CLIMATE CHANGE CENTRE
THE UNIVERSITY OF AGRICULTURE
PESHAWAR - PAKISTAN

intercooperation

CLIMATE SCENARIOS 2011-2040

BAJAUR & MOHMAND AGENCIES

FEDERALLY ADMINISTERED TRIBAL AREAS (FATA) PAKISTAN

Intercooperation (IC) Pakistan

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This report has been thoroughly discussed in a stakeholders workshop held on 21st April 2015 at the Climate Change Centre (CCC), The University of Agriculture Peshawar. Faculties from various departments of the university, officials of the government line departments and development agencies participated in the workshop and provided useful suggestions on implication of climate change on farming systems. Their suggestions are incorporated in this report.

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LIST OF ACRONYMS

AR	Assessment Report
CCC	Climate Change Centre
CCHF	Crimean-Congo Hemorrhagic Fever
CMIP	Coupled Model Intercomparison Project
CRU	Climate Research Unit
DEM	Digital Elevation Model
DRR	Disaster Risk Reduction
FATA	Federally Administered Tribal Areas
GDP	Gross Domestic Product
GIS	Geographic Information System
GPCC	Global Precipitation Climatology Centre
IC	Intercooperation
IPCC	Intergovernmental Panel on Climate Change
KP	Khyber Pakhtunkhwa
LPH	Livelihoods Programme Hindukush
OPV	Open-Pollinated Varieties
RCP	Representative Concentration Pathways
SDC	Swiss Agency for Development and Cooperation
TAR	Third Assessment Report

CONTENTS

ABSTRACT

Climate change is evolving as one of the leading environmental problems facing modern world. Pakistan is an agriculture country as 47 percent of its population make their living by agriculture. This sector contributes 21 percent to the GDP. Climate change has become a great challenge for the agrarian economy of Pakistan. A serious threat is to the crop sector which is vulnerable to change in temperature and rainfall.

This study has been conducted for Bajaur and Mohmand Agencies in Federally Administered Areas (FATA) of Pakistan. Information provided in this study is particularly valuable for agricultural researchers. They can use this information for providing a right set of guidance to the farmers in wake of changing climate. This study will also help in ensuring that irrigation and agricultural practices are adjusted according to the changing climate to minimize losses.

This report provides temperature and precipitation projections for the period 2011-2040, using the baseline data of 1981-2010. Based on CMIPS5, projections for two variables i.e. temperature and precipitation have been developed for the two Agencies. The data from Bajaur and Mohmand Agencies on future scenarios suggest that temperature and precipitation have changed and will continue to change over the years, which will cause a significant change in people's livelihoods.

In these Agencies, the annual rainfall may continue to increase in the next two decades. Decrease in winter rainfall and increase in temperature will impact the growth and productivity of winter crops particularly wheat. Winter days are becoming warmer and the nights are getting colder in the Bajaur Agency. However winter temperature is increasing in Mohmand Agency. The spring and summer rainfall and temperature projections show an increasing trend. Summer crops will benefit from increased rain in spring and summer. The minimum and maximum temperature in fall is going to increase. However the amount of precipitation shows a decreasing trend in the coming decades. The projected temperature and precipitation data reveal that climate change is a reality in these areas and timely adaptation to these changes is the only and urgent choice. Based on climate scenarios a detailed commentary has been provided in this report regarding implications for farming system in Bajaur and Mohmand Agencies.

1. INTRODUCTION

The objective of this study is to document the impact of climate change on agriculture and water resources under different climate change scenarios (temperature and precipitation pattern changes) that are likely to occur in Bajaur and Mohmand Agencies in FATA Pakistan. The location of the two Agencies is shown in Figure 1.

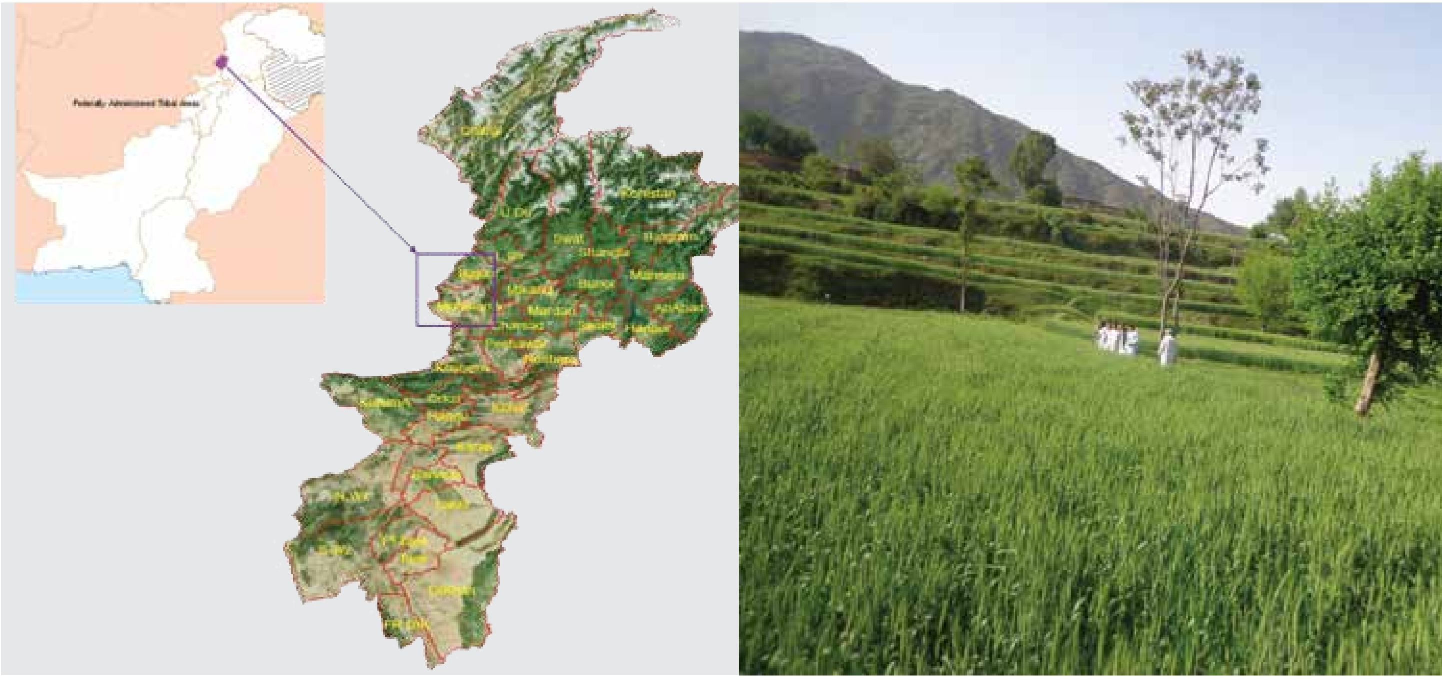

Figure 1: Location of Bajaur and Mohmand Agencies in FATA, Pakistan.

Global climate is the average climate over the planet. The Earth's global climate is changing. The planet is warming up fast–faster than at any time in history that the scientists know of from their studies of Earth's entire history. Most climate scientists agree that the main cause of the current global warming trend is human expansion of the "greenhouse effect". The harmful impacts of this global warming effect are already manifesting themselves around the world in the form of extreme weather events like storms, tornadoes, floods and droughts, all of which have been mounting in frequency and intensity (Maplecroft, 2015; IPCC, 2014). Crop yield growth rates are declining in most parts of the world, partially as a consequence of rising temperatures, while increases in prevalence of climate-induced diseases have also been recorded. Another serious threat arising from climate change is to the freshwater availability.

