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RESEARCH ARTICLE

Climate Risks, Farmers Perception and Adaptation Strategies to Climate Variability in Afghanistan

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ABSTRACT

This study examined the farmers' perception, adaptation measures and coping strategies to mitigate climate extremes in Afghanistan using parametric and non-parametric methods. We selected the central agro-climatic zone to conduct farm household's survey since it has significant climate variability in terms of maximum, minimum temperature and rainfall. Results show that majority of the farmers (>80%) perceived a "high to a very high" degree of climate induced impact on loss of employment, labor scarcity, pest and disease outbreak and decline in groundwater level. The important climate adaptation and coping strategies viz., changing cropping patterns, drilling new bore wells and farm diversification were extensively practiced by the farmers. In the policy side, establishing automatic weather stations, agro advisory services, weather-based crop insurance and climate-smart agricultural practices are the potential policy options to protect farm households from climate extremes.

Keywords: Climate change; farmers' perception; socio-economic and environmental impacts; adaptation strategies; Afghanistan

INTRODUCTION

Global climate change is a change in the long-term weather patterns of the regions (Mahato, 2014), and this will have significant consequences on food production and food security (Hasan et al. 2018; Srinivasa Rao et al. 2019; Beuchelt and Badstue, 2013). People across the world have to face the reality of climate variability; disasters will occur if no action has been taken towards limiting global warming to 2°C (Omerkhil et al. 2020). Previous studies have also pointed out that changing climate will increase the incidences of extreme weather events such as droughts, floods, late rains, decreasing annual precipitation and increasing temperatures in forthcoming years (Armah et al. 2010; Leary et al. 2013), which culminates significant adverse impact on agriculture production, farm income and farmers' livelihoods (Srinivasa Rao et al. 2019; Manivasagam and Nagarajan, 2018; Ndamani and Watanabe, 2017; Dong et al. 2015).

Significant changes in Afghanistan's climate have been observed since the 1950s (Aich and Khoshbeen, 2016) and reported a 1.8 degrees Celsius increase in the annual mean temperature, decline in annual mean precipitation with frequent occurrence of extreme weather events since 1950s (Aich et al. 2017). Another study by McSweeney et al. (2010) found that the average annual temperature has increased by 0.6 degrees Celsius, while mean rainfall has decreased slightly since 1960. Projections suggest that the mean temperature would increase by 2 to 6 degrees Celsius, and precipitation would decrease by 10 to 40 mm during spring months by 2100 (Jawid and Khadjavi, 2019). Mukhopadhyay and Khan (2014) have also projected warming of 2 degrees Celsius and an 8 to 10 percent increase of precipitation for the Upper Indus Basin, including its Hindukush part, until 2050. Future projections indicate that there will be a persistent increase in temperature and disruptions in rainfall in future, which would eventually affect the agriculture in Afghanistan (Jawid and Khadjavi, 2019; Donatti et al. 2019; Chapman et al. 2018; ADB, 2016).

Afghanistan exhibits arid and semi-arid continental climate characteristics located in the arid sub-tropics at 37° North

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of the equator (Sarwary et al. 2020; Matthew et al. 2009). Afghanistan is traditionally an agrarian country (Jawid and Khadjavi, 2019), contributing around 22 percent to the country GDP. However, agriculture remains an important sector as a source of livelihood. It is estimated that at least 70 percent of the population is continued to engage in farming ((Baizayee et al 2013);World Bank and GFDRR, 2018). Agriculture will remain important for Afghanistan's growth and development (Pain & Shah, 2009), which is also the most vulnerable sector to climate change (Aich et al. 2017). The country is characterized by large areas with less precipitation, and it had experienced a prolong drought in recent years (Matthew et al. 2009). Farmers in Afghanistan are relatively more affected by the impacts of weather extremities and limited resources for adaptation, which leads to the high vulnerability of crop yields and farmers livelihood (Jawid and Khadjavi, 2019). The major agricultural adaptations include the use of different crop varieties, early and late planting, improved irrigation, soil and water conservation (Harmer and Rahman, 2014; Etwire et al. 2013; Bryanet et al. 2009), adjustment of agronomic practices and capital investments in response to expected climate change impacts (Easterling et al. 2004). Studies reported that agricultural adaptation helps farmers in minimizing climate change (Jawid and Khadjavi, 2019; Khanal et al. 2018; Ndamani and Watanabe, 2017; Huang et al. 2015; Falco et al. 2014; Finger et al. 2012). However, adoption to climate change adaptation practices was very low among the farmers (Aich et al. 2017). Further, studies related to climate change to identify the vulnerable regions, its adaptation and coping strategies in Afghanistan are limited. Hence, the present study aims to study the farmer's perception pertaining to climate change in the highly vulnerable agro-climatic zone of Afghanistan. Further, we analyzed various adaptation measures and coping strategies under the changing climate scenario in the vulnerable zone.

