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Implications of Climate Change on Agriculture Sector of Pakistan

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Abstract

Climate change is a significant phenomenon with socio-economic effects that concern experts. Pakistan, with its diverse geographical features, is particularly vulnerable to such climate changes. Its long latitudinal area covers almost 5000 glaciers in the northern areas, which remain frozen and provide water throughout the year. The melting glaciers in northern areas and rainfall from the Arabian Sea play vital roles in water supply, agriculture, and energy production. However, Pakistan ranks at number 7 in the Global Climate Risk Index of 2017 which lists Pakistan as the most vulnerable country to climate change. It faces grave threats due to climate change and perhaps it is at the crossroads of climate change effects. These risks are further aggravated by high rates of nutrition and food insecurity. Due to changes in climatic conditions, weather becomes more erratic, resulting in severe climatic disasters which ultimately lead to food insecurity in Pakistan. It is estimated that climate changes affect every facet of food security in Pakistan, that is, its availability, access to food, utilization, and stability. Resultantly, Pakistan's agriculture sector suffers considerably, exposing the country to critical economical, developmental, and social challenges that wreak great havoc on mankind and plant lives. The current study explored the correlation between climate changes and its effects on agricultural production in Pakistan

***Keywords*:** agriculture, climate change, crops, food insecurity

Introduction

Agriculture and its related fields, that is, livestock and forestry are the most climate-sensitive sectors of an economy. The inputs, such as soil radiation, irrigation water, temperature, and precipitation are dependent on different climatic conditions. Additionally, extreme weather conditions may have catastrophic effects on agriculture production. Droughts, floods, uneven distribution of precipitation during different seasons (Ullah, 2017), extreme temperature, and other climatic disasters have greatly affected different

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socio-economic sectors and human lives across the globe. A detailed evaluation of different economic models which use inputs from different crops and climate models (Ullah, 2017) is necessary to assess the responses of consumers, producers, and different agricultural agents. Scientists are conducting collaborative and integrated research to understand the impact of climate change on agriculture production and crop yield. Climate change has greatly affected the agriculture sector in Pakistan. Resultantly, Pakistan is witnessing droughts, floods, untimely rainfalls along with the rise and fall in temperature which affects the agriculture production in the country.

Statement of the Problem

The changing climatic conditions greatly affect the agriculture sector in Pakistan. This phenomenon occurs due to high temperatures and unfavorable rainfalls (Ullah, 2017). Different agronomic models state that agriculture production in Pakistan is affected by climate change. Agriculture contributes a lion's share of third world economic growth, employment share, and exports. In Pakistan, the agriculture sector performs very poorly despite its major share in the economy in the form of GDP and generation of employment at the farms and the agriculture related industries. In addition to the politico-socio-economic factors, climate change affecting water availability, creating cycles of drought, introducing extreme weather conditions is considered to be the major factor in affecting the agriculture production in Pakistan (Raza et al., 2012). Both, in Baluchistan and Northern areas, the high rates of evapo-transpiration aggravate this already precarious situation (Adnan & Khan, 2009). The current study explored the correlation between climate change and its effects on agriculture production in Pakistan. It attempted to answer the following questions:

1. To what extent does the change in climatic conditions has affected the production pattern of major crops in Pakistan?
2. What are the different strategies to cope with the climatic conditions in order to mitigate the effects of climate change on major crops in Pakistan?

Significance and Scope

The research on climate change exclusively holds great importance in regard to its effects across the globe. The experts of climate change and scientists in the respective field have long been warning pertaining to the

disastrous impacts of climate change and its impact on agriculture production and other related fields. In this scenario, the first world countries mostly act as contributors to the causes of climate change. While, the third world countries are mostly at the receiving end since they are victims of the changing climate conditions. The third world countries do not have any access to the mechanisms which adapt to the changing climate conditions. Additionally, they lack resources to address the changing climate situations. The livelihood of almost 50% of the population of these countries depends on agriculture sector, hence, their incomes largely depend on changing climatic conditions. Pakistan is very attractive for this kind of study as the country is on the receiving end of climate change conditions and its agricultural production is suffering adversely due to these conditions. Pakistan is geographically located in an area which has very distinctive economic, climatic, and geographic realities. It does not contribute much to the causes of climate change, yet it suffers a lot due to the changing climatic conditions. Therefore, its agriculture sector, vital for the welfare of the country, heavily relies on climate stability.

