EFFECTS OF CLIMATE CHANGE ON THE MAJOR AGRICULTURAL CROPS PRODUCTIVITY IN BALOCHISTAN PROVINCE, PAKISTAN (1982-2009)

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ABSTRACT- *The study explains the impact of climate change on major crops productivity, cropping seasons (wheat, rice, cotton, tobacco and sugarcane), and adapt to its effects in the Balochistan Province over a time period of 1982-2009. The climate of the area is perceptibly, the arid having some semi-arid localities at Quetta and its surroundings. Due to aridity and water shortage, the Balochistan province is more vulnerable to climate change, and extreme weather events are threatening food security and the well being of the people. The results reveal that the declined in mean monthly temperature and precipitation have adversely affected wheat, cotton, sugarcane, rice and tobacco production. Rainfall effects on the yield of these crops are negative, except for wheat, which shows an increase in its yield per acre. The most affected crops by the prevailing climate change in Balochistan are; cotton, rice, and sugarcane. To cope with and mitigate the negative effects of temperature and precipitation variation on the productivity of the crops, there is a need to introduce drought resistant verities, improve the water sector, financial support, crops insurance policy, mechanization, research and development to ensure food security.*

Keywords- Climate Change, Kharif Crops, Rabi Crops, Crop Production, Food security, Adaptation.

1. INTRODUCTION

In Pakistan, predominantly in Balochistan, the impact of climate change on food crops is more visible and it is feared that the consequences will become severe over time. Several researchers have presented their visions about climate change and food security locally and internationally, but there is very less work on the environmental changes and their threats to food security in Balochistan. Some of them who worked on the subject are; [1-15]. The climate fluctuation and its effects on crops cultivation have drawn the attention of both local and international researchers. Human activities, community development, economic development and environmental alterations are intimately associated with the climate phenomenon. In addition, climate and environmental circumstances such as drought, aridity, catastrophes, and hydrological infrastructure have implications for food security and human welfare in Balochistan province. Due to the non-availability of water for irrigation and scanty precipitation, a major part of the Balochistan province is unproductive, rainfed or dependent on karaze based irrigation system. Balochistan is the major province among the five provinces of Pakistan, covering about 347,220 square kilometers of area and constitutes almost 43 percent of the country has a 770 kilometers coastal belt. Due to CPEC (China Pakistan Economic Corridor), the province is going to become the main hub of economic activities not only for the entire land of Pakistan and China, but also in Central Asia, Russia, Afghanistan, Nepal, India as well as Iran. The population of the province is 12.34 million that declared Balochistan as the smallest demographic entity in the country [9]. The study area is located from 25^0N to 32^0N latitudes and 62^0E to 70^0E longitudes. It covers the southwestern part of the country and is bounded by the Punjab province in the northeast, Sind province in the southeast, the Arabian Sea in the south, Iran in the west, Afghanistan in the northwest and Khyber Pukhtunkhwa in the North (Fig.1).

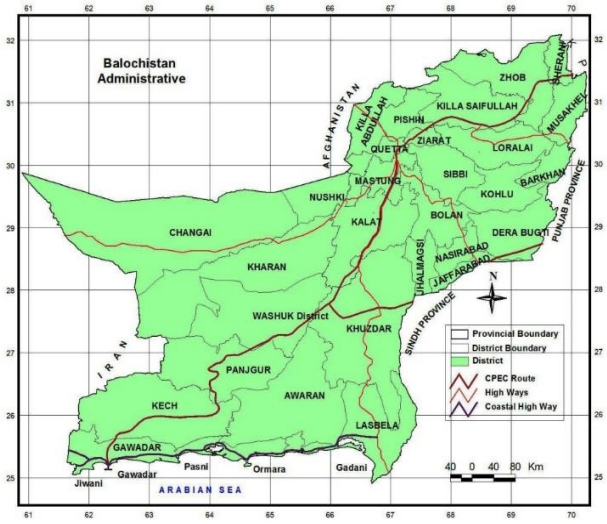

Fig. 1: Balochistan Province, Location map

II. METHODS AND MATERIALS

Precipitation has been considered as an independent variable while; temperature, cotton, sugarcane, tobacco, wheat and rice as independent variables for the period of 1982-2009. The main targets of the work were to evaluate the fluctuation of mean monthly precipitation and temperature and its effects on the productivity of the major crops produced in Balochistan Province. Primarily, annual and monthly means, as well as the deviation from the average condition, were calculated for all research indicators and presented in tabular form. Monthly and annual temperature and rainfall data were then transformed into seasonal deviations and averages. Depending on the degree of hotness, the study area was divided into two foremost seasons (summer and winter) that were then sub-divided into cold, mild, warm and hot seasons.

