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A Review on Climate Change, Vulnerability to Major Crops and Biotechnological Adaptations in Pakistan

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ABSTRACT

In the drivers of globalization, climate change is a major concern on global level but not only on globe scale but in Pakistan also. Climate change and its tremendous climatic conditions are threat to major crops of Pakistan. So, Pakistan is one of the vulnerable countries to climate change. In this study, we will examine the major crops like wheat, rice, cotton, sugarcane and maize and how these crops effecting by climate change and its harsh conditions including maximum and minimum temperature, rainfall pattern/precipitation, and relative humidity and day night effects. Studies reveal that maximum temperature is harmful for wheat production but optimal temperature is positively important for all crops (cotton, sugarcane, maize and rice). Precipitation has negative effects on all crops except rice. To overcome the effect of climate change modern technologies of biotechnology can be used that are drought resistant including genetically modified plants that can grow under stress, energy-efficient and transgenic plants of high yield. Good biotechnology improvement is contributing in increasing the agricultural productivity.
KEYWORDS: Climate change; Pakistan; Production; Major crops; Biotechnological agricultural development

INTRODUCTION

Evidence shows that there is increase on global temperature since 19 century [16]. The first decade in previous 21 century recorded the warmest decade as compare to previous decades. Since 1950 the global temperature has been increased by 0.72% [16]. Due this phenomenon there is decline in number of cold days and nights and increase in hot and dry days and nights. Intergovernmental Panel on Climate Change (IPCC) reveal that change in climate is contributing in the global warming by emitting greenhouse gases include vaporous gases, carbon dioxide which is main contributor of global warming. IPCC also studied that at the end of 21 century temperature increase by 0.3 – 4.8^{0}C [7].Other gases that bringing change in climate include methane and nitrous oxides also changing rainfall pattern, temperature and negative effect on ecological resources e.g. water and land resources. All these factors that contributing the change in climate also casing phenomenon of flooding and drought. The change in temperature causing intensification of greenhouse gases. The consequences of these variations in weather causing glacier melting, increase in rainfall and shifting in seasons as prolonged summer season.

Climate change is a global phenomenon that is not only present on global level but widely increasing in developing countries including Pakistan. The increasing trend of climate change in developing countries is due to more vulnerability and less remediation to overcome the climate change. Developing countries including Pakistan that relay on agricultural sector. During the last 50 years this division is realized as a major industrious sector of Pakistan's economy. 61% population is living in more than 50,000 villages in Pakistan. This sector is at more risk because agriculture is effecting badly due to extreme temperature. Other factors like high precipitation, flooding, drought, degradation of land resources also causing damage to agriculture [22]. As agriculture is more susceptible to change in climate. Due to climate change the production of pests and weeds reducing the requires yield of crops.

Change in precipitation pattern causing the short and long run deterioration of crops. It is predicted that till 2050 about 9 Billion people will face the problem of food uncertainty due to reduction in agricultural yield. The countries at low altitude including arid and Sami-arid areas where availability of water is low are at most risk to climate change effect on crop yield. Studies revealed that about 1-2^{0}C warming temperature is threatening to crops. This is due to decrease in moisture content in soil and increase in evapotranspiration of the plants. According to the IPCC scenario of future emission of CO_2, now the concentration of CO_2 is about 379 ppm but in future it could be reached at 550 ppm in 2100 [39]. Carbon dioxide act as fertilizer to crops and enhance the ability of photosynthesis. So, increase in the concentration of CO_2 is beneficial to crop yield but on other hand it is major contributor in climate

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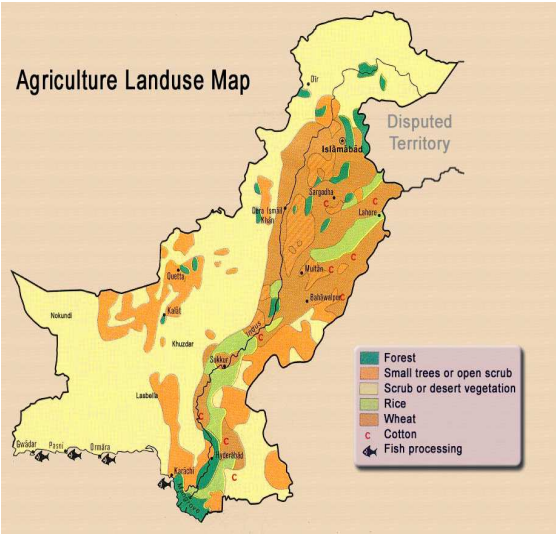
change as greenhouse gas. Extreme events of climate change effecting crop production as increasing phenomenon of droughts and flooding causing damage to agricultural lands which is decreasing the yield of crops and decline economic activities [4]. Thus, to meet the reducing goals of greenhouse gases there is need to require mitigation strategies to overcome the change in climate.