Literature Review

Ashraf et al. (2022) revealed that climate change is one of the most influential factors that affect agriculture production and its impact has increased rapidly over the years. It has also affected the production of major crops, such as cotton, wheat, maize, rice, and sugarcane in Pakistan.

Intergovernmental Panel on Climate Change (IPCC, 2017) states that global climate models reveal significant changes in temperature and precipitation, which are expected to have a profound impact on groundwater recharge. The Intergovernmental Panel on Climate Change predicts that river flows, sea levels, and rainfall patterns will be greatly affected in the next century IPCC Leaflets (2017). Several studies have investigated the effects of climate change on agricultural production in different regions.

Babu et al. (2013) found that cotton production in Maharashtra, India, is heavily influenced by rainfall and temperature fluctuations. The results of the study in this regard showed an increase in the cotton production by the inconsistency of the lesser yields which remained the same over the years.

Shakoor et al. (2011) focused on the arid agricultural region and observed negative effects on wheat production, with income declining by

Rs. 4180 for every 1% increase in temperature. They found that income expanded with an ascent in the precipitation.

Bryan et al. (2013) explored the economic impact of climate change on agriculture in Kenya, emphasizing the importance of temperature changes over rainfall in affecting productivity.

Kabubo-Mariara and Karanja (2007) examined the financial effects of climate change on agriculture in Kenya, noting a non-linear relationship between temperature, precipitation, and income. The "Ricardian approach" was used to survey the impact of atmospheric changes on net yield revenue of particular section of the land. Kabubo-Mariara and Karanja (2007) found that an adverse atmosphere resulted in a change in the net income at the farm level. The results showed a non-straight relationship between temperature and income on the one hand and income and precipitation on the other.

Shakoor et al. (2011) determined that temperature had a more significant impact on farmland incomes than precipitation.

Albergel et al. (1985) observed a positive correlation between precipitation and cotton production in Burkina Faso. Their study found positive coefficients of relation of 0.72 for the whole cotton generation zone and 0.67 for the most enhanced range of generation capacity.

Methodology

The current research was qualitative and exploratory in its approach, aiming to delve into a specific subject or an area to gain a deeper understanding of it.

A combination of primary and secondary sources was employed for data collection. The secondary data refers to an information that has been previously collected and documented by other researchers, experts, or institutions. This encompasses a wide range of materials, such as research papers, credible reports, books authored by experts, and newspaper articles that provide relevant facts, statistics, and insights related to the chosen topic.

Primary sources, on the other hand, involve gathering first-hand information directly from individuals who have a direct experience or expertise in the field. In the current study, the primary sources were exemplified by interviews conducted with farmers, agriculture experts, researchers, and field officers. These personal interactions allow the

researchers to obtain unique perspectives, personal anecdotes, and in-depth insights that might not be available through secondary sources alone.

By utilizing both primary and secondary sources, a comprehensive and well-rounded analysis of the chosen subject is created. The secondary data provides a solid foundation of existing knowledge and context, while the primary sources contribute fresh and contextualized information from those actively involved in the field. This dual approach helps to ensure the validity and reliability of the research findings by cross-referencing the information and gaining diverse viewpoints.

Organization

The current study is structured into three main sections and each section contains several subsections. The first section examines the interplay between climate and agriculture, the climate distribution in Pakistan, the significance of the agriculture sector for the country's economy, and the relationship between climate change and agriculture in Pakistan. The second section delves into the impacts of climate change on agriculture, with a particular emphasis on major crops. Additionally, it also discusses how climate change affects the livestock and forestry sectors in Pakistan. The third section addresses various measures aimed to adapt and cop with climate change, encompassing both short-term and long-term strategies. It also provides a concise overview of policies, plans, and programs relevant to future agriculture in Pakistan.

Climate and Agriculture

The change in climatic conditions has long been recognized as the most important phenomenon and its socio-economic effects have long been a matter of concern for the researchers. Policy experts, economists, and scientists are quite worried about the fact that climate change has taken place and it is real. Climate change is a dynamic phenomenon which occurs over a longer time. Resultantly, the experts and scientists in the respective field concluded that this phenomenon should be investigated and evaluated over a longer period; some say it should be at least 10 years. The IPCC, AR-3 evaluated that each of the last three decades on earth has been warmer than the other decade since 1850 (Kennedy, 2018).