Years in the series, whose worth is beyond the mean level are deemed wet (precipitation) and hot (temperature), while the opposite was declared as cold/dry. The subtraction from the average was calculated for all years and the sums of that deviation reveal high/low in precipitation, temperature and crop production. The change of the two meteorological components and crop yield matched with each other for the analysis of the data. The criteria adopted for the selection of the arid areas is rainfall, less than 10 inches (245 mm), while precipitation is between 10-20 inches (508 mm) for the semi-arid areas of the province.

The winter in plain runs from November to March (five months) and in the hilly areas from October to April (seven months). Likewise, the summers in the plains extend from April to October (7 months) and in the mountains from May to September (5 months). The yearly cycle of precipitation on two occasions reveals a negative and positive departure from the average state. Consequently, the summer and winter seasons are sub-classified into winter rainfall (December to mid-April), pre-monsoon (mid-April to June), monsoon (July to mid-September) and post-monsoon (mid-September to November). There are two main seasons of cultivation in Balochistan: “kharif” and “rabi”. *Kharif* is the summer, whereas the rabi is the winter period [16].

The geographical layers of the Balochistan map and agriculture distribution have been digitized from 1:250K and 1:50K geological maps and renewed from Google Earth. The main

elements considered for the vector layers are cultivated area, rain-fed, build up land, flora, hills, exposed land, drainage, sands and wetlands. All land features were digitized into a layer and then split using unique coding into the vector layers using Map Info as well as ESRI software (Environmental Systems Research Institute, Inc.). Layers were switched into KMZ files (Keyhole Markup Language) to update data based on current information available on Google Earth. Furthermore, the statistical tools like sum, mean, deviation and regression as well as variance have been calculated for the purpose to analyze the existing change in the data and understanding the future trend of weather fluctuation in the area thus compiling it in the shape of a report.

III. RESULTS AND DISCUSSIONS

The average temperature of the province is 22.2 ^{o}C with annual precipitation of 2.3 cm. The province recorded a high temperature of 31.3 ^{o}C in June and a low temperature of 10.8 ^{o}C in January and was declared the hottest and coolest months of the year, respectively (Table 1). The annual temperature condition of Balochistan shows that it increases from January to June and declines onward till December with the arrival of monsoon lows in the area. The highest mean monthly temperature of 27.5 ^{o}C is recorded at Sibbi and the lowest of 13.91 ^{o}C at Kalat (1982-2009). Balochistan signifies marine climate in the south and arid continental climates towards the north, which is further categorized into arid plain continental and semi-arid mountainous climates with a pure desert climate in the southwest at Kharan (Fig-2).

Table-1: Balochistan, Mean Monthly Precipitation and Temperature 1982-2009 (Source: GoP, 2021)

Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave/Sum
Temperature	10.77	13.30	18.51	24.05	30.14	31.24	29.97	28.95	26.81	22.81	16.83	12.12	22.13
Deviation	-11.36	-8.83	-3.62	1.92	8.01	9.11	7.84	6.82	4.68	0.68	-5.30	-10.01	-0.0484
Precipitation	0.34	0.32	0.48	0.43	0.23	1.32	19.07	1.10	0.69	0.30	3.09	0.24	2.30
Deviation	-1.96	-1.98	-1.82	-1.87	-2.07	-0.98	16.77	-1.20	-1.61	-2.00	0.79	-2.06	-0.0005