Agriculture in Pakistan

Agriculture sector is the backbone of Pakistan's economy. This sector makes the 26% of gross domestic production (GDP) and supporting a large of population. Major crops of Pakistan including Rice, wheat, maize, sugarcane, cotton, fruits and vegetables that all vegetated by irrigation system which is consider as world's largest irrigation system. There are two seasons for crop production one is from May to November for production of cotton, rice, maize and from November to April for wheat production. This sector involves in the great economic role of export and import and enhancing the irrigation and marketing green revolution system [34]. The annual export of Rice is about 2 million tons worldwide. Rice is fulfilling the 60% of population food needs [8-19]. Pakistan share 9.8% cotton worldwide and largest cotton producer ranked as 4th in the world in 2011 - 2012. It provides employment to about 35% of population in Pakistan [12-15]. Maize is also cash crop of Pakistan. Sugar cane contributing in 0.7% of GDP of Pakistan and it is using as biofuel in the world [35].



Source: Pakistan Metrological Department

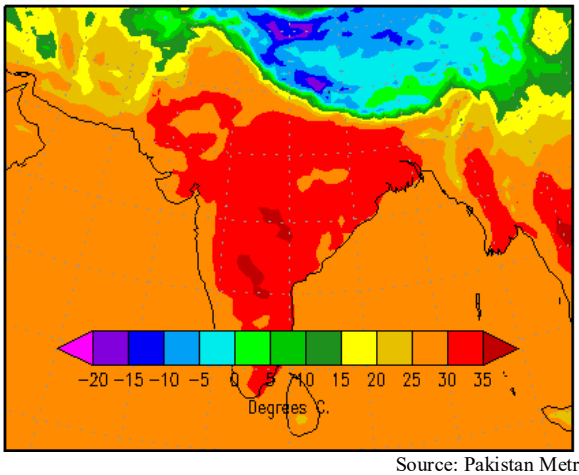
Figure 1: Land use and agriculture map of Pakistan

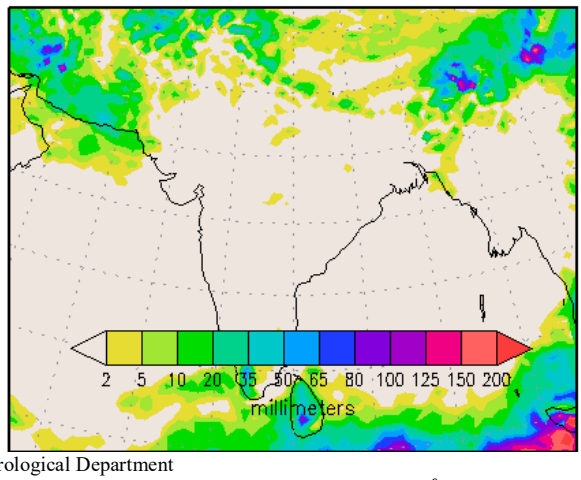
All crops depend on the water for growth but the availability of water effect the yield of crops which is predicted to decrease about from 1995 to 2020 in the range from 72-62% in developing countries [20]. There is great challenge for agriculturalist to produce sufficient crop for the growing population in Pakistan [12]. Therefore, it is suggested that there is need for the new and developed agricultural funding programmes in Pakistan.

Climate change in Pakistan

In most of the climate change susceptible countries Pakistan is ranked eight according to German Watch. In 2008 Pakistan's total emission of GHG were 310 million tons equivalent to carbon dioxide. According to National GHG inventory 2008 the amount of greenhouse gases is Carbon dioxide 54%, methane 36%, nitrous oxide 9%, Carbon Monoxide 0.7% and VOCS 0.3%. climate change effecting the volume of rivers of Pakistan by melting of glaciers. Studies investigate that the climate of Pakistan is getting harsh due to ongoing increase in temperature and temperature.