Pakistan's economy and its food security are highly dependent on agriculture. Due to high population growth rate, there is already heavy pressure on land and other natural resources, leading to severe degradation of these resources. Additional pressure due to climate change will be difficult to sustain if appropriate remedial measures were not taken in time. This scenario has made agriculture sector economically vulnerable.

Earlier studies conducted for a number of districts in Pakistan also indicate that climate change is already affecting agriculture, water sector and the livelihoods of north western parts of Pakistan where these two Agencies are located (Hanif and Ali, 2014; Ali, Nizami, Ara and Saleem, 2014; Akmal et. al. 2014; Hussain and Hanif, 2013). Agriculture and livestock are the main sources of livelihoods in these areas. Most of the agricultural land is rain fed, having insufficient rainfall. Climate of the two Agencies is semi-arid to arid having both winter and summer seasons. The prevailing temperatures are close to the tolerance limits for most crops. Any further increase in temperature will have serious implications for water resources and agricultural production throughout arid and semi-arid areas in the country and the fate of these Agencies will not be different. Water availability in these areas is from precipitation, surface flow and ground water. More than half of cultivated area is under Barani and Spate irrigation.

1.1. Methodology

The climate projections in IPCC Third (TAR) and Fourth Assessment Report (AR4) are based on Special Report on Emissions Scenarios (also called SRES Scenarios). The scientific community recently has developed a set of new emission scenarios termed as "Representative Concentration Pathways (RCPs)" under Project 5 (CMIP5) and IPCC Fifth Assessment Report (AR5) is based on these new set of emissions. In present work, the climate projections for two Agencies of Pakistan are made using the newly developed representative concentration pathways (RCPs) under the Coupled Model Inter-comparison Project 5 (CMIP5) and appropriate statistical downscaling. The CMIP5 ensemble mean climate is closer to observed climate and therefore current work is based on CMIP5 model output. In CMIP5, four RCP scenarios: RCP2.6, RCP4.5, RCP6.0 and RCP8.5 which represent pathways of radioactive forcing, have been used. RCP2.6 pathway has been used for computation of rainfall and temperature scenarios of two Agencies (Bajuar and Mohmand Agencies of FATA) for the next three decades. Under RCP2.6 scenario greenhouse gas emissions and emissions of air pollutants are reduced substantially over time by 2100.

CMIP5 models are generally of higher resolution and are available at common spatial scale of 0.5 × 0.5 deg resolution. The CMIP5 model data is freely available for research purpose to scientific community. The CMIP5 model data is available for different forcing factors. Only CO_2 emission data based on RCP2.6 has been used in the present work to develop the climate scenarios. In this work, only two variables rainfall and temperature were required. For both study areas, the base-line data (1981-2010) of temperature & precipitation were computed with the support of available observational data of Pakistan Meteorological Department and the grid point models data (0.25 x 0.25 resolution) of Climate Research Centre (CRU) for temperature and Global Precipitation Climatology Centre (GPCC) for precipitation. Both data sets were extracted from http:/www.climexp.knmi.nl and were simulated on decadal basis. The results were bias corrected with climate of the region. Statistical downscaling was used to run the precipitation and temperature scenarios for the study areas. Finally, the projected scenarios for each decade have been compared with the base-line period (1981-2010) to understand the rate of change of climate variables. The decadal CMIP5 scenario runs for two study areas have been shown separately in tabular and graphical form in the next section. In the present study, based on CMIP5 using the RCP2.6 scenarios, the projections for the two main variables, surface temperature and precipitation, for two areas of Pakistan have been developed using only one ensemble mean of CMIP5 models. Based on 1981-2010 baseline data, this report provides multi-model temperature and precipitation projections at seasonal scale for two study areas (Bajaur and Mohmand agencies) of FATA Pakistan for the period 2011-2040.

2. BAJAUR AGENCY

2.1. Location and General Features of the Area

Bajaur is an Agency of the Federally Administered Tribal Areas (FATA) of Pakistan. Its geographical coordinates are 34° 44' 16" North and 71° 31' 33" East. Bajaur has an estimated population of about 1,172,816 persons (Based on1998 and after 1988 estimated @ 4.33 annual growth rate till 2014) (Census, 1998). The total area of the Agency is 1,290 square kilometres. Bajaur is about 45 miles (72 km) long by 20 miles (32 km) broad, and lies at a high level to the east of the Kunar Valley (Afghanistan). Nawagai, Khaar and Inayat Killi are the major towns of Bajaur.

2.1.1. Geography of the area

The area is separated from Kunar Afghanistan by a continuous line of rugged frontier hills in the west. The terrain is mountainous to sub-mountainous (Figure 2). To the south of Bajaur is the wide mountain Agency of Mohmand. To the east, beyond the Panjkora River, are the hills of Malakand. To the north is an intervening watershed between Bajaur and Dir. The drainage of Bajaur flows eastwards, starting from the eastern slopes of the dividing ridge, which overlooks the Kunar and terminating in the Panjkora River, so that the Agency lies on a slope tilting gradually downwards from the Kunar ridge to the Panjkora. In the north – western half, the land slopes down to the south-east direction while the central parts slope to the north-east through the Jandool and Panjkora River. The Panjkora River flows in southern direction till it joins the Swat River, which flows along the eastern boundary of Bajaur Agency.

2.1.2. Surface water resources

Bajaur Agency is drained by Natalai River and its tributaries, which is a source of Jandool River that further tributes Panjkora River. Panjkora River emerges from mountains between Dir district and Afghanistan and flows as Boundary River between Dir and Bajaur. River is mainly fed from snowmelt. Panjkora River flows into Swat River near Chakdara. Other large streams of Bajaur Agency are Babakara, Mullah Syed, Watalai, Chaharmang, Khato, Bajaur, Arang, Barang, Dandmar and Jandool ultimately falling into the Swat River.