MATERIAL AND METHODS

Study area

The central agro-climatic zone (CACZ) of Afghanistan was selected, which is one among the seven agro-climatic zones of the country, located between 32°4' - 35°53'N and 66°16' - 70°17'E (Fig. 1a). We use parametric linear trend analyses and non-parametric Mann Kendall's test to identify the most vulnerable agro-climatic zone (i.e. central ACZ) with respect to the climatic variables viz., rainfall, minimum and maximum temperature. The results showed that the central agro-climatic zone is the most vulnerable zone in terms of climate variability and hence we selected this zone. The central agro-climatic zone is a mountainous area that accounts for 10 percent of the geographical area of Afghanistan and 24.6 percent of its population. It consists of seven provinces viz., Kabul, Bamyan, Kapisa, Parwan, Panjshir, Wardak, and Ghazni (Fig. 1b) (Reddy et al. 2017). There are two main agricultural seasons in the central agro-climatic zone, i.e., summer (May to November) and winter (October to June). The major crops cultivated during summer are rice and corn, and during winter, wheat and barley crops are extensively grown in this zone (Qutbudin et al. 2019).

Data and sampling

We collected the secondary data on climate variables viz., rainfall, maximum temperature, and minimum temperature from the Afghanistan Meteorological Department (AMD). We also collect farm households' data through well-structured and pre-tested questionnaire during the cropping seasons in the year 2020. The questionnaire was designed to collect the information on farmers' awareness of climate change impacts and their adaptation strategies. Fifteen farmers were randomly selected from each of the seven provinces of the central agro-climatic zone, hence that the total sample size of the study was 105 respondents. Each respondent was interviewed in person, and the rate of response was almost 100 percent during the farm households' survey.

Linear regression (Parametric test)

Linear regression of Y on time (t) is a test for linear trend of included variables. The null hypothesis is that the slope coefficient $\beta_1 = 0$ and it makes stronger assumptions about the distribution of Y over time. If the slope is nonzero, the null hypothesis of zero slope over time is rejected, which concludes that there is a linear trend in Y over time (Helsel and Hirsch, 1992).

$$Y_{it} = \beta_0 + \beta_{1t} + \varepsilon_{it} \quad (1)$$

Y_{it} = Rainfall, maximum and minimum temperature for the agro-climatic zone i and at time t

β_0 and β_{1t} = Vector of regression coefficients to be estimated

t = Time variable

ε_{it} = Error term.

Mann Kendall test (Non-parametric)

Mann (1945) first used the test for significance of Kendall's tau where the X variable is time as a test for trend. The Mann-Kendall test can be stated most generally as a test for whether Y values tend to increase or decrease with T (Helsel and Hirsch, 1992). It is used in meteorological data such as rainfall and temperature. This test is used because no assumptions are needed about the data that need to be tested. The null hypothesis H_0 is that there is no trend in the population from which the dataset $\{T_j$, j equal to 1, 2… n$\}$ is independent and identically distributed. The alternative hypothesis H_1 is that a trend exists in the dataset.