A global emission scenario predicted that Pakistan's temperature is rise by 3 – 5^{0}C at the end of this century. IPCC predicted that is would be higher rate of increasing temperature than global level that will impact the glaciers and monsoon rainfall pattern. As a result, this will damage the yield of agricultural crops and energy sector which relay on water availability.





Source: Pakistan Metrological Department

Figure 2: Predicted precipitation (mm) ***Figure 3: Average temperature (^{0}C)***

Figure 2 and 3 shows the predicted outlook of change in temperature and precipitation from April 7 to April 10 in 2013 according to Pakistan weather porta

Crop yield response to Climate change

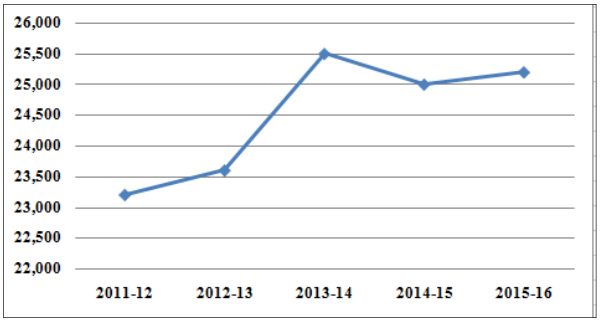
To study climate change impact on agriculture sector in Pakistan it is also important to study the sensitivity of crops in harsh temperature. There is increase in CO_2 concentration due to climate change that may positively effect the crops and increasing temperature and precipitation effect the biological activities to work efficiently in growth of crops. We observed 30% production loss due to climate change. The antagonistic effects of climate change on the agricultural sector of Pakistan could cause devastation in the country. Due to loss of 2.6 million acres of land resources and increasing flooding given rise to increase in food prices. Most of the industries are effecting due to climate change because they are dependent on agriculture.

Rabi and kharif are two crop seasons in Pakistan. Rabi grown in November to April month and kharif crops grown in May to October. These two seasons make Pakistan an agricultural country and its performance depends on the climate during the whole year. Climate changes generally affect agriculture through changes in temperature, precipitation. Since 2010, the agricultural sector is at more risk in Pakistan due to facing three major flood events in 2010, 2011 and 2014that effect the economy of country. These major events destroy the main crops including vegetables and fruits.

Wheat

Wheat is imparting 9.9% of the agricultural value and 2% in GDP of Pakistan. Winter plants require minimum temperature of 5 to 10^{0}C. Wheat is also a winter crop that need cold temperature for the dormancy period before flowering season. But the higher temperature increases the weed, disease and pests attack on plants that could effect the vernalization process in wheat. Wheat is the first most crop that effect by climate change because it need coolness and moisture to grow. But this changing weather causing prolonged summers shorter winter seasons. In some places monsoon rainfall pattern also decreasing. Many studies show that wheat is at more risk that other crops to climate change because it needs optimum temperature as compare to other crops: maize, rice, sugarcane and cotton [28].

Wheat yields in winters were likely to decrease by about 14% by 2080. A researcher concluded that wheat yields about 0.3% reduces by 1% increase in temperature. It was resolved that drought considerably reduces wheat productivity. Wheat is amongst C3 crops category. Photosynthesis process suppresses transpiration in C3 crops due to increase in concentration of CO_2. These factors cause to accelerate the growth of wheat plant. However, the CO_2 beneficial effect is offset by increase in temperature. Precipitation also increases the wheat production. From all perspective, it is concluded that climate change is most damaging to wheat because it is temperature sensitive crop. If Pakistan do not adapt the changes in agricultural practices they will lose the productivity of wheat at the end of 21 century. For example, every year in Pakistan floods damage the wheat and other crop production on large number of hectors.