3.1. Climate Fluctuation

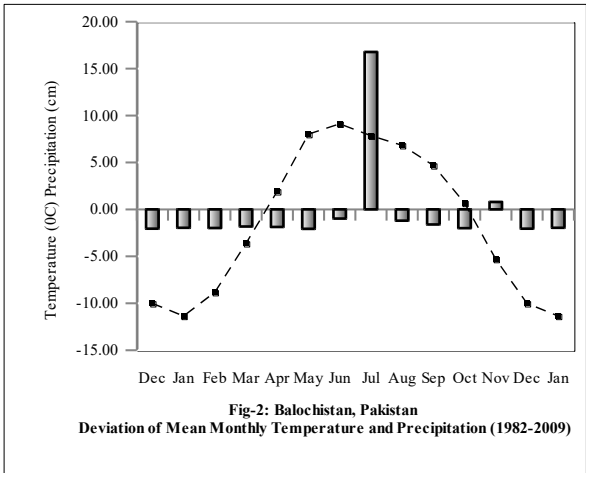

Fig-2: Balochistan, Pakistan
Deviation of Mean Monthly Temperature and Precipitation (1982-2009)

The Temperature and precipitation are the utmost elements of weather because it is hard to overcome the issues of environmental change without knowing its fluctuation and variations. The area is moving towards more severe climate change conditions with the time that will ultimately affect the hydrology, ecology, economy, biodiversity, urbanization, industrialization, mining, crops production, trade and business in the area.

The sum of deviation of the mean monthly temperature of Balochistan reveals a decrease of -0.05 ^{o}C and the mean monthly precipitation of -0.0005 cm (Table-1). The highest deviation of mean monthly precipitation of 16.8 cm has been noted in July and the lowest negative deviation of -2.07 cm in May which are declared as the wettest and driest months of Balochistan (Fig-1). The annual series of mean monthly temperature and precipitation reveals a direct relationship with each other. As far as the annual deviation cycle of mean monthly temperature has been concerned, it has remained low/high from the mean condition after every three years and indicates a variance (R^2) of 0.01 ^{o}C, which is below the normal condition and being declared non-satisfactory. The annual series of deviation of mean monthly precipitation shows that it has remained below average from 1982 to 2001 and rose onwards till 2009. The variance (R^2) of the mean monthly precipitation is 0.55 cm which indicates a normal sign for the future. The linear trend of both variables indicates an increasing trend throughout the series (1982-2009) and will cause serious environmental issues like floods, droughts, desertification, and a decrease in crop production, economy, hydrology, physiology and ecology in Balochistan.

The mountainous north of the province (Quetta, Zhob, Barkhan, and Kalat) reveals a rise in the precipitation condition with a decrease in mean monthly temperature (inversely proportional) except in Kalat, where it is directly proportional to each other (Fig-1 & Fig-2). The Sibbi region (Sibbi and Khuzdar) shows an increase in the precipitation condition however, there is a rise both in temperature as well as precipitation indices at Sibbi area and the climate becoming worst as compared to before. The southeastern region of the province covers the Lasbela Sarawan area, where both the mean monthly precipitation and temperature are above average and show a rising trend for the future.

The southwestern region of the province comprises of Dalbandin, Nokkundi and Kharan observatories, where there is a rise in mean monthly temperature and a visible decrease in the mean monthly precipitation while the region is going towards severe desertification and drought conditions. The coastal region of the province (which is the main hub of trade and commerce for the entire region in the future) comprises Gawadar, Jiwani, Ormara, and Pasni observatories. There is a certain rise in temperature conditions in overall observatories with a declining trend in the mean monthly precipitation except for Ormara where the precipitation is above the mean condition. The average (R^2) variance of mean monthly temperature over each observatory in Balochistan is 0.35 ^{o}C and the mean monthly precipitation is 0.02 cm, which is below the normal condition and signs of environmental threats in the future throughout the province.

3.2. Climate Change Effects on Major Crops

Generally, rice, sugarcane, and cotton are the major Kharif crops, whereas wheat and tobacco are rabi crops. The total area of Balochistan is 34719 thousand hectares [16] comprised of 2493.7 thousand hectares (7.2%) of cultivated and 15448.6 thousand hectares (44.5%) of non-cultivated area. The non-cultivated area consists of 3897.2 thousand hectares of cultivated waste, 1716.8 thousand hectares of forests, and 9834.6 thousand hectares of non-arable land. The net sown area of the province is 1115 thousand hectares (3.2%) with 7.1 thousand hectares (0.03%) sown more than once, while 45% of the land is covered by mountains, desert and coastal marshy lands.

Cotton is the core cash and the Kharif crop of Balochistan. The total cotton cultivated area of the province is spread over 13.8 thousand hectares having a production of 36.2 thousand bales. The total share of Balochistan in the cotton production of Pakistan is 3013.5 thousand bales) which is 1.2 % of Pakistan production during 1982-2009. The share of the Balochistan province in the national economy is very low as compared to the available cultivated land.