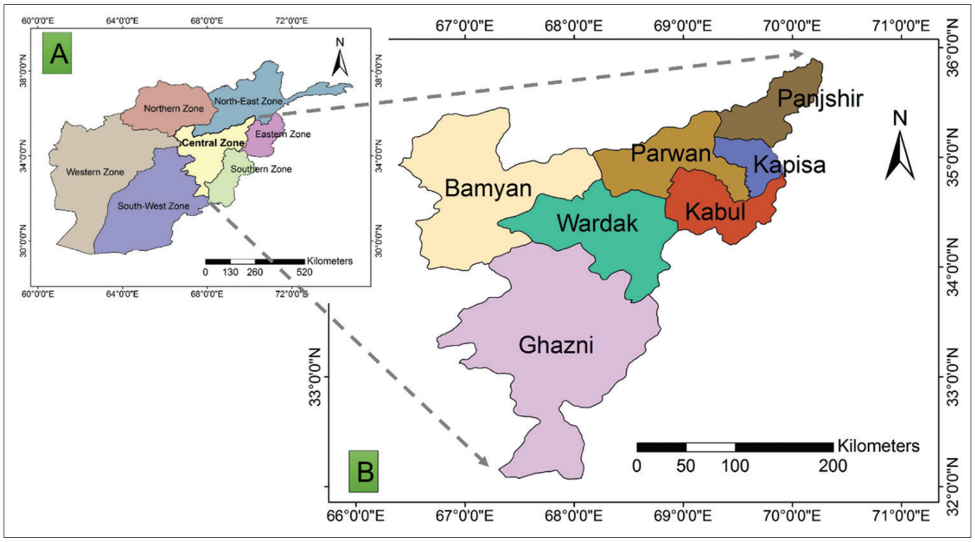

Fig 1. (a) Agro-climatic zones of Afghanistan and (b) Selected study area of Central agro-climatic zone along with provinces.

The Mann Kendall trend test, S statistic is calculated by using the below equation:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sign\left(T_j - T_i\right) \tag{2}$$

Where T_j and T_i are the sequential data value and j >i, n is the length of the data set.

$$sign\left(T_j - T_i\right) = \begin{cases} +1 \; if \; T_j - T_i > 0 \\ 0 \; if \; T_j - T_i = 0 \\ -1 \; if \; T_j - T_i < 0 \end{cases} \tag{3}$$

Variance (σ^2) for the S- statistic is determined by:

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum t_i\,(i)\,(i-1)\,(2i+5)}{18} \tag{4}$$

In which t_i denotes the number of ties to extent i., the summation term in the numerator is used only if the data series contains tied values. The standard test statistic Z_s as follows:

$$Z_s = \begin{cases} \dfrac{S-1}{\sigma} \; for \; S > 0 \\ 0 \quad for \;\; S = 0 \\ \dfrac{S+1}{\sigma} \; for \; S < 0 \end{cases} \tag{5}$$

The positive Z value indicates an increasing trend and the negative Z value indicates a decreasing trend. When testing two-sided trends at a selected level of significance, the null hypothesis of no trend is rejected if the absolute value of Z is greater than Zα/2 (Rehana et al. 2019; Bhuyan et al. 2018; Sulaiman et al. 2015 and Fiaz et al. 2015).

The test statistic Z's is used as a measure of the significance of the trend. In fact, this test statistic is used to test the null hypothesis, H_0. If $|Z|$ is greater than Zα/2, where α represents the chosen significance level (e.g., 5% with $Z_{0.025} = 1.96$), then the null hypothesis is invalid, implying that the trend is significant (Najma and Samuel, 2015; Vijayasarathy and Ashok, 2015; Motiee and McBean, 2009).

Garrett ranking technique

The questionnaire was designed to identify the perception about climate change impacts and adaptation strategies followed by farmers through conducting the primary survey. The Garrett's ranking technique was used to prioritize the farmers' responses, and it has followed as,

$$Percent \;\; position = \frac{100(R_{ij} - 0.5)}{N_j} \tag{6}$$

Where,

R_{ij} = Rank given for i^{th} factor by j^{th} individual

N_j = number of factors ranked by j^{th} individual

Garrett's score table was used to convert the percent positions of each rank into scores (Garrett and Woodworth 1969). Subsequently, for each factor, each respondent's score was added together and was divided by the total number of respondents for whom scores were added. The mean scores of all the factors arrived, and ranks will be given. The factors having the highest mean value were considered to be the most important response (Dhanavandan, 2016; Vijayasarathy and Ashok, 2015).