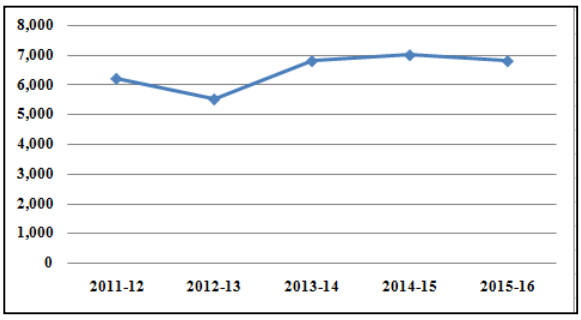
Source: Pakistan Bureau statistics (PBS)

Figure 4: production of wheat (000 Tonnes) in Pakistan

Rice

Rice is second staple crop after wheat and has an important share in export. Rice is grown on different soil characteristics because of its various geographical distributions in worldwide. At the end of this century rice crop is expected to encounter 15-20% reduction due to climate change which is twice of wheat production. Temperature rise was found important for rise production at first when temperature increases beyond certain level the production became destructive toward its production. Study shows that temperature increases by 1.5 - 3.0^{0}C will enhance the production but increase in more temperature will hurt the rice production.

There was a continuous decline in the yield of Basmati rice in the semi-arid plains of Pakistan increase in temperature up to 5°C.There was about 6% decline in the simulated yield by 1^{0}C increase in temperature; 12% decrease in grain yield by 2^{0}C increase in temperature but beyond that the decrease was higher. It was studied that extreme climatic events like heat stress, salt stress, droughts and flooding may damage the rice production [27]. It is drought sensitive so in rain fed system yield may reduce due to climate change factor. It was projected that against temperature studies shows that increase in 1°C temperature the production of rice increases by 16% but reduce yield at 4°C. Carbon dioxide play vital role in photosynthesis. Hence for plant growth increases in carbon dioxide concentration would increases the rate of plant growth and productivity. Due to fertilization effect on crops with C3 photosynthetic pathway, like rice and wheat.



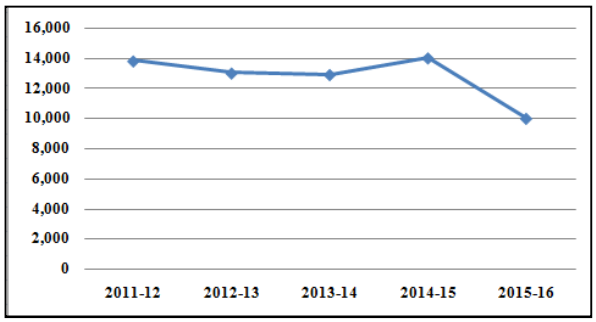
Source: Pakistan Bureau statistics (PBS)

Figure 5: production of Rice (000 Tonnes) in Pakistan

Cotton

Cotton is considering as cash crop for the rural areas of Pakistan because it is source of livelihood for people. It is playing energetic role in the economy of Pakistan [31]. Cotton is grown in hot areas of Pakistan. It is grown in humid and hot areas because it is pest hazardous that suppress the quality of its yield. Major effect of climate change on cotton production due to greenhouse gases emission and leaching effect due to climate change [18]. As the leaching factor effecting the most water bodies of Pakistan by nitrates coming from runoff that is using in agriculture and harmful for cotton productivity [1]. The growing abilities like boll size, seed per boll, reduction in fiber length that all effect the yield of cotton at maturation level due to increase in temperature [33]. The adverse impacts of climate change crop yield differ due to existence of harsh climatic conditions during growth stage. The marginal impact show that 1^{0}C in temperature during sowing season of cotton would increase yield by 1.65%. Since

cotton is heat tolerant crop, heating up of climate during sowing, flowering and picking stage will help increase in yield but further increase in temperature cause negative impact on productivity of cotton. As in Karachi due to increasing temperature and heat wave cotton yield may effecting. Another impact of higher atmospheric CO2 is that weeds will be growing more strongly as well. Precipitation has normally very small impact on yield of cotton. Cotton is grown by using various additional water sources in watered areas [37] show that precipitation reduces the yield of cotton. Temperature is beneficial and precipitation is harmful for cotton productivity. There is projection of high rainfall at the end of 21 century that is damaging to cotton productivity.