Table-2: Balochistan, Deviation from the mean of Cotton, Sugarcane, Tobacco, Wheat and Rice at District Level (1982-2009)

Location	Cotton	Sugarcane	Tobacco	Wheat	Rice	Location	Cotton	Sugarcane	Tobacco	Wheat	Rice
Quetta	-1.3	-1.1	-118.3	-17.5	-4.7	Jafferabad	1.3	0.5	-118.3	91.4	51.6
Pishin	-1.3	-1.1	1944.0	6.8	-4.7	Tomboo	-1.3	0.0	-118.3	9.1	-4.7
Killa Abdullah	-1.3	-1.1	-102.1	-21.4	-4.7	Bolan	0.0	-1.0	-118.3	-9.5	-4.5
Chagai	-0.4	-1.1	-118.3	-7.0	-4.7	Mastung	-1.3	-1.1	-118.3	-7.2	-4.7
Loralai	-0.4	-1.1	-94.8	5.9	-4.7	Khuzdar	4.1	-1.1	-118.3	52.6	-1.8
Musa Khail	-1.3	-0.9	-117.6	-20.9	-4.7	Awaran	-0.8	-1.1	-118.3	-19.3	-4.7
Barkhan	0.6	-1.1	-117.7	-10.5	-4.7	Kharan	-0.6	-1.1	-118.3	-7.7	-4.7
Zhob	-1.3	-1.1	108.8	-17.1	-4.7	Lasbela	3.3	7.6	-118.3	-17.9	-4.7
Killa Saifullah	-1.3	-1.1	838.4	-10.0	-4.6	Turbat	-1.3	-1.1	-118.3	-21.3	-4.7
Sibi	2.1	8.2	-118.3	1.2	-4.7	Panjgoor	-1.3	-1.1	-118.3	-20.8	-4.7
Ziarat	-1.3	-1.1	-118.3	-22.9	-4.7	Gwadar	-1.3	-1.1	-118.3	-22.8	-4.0
Kohlu	0.5	-1.1	-118.2	-14.2	-4.7	Jhal Magsi	-0.6	-1.1	-93.7	-1.7	-4.7
Kachhi	-0.1	-1.0	-118.2	-11.5	54.3	Kalat	-1.3	-1.1	-118.3	-0.3	-4.7
Dera Bughti	-0.5	-1.1	-118.3	-18.9	-4.4	Sum	0.1	-0.1	-0.1	0.0	-0.1
Nasirabad	8.3	9.3	-118.3	133.8	7.7						

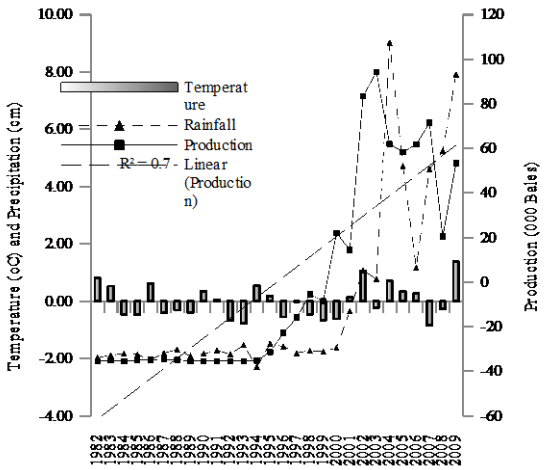

Fig-3: Balochistan
Deviation of Temperature, Precipitation, Cotton Production(1982-2009)

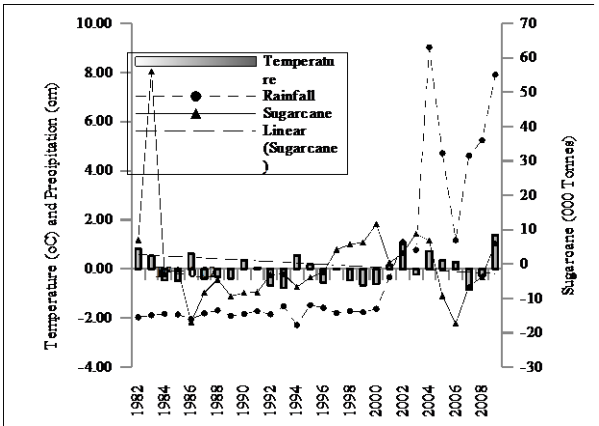

Fig-4: Balochistan
Deviation of Temperature, Precipitation, Sugarcane Production (1982-2009)