RESULTS AND DISCUSSION

We use both linear and Mann Kendall's trend analysis to identify the highly vulnerable agro-climatic zone of

Afghanistan with respect to climate variability. The results of trend in climate variability are presented in Table 1 and Table 2, respectively.

Linear trend analysis

The estimates of the trend in maximum temperature (°C), minimum temperature (°C) and rainfall (mm) of different agro-climatic zones are shown in Table 1. It could be seen that among the seven agro-climatic zones of Afghanistan, the maximum temperature shows increasing trend and statistically significant (P<0.01) for the central agro-climatic zone and the southern agro-climatic zone. No significant trend in maximum temperature was observed in other zones. The minimum temperature shows increasing and significant (P<0.01) for both the central agro-climatic zone and eastern agro-climatic zone but no significant trend was observed for the rest of the zones. Similarly, increasing trend in rainfall (P<0.01) was found in central agro-climatic zone and the eastern agro-climatic zone; whereas, it was negative for western agro-climatic zone. The rest of the agro-climatic zones did not show any trend in the case of rainfall. The results show that the central agro-climatic zone was highly vulnerable to changing climate which is in conformity with the results of Fiaz et al. (2015).

Mann Kendall's trend analysis

The results of the Mann-Kendall test on maximum, minimum temperature, and rainfall are presented in Table 2. From the results, it is evident that there is a positive and significant (P<0.01) trend in maximum temperature in the central agro-climatic zone and the southern agro-climatic zones. In case of minimum temperature, it shows increasing and significant (P<0.05) trend in the central agro-climatic zone (P<0.1) and the eastern agro-climatic zone, and it was similar to the results obtained from parametric method.

Table 1: Estimated linear trend for maximum, minimum temperature and precipitation

Agro Climatic Zones	Coefficients		
	Maximum Temperature	Minimum Temperature	Precipitation
Central Agro Climatic Zone	0.12*** (3.61)	0.09* (1.96)	11.29* (2.01)
Eastern Agro Climatic Zone	0.05 (1.30)	0.09** (2.69)	9.56** (2.39)
Northern Agro Climatic Zone	-0.04 (0.69)	-0.04 (-1.17)	5.49 (1.48)
North East Agro Climatic Zone	0.09 (1.28)	-0.06 (-1.40)	1.57 (0.22)
Southern Agro Climatic Zone	0.19*** (3.20)	0.03 (0.43)	-7.12 (-1.49)
South West Agro Climatic Zone	0.02 (0.34)	0.03 (1.22)	-0.16 (-0.05)
Western Agro Climatic Zone	-0.004 (-0.11)	-0.002 (-0.07)	-10.71* (-2.07)

Figures in parenthesis indicate t value. ***, ** and * Significant at 1 percent, 5 percent, and 10 percent level, respectively.

Rainfall has also increasing trend, which is statistically significant (P<0.1) in both the central agro-climatic zone and the eastern agro-climatic zone.

It is evident from the linear and the Mann-Kendall trend analysis that the central agro-climatic zone had significant climate variability in terms of maximum temperature, minimum temperature, and rainfall, which indicates that the central agro-climatic zone is highly vulnerable zone to climate change.