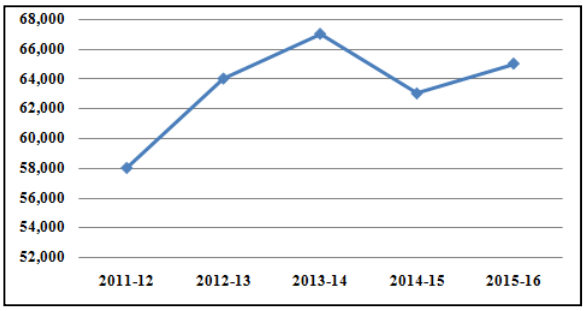
Source: Pakistan Bureau statistics (PBS)

Figure 6: production of cotton (000 bales) in Pakistan

Sugarcane

Sugarcane with high economic importance is growing in tropical and subtropical areas. Over the world in 2014 sugarcane grown in almost 27 million hectors in different countries [14]. Pakistan is ranked as 4th in the production of sugarcane [14]. Its production accounts for 0.6 percent in overall GDP of Pakistan. As it is not only produce as source of sugarcane but also using in industries as sweetener industries and residue (bagasse) may use in fuel production and electricity in sugar mills. Sugarcane need temperature range 30-32°C but above 34°C is unfavorable for crop growth [6-17]. Like other factors that controlling the bud development of sugar the rate of photosynthesis is also dependent on temperature, 8°C to a maximum of 34°C increase in temperature increase the photosynthesis efficiency. 14°C temperature in winter Cool nights and early morning and 20°C in summer significantly inhibit photosynthesis. By onset of mean day temperatures less than 21°C the peak growth of sugar-cane will have terminated because stalk is sensitive to temperature. Additional decrease in rainfall effect negatively on sucrose yield while increase in temperature of 2-3°C is beneficial for sucrose growth [21].

As a C4 crop it is studied that increasing carbon fertilization due to increase in temperature is beneficial effect of climate change [9]. Carbon consumption slow down by cool nights and sunny days, while photosynthesis may continue, thus enhancing sucrose accumulation. At high temperatures accumulation of sucrose is not favored as growth rate increases more than photosynthetic rates. Water logging is also a widespread phenomenon that drastically reduces the growth and survival of sugarcane and 18–64% reduction in cane yield due to water logging, depending on duration of water logging, plant growth stage. A shift in temperature due to climate change will effect on sugarcane production by attack of some of diseases, insects, and weeds. Sugar cane is effected by rainfall but resilience to temperature.



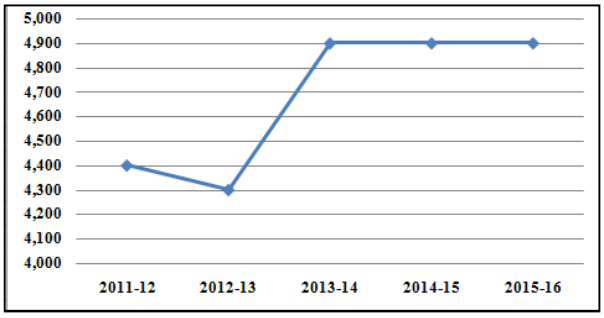
Source: Pakistan Bureau statistics (PBS)

Figure 7: production of Sugarcane (000 Tonnes) in Pakistan

Maize

Most of the population in the world is relay on organic food which is rich with nitrogen but unfortunately the production of organic crops like maize is suppressing due to leaching effect in water bodies [23]. Maize contribution in agriculture is 2.2% and 0.4% to GDP of Pakistan. Maize is able to utilize solar and can tolerate relatively high temperature being a C4 plant up to a crucial factor. Development of plants and the yield may be reduced to 101 kg per hector per day when the temperature ranges up to 35ºC in pollination. The most distressing factor that regulates the crop growth and definitive yields is high temperature. Maize can grow at the temperature range of 29ºC and optimum maize production at 25ºC. increase in temperature by 1 degree e.g. 30ºC will reduce yield by 1% under rainfed condition [25]. Other studies show that increase 1ºC will reduce 10% yield under normal condition [3].

Leaf growth in maize has been reported from 0 -350 ^{0}C, with decline at 35 -400^{0}C. Decline in photosynthesis and protein metabolism alter the aggregation, enzyme inactivation, repressed protein synthesis and its degradation was noted. Heat shock affects the endosperm development in maize and reduces grain yield due to disruption in cell division, sugar metabolism and starch biosynthesis. These studies suggest that due to increase in temperature maize not only effected by temperature stress but also become moisture sensitive. Overall the production of maize will decrease in future due to climate change scenario.



Source: Pakistan Bureau statistics (PBS)

Figure 8: production of Sugarcane (000 Tonnes) in Pakistan

Biotechnological adaptation options

To enhance the production of crops different adaptation techniques can use including soil health, conservation of water, diversity of livelihood, institution of local level [13]. All safety adaptations to effected groups provide application to efficient management of water, land and soil resources [30]. The production of cops is reducing due to changing in rainfall pattern, increase in temperature and attack of pests, weeds and diseases as a result of climate change. The productivity of crops per unit area can be improve by applying agricultural biotechnologies that enhance the crop yield and make crops able to cope harsh climatic conditions.