Cotton production in Balochistan is at a high menace in the durable climate fluctuation (Fig-3 and Table-2) and requires special attention to overcome the issue. The major cotton cultivated areas of the Balochistan province comprises Nasirabad (3.8 thousand bales), Khuzdar (2.1 thousand bales) and Lasbella (1.7 thousand bales), while the areas where its production is less than one thousand bales consists of Chagai, Loralai, Barkhan, Kohlu, Kachhi, Dera Bugti, Jaffarabad, Bolan, Awaran, Kharan, and Jhal Magsi districts. Figure 3 and Table 2 show the contrast of deviation from the mean among precipitation, temperature and cotton production. During 1982-2000, the temperature, precipitation and cotton condition indicate a direct relationship with each other throughout the series. Overall, cotton production shows an increase throughout the series; however, this production is very low as compared to the available vast land of Balochistan province. The variance of cotton production is 0.7 thousand bales, which is above the average value and shows a satisfactory condition.

The major sugarcane harvested areas consist of Kalat, Bolan, Nasirabad, and Sibbi districts with moderate/intense temperature and average precipitation conditions (Fig-1). The same weather condition also exists in the Pashin, Chaman, Loralai, Barkhan, Zhob, Lasbella and Khuzdar districts, but due to the non-availability of water resources and manpower; it is hard to promote sugarcane cultivation as well as the sugar industry in these areas. The sugarcane cultivated in 0.7 thousand hectare area added almost 63.6 thousand tonnes of production to the national value.

There is no sugar mill in Balochistan since Pakistan's independence to date to promote its product value and local interests. Resultantly, the share of the Balochistan province in the production of sugarcane is going to decline over time and shows a sum of -0.1 thousand tonnes decrease during 1982-2009 (Table-2). The comparative analysis of sugarcane, precipitation and mean monthly temperature reveals that the deviation from the mean production of sugarcane is above the average level during 1982-85 which turns into a negative trend from 1986 to 2005 and rose onwards till 2009 (Fig-4 and Table-2). It is directly proportional to temperature and inversely proportional to the available showers and is mostly based on irrigation from khushkaba, sailaba and karaze systems. The regression value of the sugarcane production of the province is 0.02 thousand tonnes, which is below the average and shows non-satisfactory signs for the future.

The total share of the Balochistan province in the harvesting of tobacco is 2163.8 (0.006% of total Balochistan) hectares having an annual production of 3311.4 tonnes. The major tobacco cultivated areas of the province comprise Pishin, Killa Abdullah, Loralai, Musa Khel, Barkhan, Zhob, and Jhal Magsi (Fig-5 and Table-2). The annual trend of tobacco cultivation, temperature and mean monthly precipitation plotted on fig-5, shows a marked decrease (-0.1 tonnes) in the annual production of the crop, having a regression value of 0.04 tonnes and indicates an alarming situation. Generally, the tobacco yield of the province is directly proportional to temperature and inversely proportional to the precipitation condition. The linear trends of the crop production indicate a decrease throughout the series and needs investment in this sector massively.

It is both a food and a cash crop that is cultivated in 132.4 thousand hectares area of Balochistan with a total production of 361.8 thousand tonnes. The major rice cultivation areas of the province are located in the surroundings of Nasirabad, Killa Saifullah, Bolan, Khuzdar and Zhob districts having hot short summers and long cold winters. The annual trend of deviation

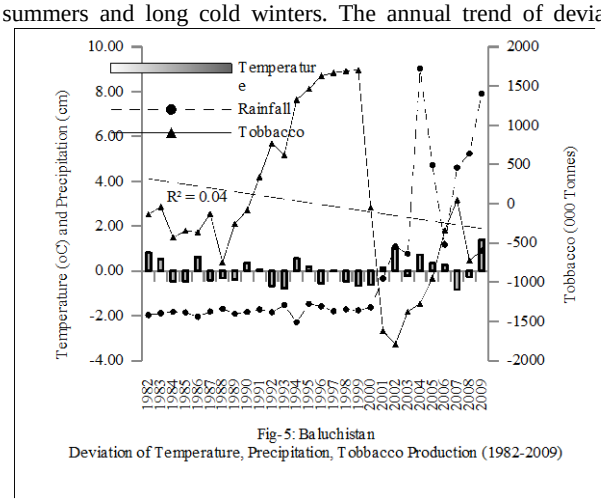

Fig-5: Baluchistan
Deviation of Temperature, Precipitation, Tobbacco Production (1982-2009)