Climatic features of the central agro-climatic zone

The observed monthly total precipitation, mean monthly maximum and mean monthly minimum temperature of the central agro-climatic zone for the period between 2005 and 2018 are depicted in (Fig. 2). It could be seen that most of the annual rainfall of this region was received during the winter and spring season alone from November to May. Further, it was observed that from June to October, the monthly rainfall has flattened to less than 10 mm, which coincided with a higher temperature. Further, the temperature was relatively high during June to October; subsequently, the peak mean monthly maximum and mean monthly minimum temperature

Table 2: Mann Kendall's test for maximum, minimum temperature and precipitation

Particular	Kendall's tau	P-value
Central Agro Climatic Zone		
Max Tem °C	2.08**	0.04
Min Tem °C	1.97**	0.05
RF (mm)	2.08**	0.04
Eastern Agro Climatic Zone		
Max Tem °C	0.99	0.32
Min Tem °C	2.30**	0.02
RF (mm)	2.19**	0.03
Northern Agro Climatic Zone		
Max Tem °C	-0.22	0.83
Min Tem °C	-1.64	0.10
RF (mm)	1.09	0.27
North East Agro Climatic Zone		
Max Tem °C	1.53	0.13
Min Tem °C	-0.99	0.32
RF (mm)	0.33	0.74
Southern Agro Climatic Zone		
Max Tem °C	2.30**	0.02
Min Tem °C	0.66	0.51
RF (mm)	-1.86	0.06
South West Agro Climatic Zone		
Max Tem °C	0.99	0.32
Min Tem °C	1.20	0.23
RF (mm)	0.55	0.58
Western Agro Climatic Zone		
Max Tem °C	-0.22	0.83
Min Tem °C	0.22	0.83
RF (mm)	-1.64	0.10

**indicates significant at 5 per cent level was recorded during this period, which was 29.58°C and 15.11°C respectively. The mean monthly maximum temperature of the central-agro climatic zone was ranged between 4.34°C and 29.58°C, whereas the mean monthly minimum temperature was ranged between -8.66°C and 15.11°C. These results would clearly state that as per the climate classification of the Köppen-Geiger system, the central agro-climatic zone of Afghanistan broadly represents mid-latitude steppe, desert and Mediterranean climate (Reddy et al. 2017).

Inter-annual variations in rainfall and yield of major crops

The year-to-year variations in rainfall and the yield of the major crops of the central agro-climatic zone are presented in Fig. 3. The major peaks and troughs between observed rainfall and the yield of major crops have a correspondence with the few years. However, the relationship is not perfectly coincided with all the years. Nevertheless, the relationship is a better fit for the maize and barley compared to rice and wheat yield. A continuous rainfall deficiency of more than 15 percent observed from 2005 to 2008, had a significant impact on cereals production, and the yield reduction was reached its maximum (19.50 percent yield reduction in rice) during 2007.

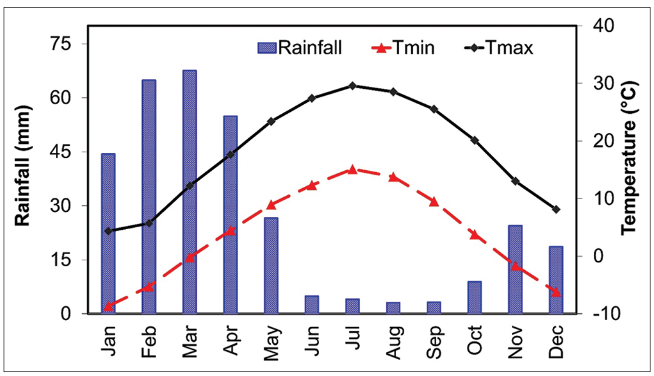

Fig 2. Observed monthly precipitation, maximum and minimum temperature in CACZ for the period of 2005-2018.

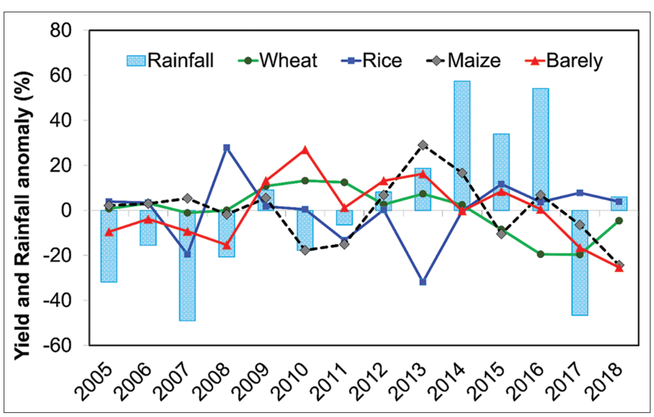

Fig 3. The year-to-year variations in observed rainfall and yield of major crops in CACZ.

