. Richey. 2010. Crop yield responses to climate change in Huang-Huai-Hai Plain of China. *Agric. Water Manage.*, 97(8): 1195-1209. <https://doi.org/10.1016/j.agwat.2010.03.001>
- Lobell, D.B. and M.B. Burke. 2010. On the use of statistical models to predict crop yield responses to climate change. *Agric. For. Meteorol.*, 150(2): 1443-1452. <https://doi.org/10.1016/j.agrformet.2010.07.008>
- Lorenzoni, I., S. Nicholson-Cole and L. Whitmarsh. 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. *Glob. Environ. Change*, 17(3–4): 445–459. <https://doi.org/10.1016/j.gloenvcha.2007.01.004>
- Lu, E., W. Higgins, K. Morton and M. Halpert. 2011. A method for identifying the events that can best become extremes. Paper presented at the NOAA Climate diagnostics and prediction, Camp Springs, USA. (<http://www.nws.noaa.gov/ost/climate/STIP/index.htm>)
- Mo, X., S.L. Zhonghui and L.R. Guo. 2009. Regional crop yield, water consumption and water use efficiency and their responses to climate change in north China Plain. *Agric. Ecosyst. Environ.*, 134(1-2): 67-78. <https://doi.org/10.1016/j.agee.2009.05.017>
- Mortimore, M.J. and W.M. Adams. 2001. Farmer adaptation, change and crisis in the Sahel. *Glob. Environ. Change*, 11(1): 49-57. [https://doi.org/10.1016/S0959-3780\(00\)00044-3](https://doi.org/10.1016/S0959-3780(00)00044-3)
- Nasir, M.J., A.S. Khan and S. Alam. 2018. Climate change and agriculture: An overview of farmers perception and adaptations in Balambat Tehsil, District Dir Lower, Pakistan. *Sarhad J. Agric.*, 34(1): 85-92. <https://doi.org/10.17582/journal.sja/2018/34.1.85.92>
- O'Connor, R.E., R.J. Bord, B. Yarnal and N. Wiefek. 2002. Who wants to reduce greenhouse gas emissions? *Soc. Sci. Q.*, 83(1): 1–17. <https://doi.org/10.1111/1540-6237.00067>
- Pakistan Poverty Alleviation Fund, (PPAF), 2015. Situation analysis and baseline surveys for poverty reduction through rural development in KPK, FATA and Balochistan. Development of lower Dir District: pp. 7-8.
- Pakistan Poverty Alleviation Fund, 2014. Situation

- analysis and baseline surveys for poverty reduction through rural development in KPK, FATA and Balochistan. Development of Upper Dir District: 6-8.
- Parry, M., C. Rosenzweig, A. Iglesias, G. Fischer and M. Livermore. 1999. Climate change and world food security: A new assessment. Glob. Environ. Change, pp. S51-S67. [https://doi.org/10.1016/S0959-3780\(99\)00018-7](https://doi.org/10.1016/S0959-3780(99)00018-7)
- Prokopy, L., K. Floress, D. Klotthor-Weinkauff and A. BaumgartGetz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. J. Soil Water Conserv., 63(5): 300-311. <https://doi.org/10.2489/63.5.300>
- Rehman, M.U., G.H. Rather, Y. Gull, M.R. Mir, M.M. Mir, U.I. Waida and K.R. Hakeem. 2015. Effect of climate change on horticultural crops. In: Crop production and global environmental issues (eds Hakeem K). Springer, Cham. https://doi.org/10.1007/978-3-319-23162-4_9
- Semenza, J.C., D.E. Hall, D.J. Wilson, B.D. Bontempo, D.J. Sailor and L.A. George. 2008. Public perception of climate change: Voluntary mitigation and barriers to behavior change. Am. J. Prev. Med., 35(5): 479-487. <https://doi.org/10.1016/j.amepre.2008.08.020>
- Sen, V., R.S. Rana and R.C. Chauhan. 2015. Impact of climate variability on apple production and diversity in Kullu valley, Himachal Pradesh. Indian J. Hortic., 72(1): 14-20. <https://doi.org/10.5958/0974-0112.2015.00003.1>
- Shah, T., F. Rabbi, U. Hayat, I. Ullah, S.B. Khan and F. Shah. 2019. Assessing the awareness level of farming community regarding climate change: A survey of districts Malakand and Swat of Khyber Pakhtunkhwa province, Pakistan. Fresenius Environ. Bull., 28(12 a): 9877-9885.
- Shakoor, U., A. Saboor, I. Ali and A.Q. Mohsin. 2011. Impact of climate change on agriculture: Empirical evidence from arid region. Pak. J. Agric. Sci., 48: 327-333.
- Snyder, R.L., 2017. Climate change impacts on water use in horticulture. Horticulturae, 3(2): 27. <https://doi.org/10.3390/horticulturae3020027>
- Ullah, H., A. Rashid, G. Liu and M. Hussain. 2018. Perceptions of mountainous people on climate change, livelihood practices and climatic shocks: A case study of Swat District, Pakistan. Urban Clim., 26: 244-257. <https://doi.org/10.1016/j.uclim.2018.10.003>
- Ullah, S., T.M. Khan, U. Khan, K. Rahman, N. Ullah and T. Ahmad. 2015. The perception of local community about climate change and its impacts on their lives at tehsil Timergara, district Dir (lower), Khyber Pakhtunkhwa, Pakistan. Asian. J. Agric. Biol., 3(1): 15-22.
- Usman, M.T. and C.J.C. Reason. 2004. Dry spell frequencies and their variability over southern Africa. Clim. Res., 26(3): 199-211. <https://doi.org/10.3354/cr026199>
- Vedwan, N. and R.E. Rhoades. 2001. Climate change in western Himalayas of India. A study of local perception and response. Clim. Res., 19: 109-117. <https://doi.org/10.3354/cr019109>
- Vogel, C., 2005. Seven fat years and seven lean years? Climate change and agriculture in Africa. <https://doi.org/10.1111/j.1759-5436.2005.tb00192.x>
- Yinhong, K.Y., S. Khan and X. Ma. 2009. Climate change impacts on crop yield, crop water productivity and food security. A review. Prog. Nat. Sci., 19: 1665-1674. <https://doi.org/10.1016/j.pnsc.2009.08.001>
- Zahid, M. and G.G. Rasul. 2010. Rise in summer heat index in Pakistan. Pak. J. Meteorol., 6(12): 85-95.
- Zamin, M., A.M. Khattak, A.M. Salim, K.B. Marcum, M. Shakur, S. Shah, I. Jan and S. Fahad. 2019a. Performance of *Aeluropus lagopoides* (mangrove grass) ecotypes, a potential turfgrass, under high saline conditions. Environ. Sci. Pollut., 26(13): 13410-13421. <https://doi.org/10.1007/s11356-019-04838-3>
- Zamin, M., S. Fahad, A.M. Khattak, M. Adnan, F. Wahid, A. Raza, D. Wang, S. Saud, M. Noor, H.F. Bakhat and M. Mubeen. 2019b. Developing the first halophytic turfgrasses for the urban landscape from native Arabian desert grass. Environ. Sci. Pollut. Res., 26(279): 1-15.