from the mean level of rice harvesting, temperature and precipitation reveal an increasing trend in the rice production during 1982-2009 (Fig-6 and Table-2); however, the sum of deviation indicates a -0.003 thousand tonnes decrease in the provincial production of rice throughout the period.

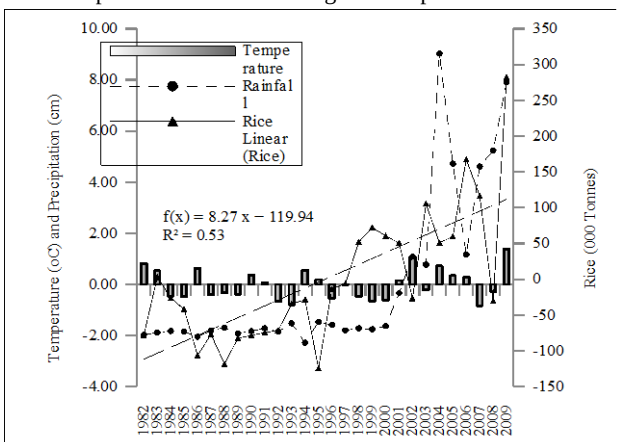

Fig-6: Baluchistan
Deviation of Temperature, Precipitation, Rice Production(1982-2009)

The regression value of the rice production is 0.53, which is an almost in stable condition. The linear trend of rice production shows a direct relationship with temperature and atmospheric moisture throughout the study period. The total wheat cultivable area of Balochistan is 322.7 thousand hectares having a total production of 642.9 thousand tonnes. The leading wheat cultivated district of the province is Nasirabad with an annual production of 156.7 thousand tonnes. The deviation of wheat yield, temperature and precipitation show an increasing trend throughout the series with a regression of 0.49, which is near to satisfactory level (Fig-7 and Table-2). Generally, wheat production shows a positive relationship to the precipitation and temperature condition. However, the province is still not stable in the production of wheat (-0.1 thousand tonnes decrease) and is mostly dependent on the national production.

IV. CONCLUSION

Balochistan, the largest province of Pakistan by area, is experiencing an arid and semi arid climates. Both mean monthly temperature and precipitation indicate a negative deviation with a fall in the production of all crops. Due to aridity, drought conditions, water scarcity, scare precipitation, high temperature, evapotranspiration and lack of mechanization as well as technology, the area is not able to participate in the national GDP

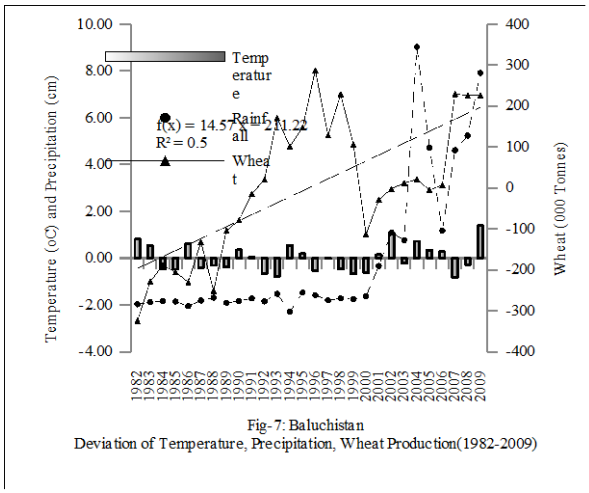

Fig-7: Baluchistan
Deviation of Temperature, Precipitation, Wheat Production(1982-2009)

and required special attention. The northern, central, and southeastern part of the province is more suitable for the cultivation of major crops but there is a lack of expertise and water resources. The current production of the major crops in the province is very low as compared to its total acreage. The crop yield is even not enough for the survival of the local communities and the province mostly relies on other provinces. Therefore, it is concluded, that the existing climate change in the province is threatening for both kharif and rabi crops and required adaptation.

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