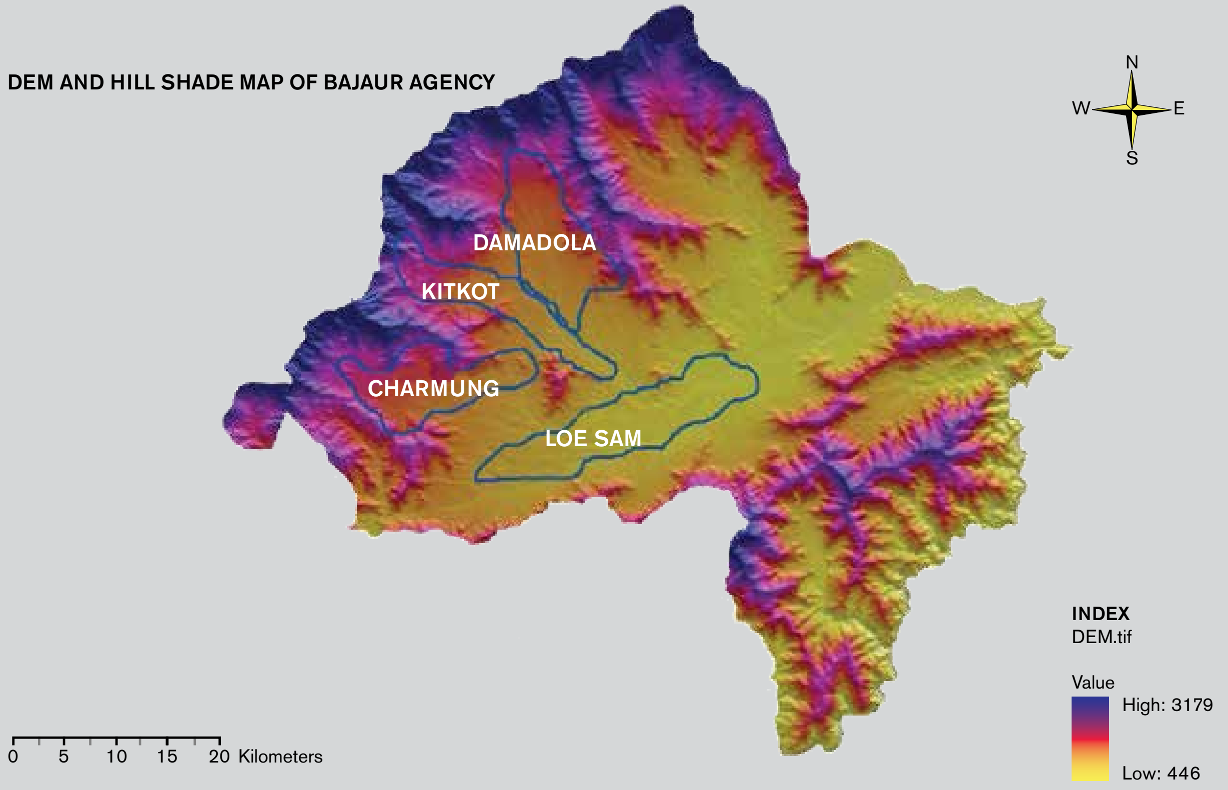

Figure 2: DEM and hill shade of Bajaur Agency.

2.1.3. Groundwater resources

In Bajaur Agency, most of the precipitation falling on mountains enters into streams as runoff, but a significant portion of precipitation over the plain area infiltrates to groundwater. Water table varies from few to 100 meters. Aquifers are also recharged during high flows while there is partial depletion during dry periods. Annual recharge in the area is 98.647, 116.321 and 191.992 million m^3 for dry, average and wet years, respectively. Average annual groundwater abstractions are 127.921 million m^3. Net over-drawn is 11.601 million m^3 in an average year.

2.1.4. Climate

Climate is semi-arid to arid having both pronounced winter and summer seasons. The winter season begins in November and lasts up to March. The winters are extremely cold and sometimes temperature falls below freezing point. December, January and February are the coldest months. The mean maximum and minimum temperatures in these months are in the range of 4 to 16 degree Celsius. The summer season lasts from May to October. June, July and August are the hottest months. The mean maximum and minimum temperatures in this period are in the range of 23 to 36 degrees Celsius.

2.1.5. Livelihood resources

Sources of livelihoods include agriculture, livestock, mining and forestry. Wheat is the major crop in the area followed by barley. Rice, rapeseeds, mustard, maize and vegetables also have significant shares in the cropped area. Cultivable area is 0.086 million ha and only 0.020 million ha is irrigated, representing 23% of cultivated area. Three-fourth of cultivated area is under Barani and Spate irrigation managed by farmers. Livestock is an important livelihoods source in rural areas. Goats and cattle are the major type of livestock in the Agency. Mining of marble and chromites are reported.

2.2. Precipitation Scenario for Bajaur

The decadal changes in precipitation for Bajaur Agency are shown in Table 1 and Figure 3.

Table 1: Annual and seasonal precipitation projections for the next three decades- Bajaur Agency.

Rainfall (mm)	Base	**Projected**	% change	**Projected**	% change	**Projected**	% change
			from		from		from
	1981-2010	2011-2020	Base	2021-2030	Base	2031-2040	Base
Annual	684.3	693.1	1.28	705	3.02	711.6	3.98
Winter	183.4	163.5	-10.85	151.8	-17.23	142.3	-22.41
Spring	244.0	257.3	5.44	269.4	10.40	281.4	15.31
Summer	194.6	214.5	10.22	232.3	19.37	241.3	23.99
Fall	62.3	57.8	-7.22	51.5	-17.33	46.6	-25.20

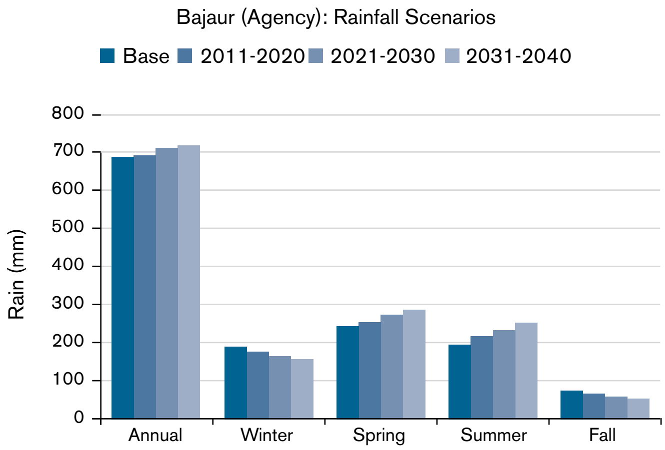

Figure 3: Annual and seasonal rainfall projections of Bajaur for the next three decades.

2.2.1. Discussion of projected results for precipitation scenarios

Computed information gleaned from the rainfall projections unveils the following scenario:-

1) An increasing annual rainfall trend is observed for the next three decades.

a) Annual rainfall for the decade 2011–2020 increases marginally at a rate of 1.28%.

b) Annual rainfall for the decades 2021–2030 and 2031–2040 increases significantly at a rate of 3.02% and 3.98% respectively.

2) A decreasing trend in winter rainfall is observed for the next three decades.

a) Winter rainfall for the decade 2011–2020 decreases dramatically at a rate of 10.85%.

b) Winter rainfall for the decades 2021–2030 and 2031–2040 declines quite significantly at rates of 17.23% and 22.41% respectively.

3) A surging trend can be seen in the spring precipitation for the next three decades.

a) Spring rainfall for the decade 2011–2020 increases at a rate of 5.44%.

b) Spring rainfall rate for the decades 2021–2030 and 2031–2040 surges notably at 10.4% and 15.31%.

4) Summer Precipitation data indicates an increasing progression.

a) Summer (monsoon) precipitation for the decade 2011–2020 increases by a factor of 10.22%.

b) Monsoon rainfall for the decades 2021–2030 and 2031–2040 increases multi-fold at rates of 19.37% and 23.99% correspondingly.

5) A declining trend is seen for fall rainfall from the dataset.

a) For decade 2011–2020, the fall precipitation drops by 7.22%.

b) For decades 2021–2030 and 2031–3040, the fall precipitation drops quite notably by 17.33% and 25.20%.

2.3. Temperature Scenarios for Bajaur

Decadal temperature scenarios for Bajaur Agency are shown in Table 2. These are analysed for the four seasons and graphical representation of the minimum and maximum projected temperatures is shown in the Figure 4 and 5 respectively.