Socio-economic profile of the sample farmers

The socio-economic characteristics of the sample respondents are presented in Table 3. Majority of the respondents were in the middle age group, with an average age of 43 years and 26 years of farming experience. Regarding educational status, most of the respondents were illiterates (52.38 %) followed by secondary education (23.81 %) and graduates (16.19 %). The average annual household income from different sources was about 2968 USD (1 USD = 77.10 Afghani currency as on February 20, 2020). Their primary sources of income were crop farming (41 percent) followed by livestock farming (33 percent) and small business (13 percent). These results clearly state that the socio-economic characters of the sample respondents would favor their better adaptability to climate change due to respondents' literacy level and vast experience in farming, which is similar to the results of Iqbal et al. 2018.

Farmers' perception on climate change

The farmers were interviewed in their local languages (Pashto and Dari), a number of response options were given to farmers as open-ended questions, and their perceptions towards the climate change impacts are presented in (Fig. 4). The major impacts of climate change are drying of water sources (80 %) followed by famine (71 %), crop failure (67 %), increase in food price (38 %), poor health of human leads to malnutrition (37 %) and poor health of livestock (18 %). Besides these impacts, loss of livestock and decline in livestock prices due to drought were also perceived by the farmers.

Socio-economic and environmental impact of climate change

A number of Likert-type responses were asked to the respondents that are associated with the socio-economic impacts of climate change, and their responses in terms of percentage are presented in (Fig. 5). The results revealed that more than 80 % of the respondents were perceived the level of "high to very high impact" on loss of employment, labor scarcity, reduction on household income, pest and disease outbreak, and poor germination of crops as the result of climate change. Further, it was found that around 73% of sample respondents were reported a "high to a very high" level of reduction in their expenses on festival celebrations, which retrograde their social life. Regarding food security issues, more than 70 % of respondents were reported a "high to a very high" level of impact on their choices for food preferences in their daily consumption.

Studies in the past have reported that the implications of climate change on the ecosystem as a whole specifically dealt with the environmental impacts such as water quality, soil fertility, biodiversity, and wildlife (Massarutto et al.2013; Turok, 2012; Singh, 2015; Iqbal et al. 2018). In this connection, questions with respect to climate change impacts on environmental variables were placed in front of the respondents, and their perceptions are presented in (Fig. 6). More than 75 % of respondents reported "high to very high" levels of impact on groundwater depletion, forest degradation, and pasture degradation. Further, it was observed that about 64 % of the respondents reported "high to very high" levels of impact on rainfall and about 56 % reported high to a very high" level of impact on surface water bodies. Interestingly, only 20 % of the respondents reported a "high to a very high" level of impact on temperature as a result of climate change. Thus, most of the sample respondents have strong perception on climate change affects the farming environment.

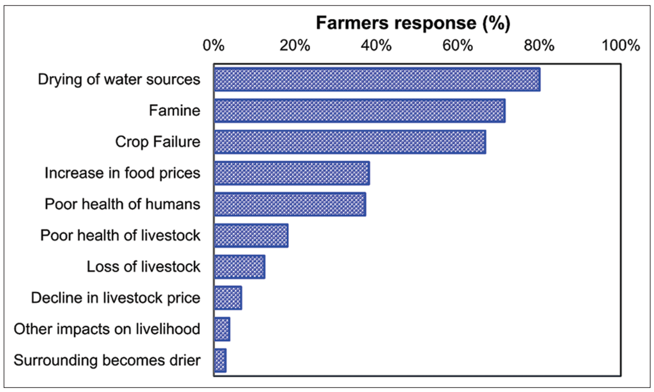

Fig 4. Farmers' perception on impacts of climate change in CACZ of Afghanistan.