1. **Increase in area of land for yield**

To accomplish the need of nutrition crops over the world there are two options: first is to rise the production land and second is to enhance the farmland production of crops [10]. The second option is more practicable because of changing climate change dynamics and availability of arable land for the production. There are some modern and sustainable options to increase productivity including utilization of organic residue as a for nutrition of plants, efficient agricultural performs e.g. managing the landscape, crop revolution. The other factors to decrease the pest and diseases attack use of non-chemical traditional and local knowledge to farmers [2].

2. **Biotic stress resistant adaptations**

In this scenario of climate change the aim of biotechnology is to use fewer resources for sustainable productivity and capacity of crops. The production of stress that are resilient to insects, fungi and bacteria that are biotic stresses on crops can be developed by useful landscape practices increase breeding [41-2]. To produce protection against the insects, biotechnology provides the soil bacterium (Baccilus) that transform the genetic makeup of crops like maize and cotton that play a vital role in the pest control strategies. Studies shows that the productivity of crops by 11-12% e.g. canola and maize has been increasing by using biotic stress resistant genetically modified crops.

3. **A biotic stress resistant adaptation**

The challenges of climate change that impose negative impact on agriculture include shortage of land use and availability of water for irrigation. A biotic stain that poses negative impacts on environment due to climate change

are salinization, drought events, toxicity by chemicals and increase in temperature. Therefore, biotechnology provide adaptively measure to overcome a biotic stress like droughts and salinization.

***Drought and salt resistant crops*:** production in forests is a programme of biotechnology that are developed by breeding. There is selection of some drought resistant plants like millet, cassava and sunflower that grown by conventional method in extreme climatic conditions to resist the harsh environmental conditions [26].

***Molecular control mechanisms*:** In which production and regulation of genes that are stress tolerant. Some kinds of transgenic species produce that are metabolic, ion transported, antioxidants and less toxicants process to tolerate climatic stress. Other engineering method to cope these conditions include process of heat shock and heat resistant proteins. The activation and regulation of definite stress tolerant genes against abiotic stress[42]. The production of genetically modified enzyme like ADP ribose that can survive in harsh conditions. Studies shows that 44% of crop yield has been increased by using GM plants [5].

4. Agroecological and agroforest

The management approached of farmers to reduce the ecological and economical risks of crop damage by using different application to regenerate degraded soil and forests like mycoforestry and mycorestoration that resist extreme climatic conditions. To increase the ability of water uptake and fertility of soil technologies like mycorrhizal fungi and actinorhizal bacteria can be used [37].

Afforestation is also a contributing factor in lowering extreme temperature because forest and trees are carbon sinks that cause rainfall and reduce greenhouse gases. This is sustainable and effective mitigation method for climate change.

5. Biofertilizers

Biotechnology providing the new methods of using bio based fertilizer instead of artificial fertilizer like composting humus and animal manure. Also, production of non-leguminous plants to fix nitrogen in soil for the improvement in production of cereal crops[19]. For example, GM canola which is nitrogen efficient and economically beneficial for farmers [40].

Conclusion

The study shows that climate change prevalently effecting main agricultural crops. The result asses that wheat productivity is reducing due to short changes in temperature but long run increase effect positively on wheat production. Likewise, the changing in precipitation negatively effecting the wheat production in both short and long term. Rice production is initially grown by increasing temperature but further increase in optimal temperature will harmful for productivity. As wheat production reduce by increasing precipitation rice will not effected by this increasing phenomenon. Interestingly, the increase in precipitation does not harm the rice productivity. It has been obvious that the change in temperature and precipitation as variables of climate has a substantial negative impact on cotton productivity. As increase in temperature is advantageous but increase in precipitation is harmful for cotton productivity. Other crops like maize and sugarcane negatively effecting by increase in temperature. To overcome the problem of food security the mostly adaptive method is irrigation in rainfed areas that could be enhanced but farmers cannot afford. Farmers should adopt water and soil conservation methods for resilience to future climate change. The production of drought and heat resistant crops is effective method to cope harsh conditions of climate change.

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