Table 2: Decadal Temperature Scenarios (°C) of Bajaur Agency.

Temperature	Base	Projected	% change from	Projected	% change from	Projected	% change from
	1981-2010	2011-2020	Base	2021-2030	Base	2031-2040	Base
Annual							
Average	19.7	20.2	2.5	20.7	5.1	21.3	8.1
Minimum	13.0	13.3	2.3	13.6	4.6	14.0	7.7
Maximum	26.5	27.1	2.3	27.8	4.9	28.5	7.5
Winter							
Average	10.1	10.3	1.6	10.5	3.6	10.8	6.5
Minimum	3.5	3.1	-12.6	2.7	-23.9	2.5	-29.5
Maximum	16.7	17.5	4.6	18.3	9.4	19.0	13.6
Spring							
Average	21.0	21.8	3.9	22.5	7.2	23.2	10.5
Minimum	14.3	15.3	6.7	16.1	0.7	17.0	18.5
Maximum	27.6	28.2	2.0	28.8	4.2	29.3	6.0
Summer							
Average	28.9	29.3	1.3	29.7	2.6	30.2	4.4
Minimum	22.8	23.0	0.8	23.2	1.7	23.5	3.0
Maximum	35.1	35.6	1.5	36.2	3.3	36.9	5.3
Fall							
Average	18.8	19.4	3.1	20.0	6.3	20.8	10.5
Minimum	11.2	11.8	5.1	12.4	10.4	13.0	15.8
Maximum	26.4	27.0	2.2	27.6	4.5	28.6	8.3

2.3.1. Discussion of projected results for temperature scenarios

From the computed datasets, the following projected temperature information is analysed.

Annual temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (19.7°C) is 2.5% (20.2°C). Minimum temperature will rise from baseline temperature 13°C to 13.3°C at a rate of 2.3% and maximum temperature will go up to 27.1°C from baseline temperature of 26.5°C at a rate of 2.3%.

I) For decade 2021–2030 the average increase from baseline temperature (19.7°C) will be 5.1% (20.7°C). Minimum temperature will go up to 13.6°C at a rate of 4.6% and maximum temperature up to 27.8°C at a rate of 4.9% respectively.

II) For decade 2031–2040 the average increase from baseline temperature (19.7°C) will be 8.1% (20.7°C). Minimum temperature will go up to 14°C at a rate of 7.7% and maximum temperature will rise to 28.5°C at a rate of 7.5% correspondingly.

Winter temperature: (Days becoming warmer and nights cooler)

I) For decade 2011–2020 the average increment from baseline temperature (10.1°C) is 1.6% (10.3°C), while minimum temperature will drop from baseline temperature 3.5°C to 3.1°C at a declining rate of 12.6% and the maximum temperature will go up to 17.5°C from baseline temperature of 16.7°C at a rate of 4.6%.

II) For decade 2021–2030 the average increase from baseline temperature (10.1°C) will be 3.6% (10.5°C). Minimum temperature will go down to 2.7°C at a declining rate of 23.9% and maximum temperature will rise to 18.3°C at a rate of 9.4% respectively.

III) For decade 2031–2040 the average increase from baseline temperature (10.1°C) will be 6.5% (10.8°C). Minimum temperature will decline to 2.5°C at a declining rate of 29.6% and maximum temperature will rise to 19°C at a rate of 13.6% correspondingly.

Spring temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (28.9°C) is 1.3% (29.3°C). Minimum temperature will rise from baseline temperature 22.8°C to 23°C at a rate of 0.8% and maximum temperature will go up to 35.6°C from baseline temperature of 35.1°C at a rate of 1.5%.

II) For decade 2021–2030 the average increase from baseline temperature (28.9°C) will be 2.6% (29.7°C). Minimum temperature will go up to 23.2°C at a rate of 1.7% and maximum temperature up to 36.2°C a rate of 3.3% respectively.

III) For decade 2031–2040 the average increase from baseline temperature (28.9°C) will be 4.4% (30.2°C). Minimum temperature will go up to 23.5°C at a rate of 3% and maximum temperature will rise to 36.9°C at a rate of 5.3% correspondingly.

Summer temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (21°C) is 3.9% (21.8°C). Minimum temperature will rise from baseline temperature 14.3°C to 15.3°C at a rate of 6.7% and maximum temperature will go up to 28.2°C from baseline temperature of 27.6°C at a rate of 2%.

II) For decade 2021–2030 the average increase from baseline temperature will be 7.2% (22.6°C). Minimum temperature will go up to 16.1°C at a rate of 0.7% and maximum temperature up to 28.8°C a rate of 4.2% respectively.

III) For decade 2031–2040 the average increase in temperature will be 10.5% (23.2°C). Minimum temperature will go up to 17°C at a rate of 18.5% and maximum temperature will rise to 29.3°C at a rate of 6% correspondingly.

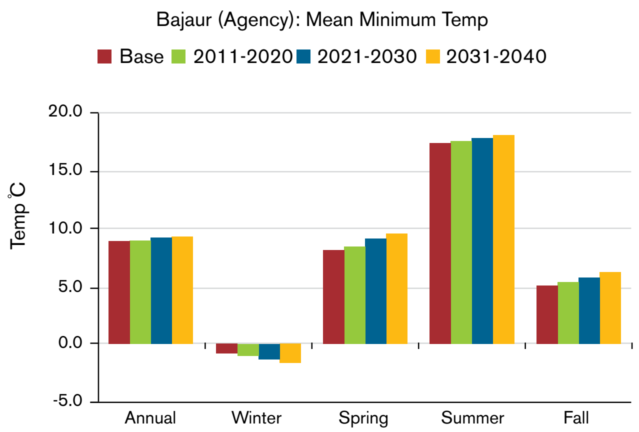

Figure 4: Annual and seasonal mean minimum temperature of Bajaur for the next three decades.

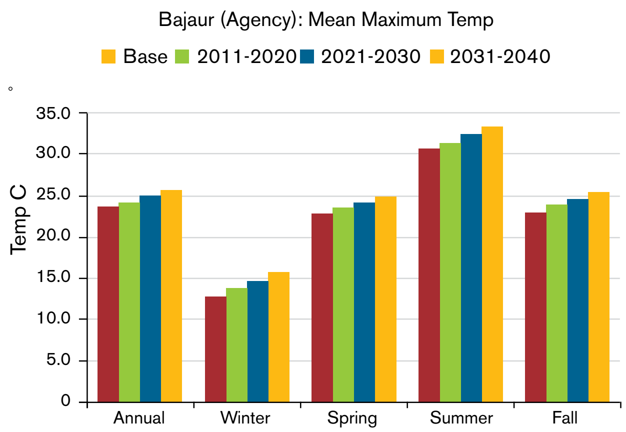

Figure 5: Annual and seasonal mean maximum temperature of Bajaur for the next three decades.

Fall temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (18.8°C) is 3.1% (20°C). Minimum temperature will rise from baseline temperature 11.2°C to 11.8°C at a rate of 5.1% and maximum temperature will go up to 27°C from baseline temperature of 26.4°C at a rate of 2.2%.

II) For decade 2021–2030 the average increase in temperature will be 6.3% (20°C). Minimum temperature will go up to 12.4°C at a rate of 10.4% and maximum temperature up to 27.6°C a rate of 4.5% respectively.