Table 3: Socio-economic characteristics of the respondent households (n=105)

Category	Respondents (%)	Mean	Standard Deviation
Age (years)			
Young (18-40)	42.86	43	12.19
Middle (41-60)	54.29		
Old (above 60)	2.86		
Education (year of schooling)			
Illiterate	52.38	5.79	6.49
Primary school (1-9)	7.62		
Secondary school (10-12)	23.81		
Higher education (13-16)	16.19		
Farming Experience (years)			
Low (Up to 10)	18.10	26.38	12.88
Medium (11-25)	31.43		
High (above 25)	50.48		
Landholding size (ha)			
Small (up to 1)	56.19	1.41	1.50
Marginal (1.1-2.00)	28.57		
Medium (2.1-5.00)	13.33		
Large (above 5)	1.90		
Annual Income (USD $)(1 USD=77.10 Afghani as on February 20, 2020)			
Up to 1297	27.62	2968	3127.10
1298-2594	39.05		
2595-3891	16.19		
3892-5188	6.67		
Above 5189	10.48		

Climate change adaptation and coping strategies

The impact of climate change has been reduced through adoption strategies such as sustainable agricultural practices, protecting water sources (Matthew et al. 2009), increasing water use efficiency (Kuppannan et al. 2017), weather prediction, crop-based advisories (Reddy et al. 2017) and developing crop cultivars capable of maintaining the yield under extreme climate conditions (Senthilnathan et al. 2018). The sample respondents were asked to specify their perception of coping strategies to mitigate the adverse impacts of climate change. Their perceptions were converted into scores and ranked using the Garret ranking technique, and the results are shown in (Table 4). It could be seen that among the nine major coping strategies, changing cropping pattern was ranked first (mean score 64.50), which is considered as the best coping strategy to minimize climate change impacts. Drilling new bore wells is considered as the second-best coping strategy (mean score of 54.60) to mitigate climate change impacts. Further, farm diversification (Palanisami et al. 2009) was ranked as third followed by reduction in the number of irrigation (4^{th} rank) and adoption of water-saving technologies (5^{th} rank) were the important copping strategies followed by the farmers. Interestingly water conservation technologies such as farm ponds, contour bunds and mulching were ranked as seventh position, though it is one of the most important coping strategies to mitigate climate change impacts and this may be due to lack of knowledge in water conservation technologies.

CONCLUSION AND POLICY RECOMMENDATIONS

This study focused to analyze the climate variability, farmer's perception towards climate change impacts and coping strategies to mitigate the adverse impacts of climate extremes in Afghanistan. The results showed that among the seven agro-climatic zones of Afghanistan, the central agro-climatic zone was the most vulnerable zone to climate change. The respondents perceived that drying of water sources, famine, crop failure and food inflation were the major impacts of climate change. Besides these impacts, respondents had also perceived a very high impact on socio-economic factors (loss of employment, reduction in household income, food security, etc.) and environmental factors (groundwater depletion, forest degradation, pasture degradation, etc.). As far as copping strategies concerned, nine strategies were identified to mitigate climate change impacts, of which, changing cropping patterns, drilling new bore wells, farm diversification, reducing the number of irrigations, and