III) For decade 2031–2040 the average increase in temperature will be 10.5% (20.8°C). Minimum temperature will go up to 13°C at a rate of 15.8 % and maximum temperature will rise to 28.6°C at a rate of 8.3% correspondingly.

3. MOHMAND AGENCY

3.1. Location and General Features of the Area

Mohmand Agency is situated in the Federally Administered Tribal Areas of Pakistan. Its geographical coordinates are 34° 0' 30" North and 72° 1' 0" East. The Agency is bounded by Bajaur Agency to the north, Khyber Agency to the south, Malakand and Charsadda districts to the east and Peshawar district to the south east. Estimated population of Mohmand Agency is about 653,960 persons (Based on 1998 Census population 334,453; estimated @ 4.28 annual growth rate till 2014) (Census, 1998). The Agency spreads over 2,296 square kilometres.

3.1.1. Geography of Mohmand Agency

The Mohmand Agency is an area of rugged mountains with barren slopes (Figure 6). General slope of the area is from north-east with an average height over 1,450 meters. Ilazai (2,716 meters) is the highest peak near the Pak -Afghan border. Other important peaks are Yarisar (1,929 meters) and Silai of Mohmand agency. The most extensive part of Mohmand Agency lies in the glens and valleys that start from the mountains of Tartara, south of the Kabul river; and Ilazai, north of this river, and main places among these settlements are the valleys of Shilman, Gandab, Pindiali and the banks of the Kabul river. Mohmand Agency is geographically sub divided for administrative convenience into Upper and Lower Mohmand areas. Lower Mohmand area is rather fertile whereas Upper Mohmand area is comparatively less productive.

3.1.2. Surface water resources

The Kabul River and the Swat River are the two rivers that pass through the area of the Lower Mohmand. The Swat River flows from north towards south after entering the Agency limits from Malakand and passes through the area of Prang Ghar/Pindiali Tehsil. The Kabul River forms the boundary between the Khyber and Mohmand Agencies after entering into Pakistan territory, The River flows from west towards east. In Pakistan's territory, the course of the Kabul River is through high mountains and gorges till it passes through the Warsak Dam and thereafter it starts running through the Peshawar valley area.

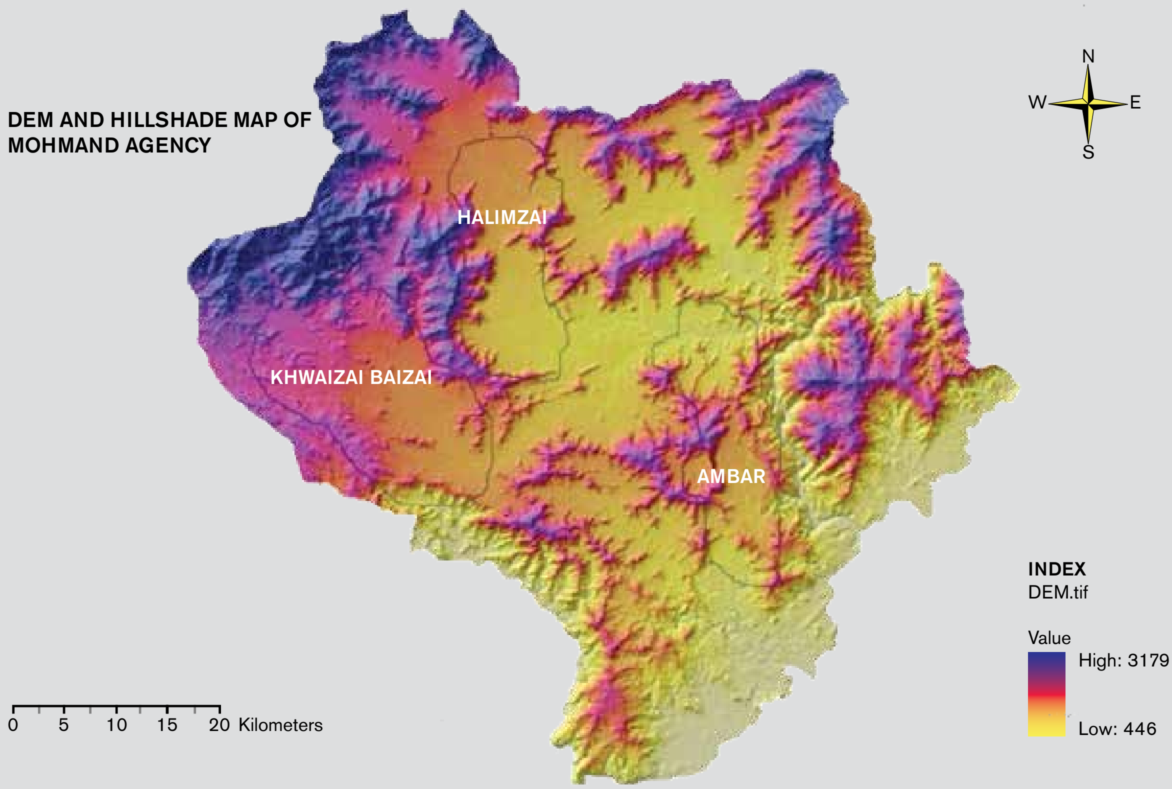

Figure 6: DEM and hill shade of Mohmand Agency.

3.1.3. Groundwater resources

Precipitation falling on mountains enters into streams as runoff and a significant portion over the plain area infiltrates to the aquifer. Water table varies from few to 100 meters. Aquifers are also recharged in wet seasons while there is partial depletion during dry periods.

3.1.4. Climate

Climate of the Agency is semi-arid, subtropical and continental highlands having both winter and summer seasons. The summer season commences from May and continues for 4 months till 31st August. The winter season starts from November and continue till February. The rainfall is scanty. Most of the rainfall is received during spring season.

3.1.5. Livelihood resources

The sources of income are very limited in general except agriculture and some trade/business. Cultivable area is 0.031 million ha, out of which 0.009 million ha are irrigated, representing 29% of the cultivated area. More than half of the cultivated area is under Barani or Spate irrigation.

3.2. Precipitation Scenario for Mohmand Agency

The decadal changes in precipitation for Mohmand are shown in Table 3 and Figure 9.

Table 3: Annual and seasonal precipitation projections for the three decades- Mohmand Agency.

Figures 7 & 8: Barani and irrigated farming in Mohmand Agency

Table 3: Annual and seasonal precipitation projections for the three decades - Mohmand Agency.

Rainfall (mm)	Base	Projected	% change from	Projected	% change from	Projected	% change from
	1981-2010	2011-2020	Base	2021-2030	Base	2031-2040	Base
Annual	309.8	326.4	5.36	342.8	10.65	355.8	14.85
Winter	75.2	70.6	-6.16	66.6	-11.48	62.3	-17.19
Spring	124.7	136.7	9.61	147.5	18.27	155.4	24.61
Summer	86.2	97.7	13.36	110.2	27.86	119.8	39.00
Fall	23.7	21.4	-9.71	18.5	-21.94	16.6	-29.96

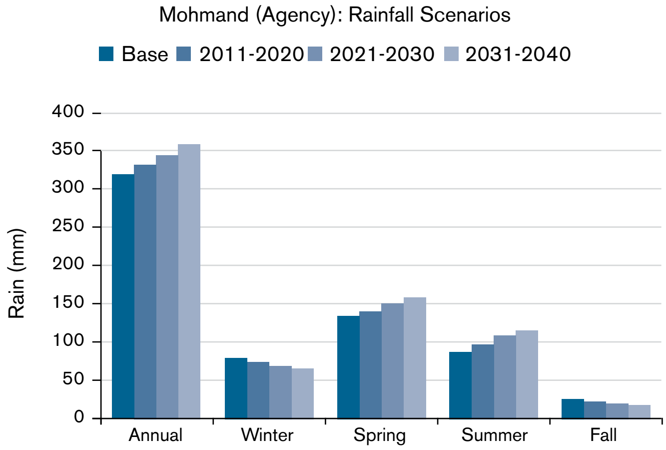

Figure 9: Annual and seasonal rainfall projections of Mohmand Agency for the three decades.

3.2.1. Discussion of projected results for precipitation scenarios

Computed information gleaned from the rainfall projections unveils the following facts:-

1) An increasing annual rainfall trend is observed for the next three decades.
a) Annual rainfall for the decade 2011–2020 increases at a rate of 5.36%.
b) Annual rainfall for the decades 2021–2030 and 2031–2040 increases significantly at a rate of 10.65% and 14.85% respectively.
2) A decreasing trend in winter rainfall is observed for the next three decades.
a) Winter rainfall for the decade 2011–2020 declines at a rate of 6.16%.
b) Winter rainfall for the decades 2021–2030 and 2031–2040 decreases dramatically at the rates of 11.48% and 17.19% respectively.
3) A surging trend can be seen in the spring precipitation for the next three decades.
a) Spring rainfall for the decade 2011–2020 increases at a rate of 9.61%.
b) Spring rainfall rate for the decades 2021–2030 and 2031–2040 surges notably at 18.27% and 24.61%.
4) Summer Precipitation data indicates an increasing progression.
a) Summer (monsoon) precipitation for the decade 2011–2020 increases considerably by a factor of 13.36%.
b) Monsoon rainfall for the decades 2021–2030 and 2031–2040 increases multi-fold at rates of 27.86% and 39% correspondingly.
5) A declining trend is seen for fall rainfall from the dataset.
a) For decade 2011–2020, the fall precipitation drops by 9.71%.
b) For decades 2021–2030 and 2031–3040, the fall precipitation drops quite notably by 21.94% and 29.96%.

3.3. Temperature Scenarios for Mohmand Agency

Decadal temperature scenarios for Bajaur Agency are shown in Table 4. These are analysed for the four seasons and graphical representation of the minimum and maximum projected temperatures is shown in the Figure 10 and 11 respectively.

Table 4: Decadal Temperature Scenarios (°C) of Mohmand Agency.

Temperature	Base	Projected	% change from	Projected	% change from	Projected	% change from
	1981-2010	2011-2020	Base	2021-2030	Base	2031-2040	Base
Annual							
Average	13.1	13.7	4.6	14.3	9.2	15.0	14.5
Minimum	7.4	7.9	6.8	8.4	13.5	9.0	21.6
Maximum	18.9	19.4	2.6	20.1	6.3	20.9	10.6
Winter							
Average	4.3	4.7	10.3	5.0	17.3	5.5	29.1
Minimum	-1.4	-1.2	-13.2	-1.0	-27.7	-0.7	-49.4
Maximum	9.9	10.5	6.0	11.0	11.0	11.7	18.1
Spring							
Average	13.7	14.3	4.2	14.9	8.6	15.6	13.7
Minimum	8.0	8.8	9.5	9.6	0.7	10.4	29.4
Maximum	19.4	19.8	2.1	20.2	4.1	20.8	7.2
Summer							
Average	21.6	22.3	3.5	23.1	7.2	24.0	11.4
Minimum	16.2	17.0	4.8	17.8	9.7	18.6	14.6
Maximum	26.9	27.5	2.3	28.3	5.3	29.3	9.0
Fall							
Average	13.0	13.4	3.4	13.9	7.3	14.6	12.7
Minimum	6.6	6.8	2.8	7.1	7.4	7.7	16.4
Maximum	19.3	19.9	3.1	20.7	7.3	21.5	11.4

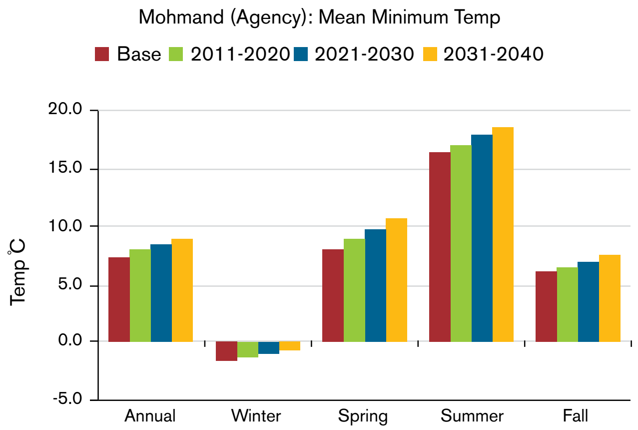

Figure 10: Annual and seasonal mean minimum temperature of Mohmand for the next three decades.

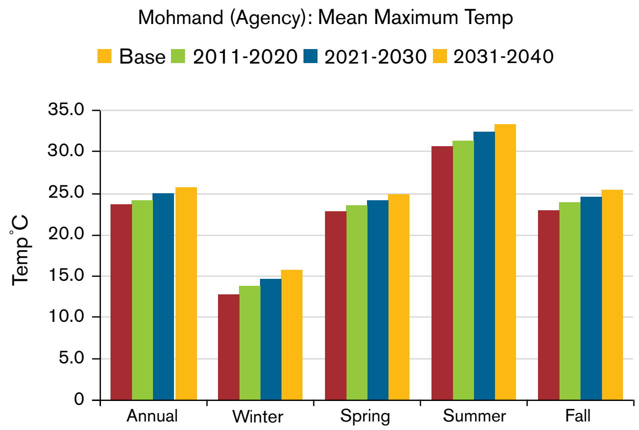

Figure 11: Annual and seasonal mean maximum temperature of Mohmand for the next three decades.

3.3.1. Discussion of projected results for temperature scenarios

From the computed datasets, the following projected temperature information is analysed.

Annual temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (13.1°C) is 4.6% (13.7°C). Minimum temperature will rise from baseline temperature 7.4°C to 7.9°C at a rate of 6.8% and maximum temperature will go up to 18.9°C from baseline temperature of 19.4°C at a rate of 2.6%.

II) For decade 2021–2030 the average increase from baseline temperature will be 9.2% (14.3°C). Minimum temperature will go up to 8.4°C at a rate of 13.5% and maximum temperature up to 20.1°C at a rate of 6.3% respectively.

III) For decade 2031–2040 the average increase in temperature will be 14.5% (15°C). Minimum temperature will go up to 9°C at a rate of 21.6% and maximum temperature will rise to 20.9°C at a rate of 10.6% correspondingly.

Winter temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (4.3°C) is 10.3% (4.7°C) while minimum temperature will rise from baseline temperature -1.4°C to -1.2°C at a rate of 13.2% and a maximum temperature will go up to 19.4°C from baseline temperature of 18.9°C at a rate of 6%.