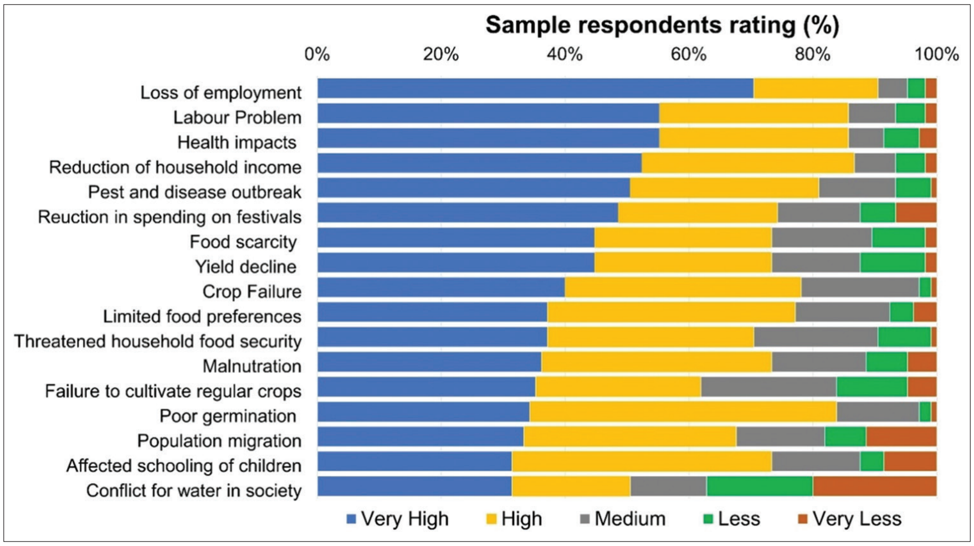

Fig 5. Farmers' perception on various socio-economic impacts in the central agro-climatic zone of Afghanistan.

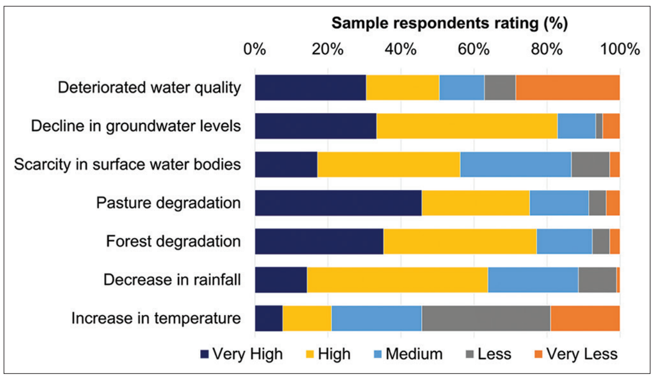

Fig 6. Farmers' perception on various environmental impacts in the central agro-climatic zone of Afghanistan.

Table 4: Climate change coping strategies adapted by sample farmers in CACZ

Coping Strategies	Respondents Mean Score	Rank
Change in cropping pattern	64.50	I
Drilling new bore wells	54.60	II
Farm diversification	52.44	III
Reduction in the number of irrigation	51.53	IV
Water-saving technologies	50.50	V
Advancement/Delaying of cropping season	49.73	VI
Water conservation technologies (farm ponds, contour bunds, mulching etc.)	44.52	VII
Migration for employment to non-agricultural sectors	42.27	VIII
Sale of some livestock	41.45	IX

adopting water-saving technologies were perceived as the most important coping strategies. This study suggested the following recommendations to farmers and governments to combat the impacts of climate change in future.

- Establishing Automatic Weather Stations (AWS) at the province and sub-province level and deliver better agro advisory services to the farming community through quality weather information.
- Coordinated efforts for developing new varieties in major crops that could withstand climate extremes (Senthilnathan et al. 2018) and government interventions including precision farming practices, subsidies for drip and sprinkler irrigation systems (Palanisami et al. 2012).
- Organizing Capacity building programmes on crop-specific climate-smart agricultural practices viz., in-situ moisture conservation, biomass mulching, alternate wetting and drying irrigation methods, introducing drought tolerant varieties, direct seeding, water harvesting and recycling for supplemental irrigation for farmers through the trained personnel from extension and line departments for sustainable agriculture in Afghanistan is one of the viable options to practice climate change adaptation.
- Implementation of weather-based crop insurance schemes (Kuppannan et al. 2010) and increasing irrigation water productivity to protect the farmers from climate extremes.

Authors' contributions

Meraj Sarwary collected the data on climate variables and conducted farm household's survey, data analysis and drafted the manuscript. Senthilnathan; Research supervision and discussed the results and wrote the final manuscript. Saravanakumar; verified the analytical methods and manuscript review and editing; Arivelarasan; Questionnaire preparation, verified the data collection, and review and Manivasagam; Data analysis and drawn the figures using the software.

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