II) For decade 2021–2030 the average increase from baseline temperature will be 17.3% (5°C). Minimum temperature will go up to -1°C at a rate of 27.7% and maximum temperature will rise to 11°C at a rate of 11% respectively.

III) For decade 2031–2040 the average increase in temperature will be 29.1% (5.5°C). Minimum temperature will rise to -0.7°C at a rate of 49.4% and maximum temperature will rise to 11.7°C at a rate of 18.1% correspondingly.

Spring temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (13.7°C) is 4.2% (14.3°C). Minimum temperature will rise from baseline temperature 8°C to 8.8°C at a rate of 9.5% and maximum temperature will go up to19.8°C from baseline temperature of 19.4°C at a rate of 2.1%.

II) For decade 2021–2030 the average increase from baseline temperature will be 8.6% (14.9°C). Minimum temperature will go up to 9.6°C at a rate of 8.3% and maximum temperature up to 20.2°C at a rate of 4.1% respectively.

III) For decade 2031–2040 the average increase in temperature will be 13.7% (15.6°C). Minimum temperature will go up to 10.4°C at a rate of 29.4% and maximum temperature will rise to 20.8°C at a rate of 7.2% correspondingly.

Summer temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (21.6°C) is 3.5% (22.3°C). Minimum temperature will rise from baseline temperature 16.2°C to 17°C at a rate of 4.8% and maximum temperature will go up to 27.5°C from baseline temperature of 26.9°C at a rate of 2.3%.

II) For decade 2021–2030 the average increase from baseline temperature will be 7.2% (23.1°C). Minimum temperature will go up to 17.8°C at a rate of 9.7% and maximum temperature up to 28.3°C at a rate of 5.3% respectively.

III) For decade 2031–2040 the average increase in temperature will be 11.4% (24°C). Minimum temperature will go up to 18.6°C at a rate of 14.6% and maximum temperature will rise to 29.3°C at a rate of 9% correspondingly.

Fall temperature: (Rising)

I) For decade 2011–2020 the average increment from baseline temperature (13°C) is 3.4% (13.4°C). Minimum temperature will rise from baseline temperature 6.6°C to 6.8°C at a rate of 2.8% and maximum temperature will go up to 19.9°C from baseline temperature of 19.3°C at a rate of 3.1%.

II) For decade 2021–2030 the average increase in temperature will be 7.3% (13.9°C). Minimum temperature will go up to 7.1°C at a rate of 7.4% and maximum temperature up to 20.6°C at a rate of 7.3% respectively.

III) For decade 2031–2040 the average increase in temperature will be 12.7% (14.6°C). Minimum temperature will go up to 7.7°C at a rate of 16.4 % and maximum temperature will rise to 21.5°C at a rate of 11.4% correspondingly.

4. IMPLICATIONS OF EMERGING CLIMATE SCENARIOS

4.1. Implications for Water Resources and Farming Systems in General

In general the changed weather conditions are no longer suited to the current farming system in Bajaur and Mohmand Agencies. Crop yields are especially expected to decrease as a result of climate change scenarios. Spatial shifts in cropping zones and agro-ecological boundaries is observed. Therefore the entire cropping system needs to be studied for adjustments according to the changed temperature and rainfall conditions. As a result of climate change, extreme fluctuations in supply of irrigation water are also expected. Summary of temperature and precipitation change scenarios for Bajaur and Mohmand Agencies are shown in Table 5 and 6 respectively.

Table 5: Summary of temperature change scenarios for Bajaur and Mohmand Agencies

Season	Bajaur Agency	Mohmand Agency				
	Avg	Max	Min	Avg	Max	Min
Annual	+	+	+	+	+	+
Winter	+	+	+	+	+	-
Spring	+	+	+	+	+	+
Summer	+	+	+	+	+	+
Fall	+	+	+	+	+	+

Table 6: Summary of precipitation change scenarios for Bajaur and Mohmand Agencies

Season	Bajaur Agency	Mohmand Agency
Annual	+	+
Winter	–	–
Spring	+	+
Summer	+	+
Fall	–	–

Increased temperature and reduction in rainfall in winter and fall indicate certain worries for the winter crops. There is a fear of drought in these areas especially in Mohmand Agency where the winter rainfall is scanty. Construction of small dams and storage tanks to harvest rain water for irrigation and domestic purposes is urgently required. Recharge of groundwater by using rain water harvesting techniques can also be promoted. Due to decrease in winter rainfall, the productivity of wheat crop will be seriously affected. Increased winter and spring temperatures will shorten growing season length for wheat (wheat-rice, wheat-cotton, wheat-sugarcane systems). However a longer time stretch will be available for summer crops. Drought resistant varieties of winter crops should be introduced in the two Agencies. Winter days are becoming warmer and nights are getting cooler in Bajaur Agency. This will affect the growth of winter crops and vegetables.

The temperature and precipitation projection for the three decades shows that the spring and summer temperature and rainfall would increase. Both the Agencies will experience hotter springs implying that summers will become longer. The average and maximum temperatures will also increase in the other seasons in both the Agencies. In summers, more extreme temperature and precipitation in Bajaur and Mohmand agencies may prevent crops from growing. Genetic research to develop stress resistant varieties should be carried out immediately to prevent food insecurity in Bajaur and Mohmand Agencies. Extreme events, especially extensive rains and flash floods in steep topographic areas can harm crops and reduce yields. Due to increase rainfall in spring and summer the production of tobacco will increase and the quality will improve. The prevailing weather conditions will also be beneficial for the cultivation and production of maize. There will be increased rainfall in summer but temperature increase will also cause more evapotranspiration. Many weeds, pests and fungi thrive under warmer temperatures, wetter climates. Therefore, there is a likelihood of an increased tendency to use pesticides and fungicides which in turn may negatively affect environmental quality and human health.

Decline in water levels in reservoirs can be caused by reduced water supply caused by dry spells (or late winter rains). The increase in snowmelt might, however, help temporarily. Methods for conserving water from early/increased snow/glaciers melting are required.

Heat waves, which are projected to increase under climate change in the two Agencies, could directly threaten livestock. Heat stress affects animals both directly and indirectly. Over time, heat stress can increase vulnerability to diseases, reduce fertility, and reduce milk production. Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of spring and warmer winters may allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens may also thrive.

4.2. Implications for Watershed Management and Agro-Ecological Zones

- Identification of suitable species of trees and grasses
- Summer floods - DRR measures should be initiated well in time
- Winter drought – requires proper adaptation measures i.e. water retention and recharge etc
- Better understanding of local weather pattern needs to be developed – Agro-ecological zones
- Cases of micro weather systems within the agencies
- Understanding changes in the hydrology of the area (Rainfall run off relation in the area)
- Agro-ecological zone re-alignment using remote sensing and GIS and suitable indices
- Surface and Ground water monitoring

4.3. Implications for Animal Production

Decrease in production and reproduction efficiencies

When there is change in the climatic condition particularly raise in temperature causes stress condition in the animal body. The stress consequently effect the normal physiological parameters that lead to decrease in feed intake, anorexia and depression which lead to decrease in body weight gain, milk and meat production. The high rise of environmental temperature causes disturbances of hormonal mechanism of the body particularly depressed the L.H hormone which ultimately leads to decrease the reproductive efficiency of the animals. The high temperature lead to loss of body water and induce free radical formation in the body causing injury at cellular level that badly effect the spermatogenesis in male that lead to decrease reproductive efficiency.

Increasing diseases

With change in climatic temperature there are greater chances of emerging and re-emerging of disease. It provides an opportunity for the growth and propagation of thermophilic pathogens which were not the normal inhabitant of that area. Secondly with change in climate provide an opportunity for migration of human and animals introducing pathogens to the newly adapted areas. The classical example is Leishminiasis from southern part of the country to central and northern areas. Similarly, the outbreak of Dengue fever in northern areas was due to visitor during summer from central Punjab. The CCHF is the animal disease, having zoonotic potential and causes havoc in human population, emerged in KP because of Trans-boundaries migration of nomads from Afghanistan.

Elimination of local diseases resistant breeds and forage species

When there is change in climatic condition the inhabitant of the area will opt for rearing of new species of animals having better adaptation. The new species of animals have different grazing pattern and chances of elimination of fodder species is increased. For example, the rearing of goat in place of cow or rearing of exotic breeds to substitute the local one may result in elimination of local breed and fodder species.

Decrease in disease tolerance (Stress, Immuno-suppression)

The elevated environmental temperature may disturb the physiological mechanism of the body by releasing corticosterone from adrenal cortex. This hormone target the lymphoid organs of the animals causing its atrophy that eventually lead to immune-suppression. The animals are then prone to multiple infectious diseases.

Spreading of public health hazards due to animal mortalities in flooding and famine

Flooding and famine conditions, caused by changing climatic conditions, may lead to high mortality in the animal population. The dead bodies provide an opportunity for the growth of different pathogenic microorganism to cause environmental pollution that increases public health hazards in the respective locality.

Provide opportunities for introduction of new high producing animal species

The climatic change is not always harmful. Sometimes it may bring an opportunity for the community. For example in the study area of northern FATA, the people adapted to rearing of exotic breeds. The exotic species of animals produced more milk than the local breed and brought positive change in the earning capacity of the poor farmers.

4.4. Implications for Crops

Under changing climate, it is expected that there would be two main seasons i.e. summer and winter. It is also expected that summer would be relatively cooler and wet. This would affect the main crops and its productivity. Expected implications and required possible research on crops could be given below.

Wheat Crop

- Sowing time and drought stress on germination and emergence rate
- Disease attack (e.g. rust and smut) and resistant variety for the wet areas
- Late maturing variety identification to avoid wet rainy season of April-May
- Resistant variety identification against lodging and hailstorm in March-April
- Study on termites, aphids, and downy mildew disease that is expected to increase in wheat field and crop
- Post-harvest management of the wheat grains and straw in wet rainy seasons
- High yielding variety identification for the agro-ecological conditions of KP
- Re-validation of inputs and agronomic practices for optimum wheat production
- Intercropping versus sole cropping to avoid losses at maturity of the crop
- Probability of identification of good companion crops that yield maximum in inter-cropped conditions than sole wheat crop in wet area
- Nitrogen fertilizer management for wheat to sustain optimum soil N-content for good baking quality when crop is at grain developmental stage
- Identification of suitable variety for agro-ecological conditions
- Fertilizer application timing, rates and timing for nutrients combination
- Adjustment of sowing date with changing climate for optimum production
- Study decline of water table and its impact on the future crop production system
- Measures to increase soil organic matter for future crop production
- Seed grading and treatment with fungicides at sowing in dry soils in drought stress condition
- Wind breaks for the crop to avoid lodging of the crop at maturity and rainy season
- Moisture conservation practices with alternate crops that are more economical for the area

Maize Crop

- Hybrids vs. OPV cultivation in the existing resources and climate of the area
- Stress and drought at anthesis and its effect on yield
- Sudden temperature rises in the day when the crop is in grain development stage and its effect on yield and production at harvest
- Sustain uniformity of the desired density from sowing to harvest of the crop
- Optimum time of sowing of maize for different cropping systems with appropriate variety to be sown
- Seed availability, its quality and desired planting geometry so that the optimum produce can be harvested under the existing climate of the area
- Resources utilization, i.e. air, water and solar radiation for maize sowing with proper variety selection, its timing for vegetative and reproductive growth as well as input management
- Post-harvest management of the produce (i.e. seed and straw)
- Sowing of sole and inter-crops for maximum dry matter in the area where fodder is acute short and growers prefer the crops for biomass production
- Decision for the cultivation of a hybrid and/or OPV subject to its time of sowing and local climate of the crop growth season
- Fertilizer requirements, seed rates, and timing of nutrients application for maximum return per unit area
- Increase practices for improved soil organic matter, mulch and plant stand for improved water holding capacity at anthesis
- Comparison of hybrid with OPV for yield and production cost per unit area in a cropping system
- Seed source and its quality study for yielding a uniform crop stand that could intercept the maximum solar light, water and air for biomass production.
- Recommendation for the sowing methodology of the crop with desired density so that highest return of yield and biomass can be obtained.

Sorghum and Millet

- Timing of the growth stage of the crop with chances of water availability for growth and production
- Variety selection for the area and its optimum sowing timing, and harvesting for maximum biomass production
- Cultivation of sole or mix (sorghum with millet) OR with another species to avoid drought stress and yield losses
- Seed treatment before sowing

- Identification of disease resistant variety of both sorghum and millet
- Use of optimum seed rate, sowing time and nutrients application for maximum production
- Appropriate variety selection for the different agro-ecological condition
- Sowing time, nutrients and seeding rate study for both sorghum and millet as sole and mix crop
- Disease resistant variety for the area and measures to control disease attack on grains that adversely affect the yield
- Measures for improvement in soil's water holding capacity and rain harvesting for crop growth and development in the area
- Identification of other crops that are more resistant to climate changes and better in return in terms of biomass and yield

4.5 Implications for Horticulture

Increase in temperature may eradicate some common growing fruit plants cultivars having marginal chilling requirements. This includes Peach 6-A, Tex-69 (300 to 400 hours below 7°C). Solution lies in introduction and selection of low chilling fruit cultivars.

Increase in temperature beside heavy rainfall is a cause of physiological disorders in fruits. This includes fruit cracking and rotting (Pomegranate, Citrus) and bark cracking and borer attack. Micronutrient fortification and high density orchards may be introduced with proper micro irrigation system

- Increase in temperature may increase water sprouts in orchards which causes nutrient drain. Solution: Research on Summer Pruning of Orchards
- Increase in pre-harvest infestation and post-harvest losses. Solution: Research on Pre and Post-Harvest Management.
- Increase in Temperature is a threat to autumn crop of potato. Solution: Research on frost tolerant varieties.
- Late spring rains posing a threat to off-season vegetables. Solution: Research on plant geometry and vertical farming techniques
- High temperature and light intensity is a cause of serious physiological disorders and subsequent yield losses including sun burn in tomatoes and bell pepper. Solution: Research in light intensity and shade effects
- Loss of Germplasm due to interventions in natural system. Solution: Germplasm preservation
- Diminishing spring affects cut-flowers production. Solution: Introduction of new varieties of floriculture
- Due to climate change indigenous medicinal plants are fast vanishing. Solution: Medicinal plants preservation, value addition and utilization

Conclusion: Climate change is a multidisciplinary subject which can be dealt with an interdisciplinary research and development approach where expert from various disciplines combine resources and expertise to find solution to the challenges posed by climate change.

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