Additionally, the study determined that the amplified concentration of anthropogenic greenhouse gases in the earth’s atmosphere was the major cause of a change in climatic conditions (Kennedy, 2018). Therefore, the

impact of climate change on agriculture production must be investigated over at least a decade or more. These changes in the climatic conditions are largely driven by population and economic growth. The atmospheric concentration of these factors is more than ever. Some natural causes include the volcanoes and solar activities. However, they have caused very minimal effects on climate change conditions. The rising sea level, irregular pattern of precipitation, rising temperature, recession of glaciers, and melting of snow are some of the factors that are contributing to climate change in the world. The researchers have evaluated and analyzed the impacts of climate change on natural and human systems of the world. They have observed that the effects of climate change are not limited to the melting of glaciers and snows, irregular precipitation or change in temperatures. These effects reach across the globe and eventually affect the agricultural production in the world. It has been estimated that the climate change and consequent decrease in food production would cause death of half a million population by 2050 (Khan & Tahir, 2018).

The nature and rate of change vary from country to country and region to region, affecting every facet of human life. However, one alarming situation is the prediction of different scientists that earth's temperatures would raise in all types of climatic conditions. They have predicted that severe heat waves would hit and affect the entire world. This phenomenon would occur very often and may last for a longer time period. The precipitations would occur time and again and their ferocity may be more severe than ever. The scientists have predicted a continuous rise in the sea level, as well as the seas would be warmer and acidified. Since, oceans absorb more than 30% of CO2, it might make them more acidified. By using the national panel dataset which comprises data from the time period 1950-1990, scientists have predicted that the emissions of CO2 would further increase by 2050 (Khan & Tahir, 2018). It makes the situation even more alarming. Moreover, these scientists have also analyzed the reliability of the conclusions made by the Intergovernmental Panel on Climate Change on CO2 emissions. Their results show a significant shift from the historical data.

Climate Distribution of Pakistan

Pakistan is endowed with unique socio-economic geo-strategic realities. Its long latitudinal area covers almost 5000 glaciers in the northern areas which keeps frozen and provide required water throughout the year as well

as vast arid and semi-arid lands near the southern Arabian Sea. Pakistan is bestowed with vast mountain ranges, such as Himalayas, Karakoram, and Hindukush, containing many glaciers. The rise in temperatures is melting the glaciers at a faster rate. The moisture created by the Arabian sea in the South results in rainfalls which is an alternative source of watering the crops, electricity generation, industrial usage, and domestic consumption. Pakistan, being an agricultural country, is not contributing much to the increase in greenhouse gases being emitted in the atmosphere. In comparison to other countries, Pakistan only produces 0.8% of the greenhouse gases, which is 135th part of the entire greenhouse gases produced by the world (Bocchiola & Diolaiuti, 2013). However, Pakistan ranks at number 7 in the Global Climate Risk Index of 2017, which lists Pakistan as the most vulnerable country to have suffered due to climate change conditions. Pakistan is located in a geographical region where the average increase in temperatures is more than the world average. Here, the glaciers are melting at a faster pace which is the only source of water in the rivers, where a vast chunk of land is arid and semi-arid, where majority of the population is involved in the agriculture sector and its related sectors which are climate dependent. Whereas the variation in monsoon rains cause severe floods and drought over the years. According to these factors, Pakistan is facing severe water security, food security, and energy security issues. Pakistan's response to the climate change conditions is lined up with the objectives of conventions on climate change and sustainable development goals (SDGs). By identifying the effects of climate change on socio-economic sectors of the country, the changing climatic conditions can be coped with. Pakistan adopted National Climate Change Policy and National Disaster Risk Reduction Policy in 2012 (Chaudhary, 2017). These policies provided an exhaustive structure to reach out to the objectives and initiate activities towards "mainstreaming climate change in the field of socially and financially helpless sectors of the economy. Its follow up was the dispatch in 2013 of the Framework for Implementation of the Climate Change Policy (2014-2030)". It highlights the vulnerable sectors of the economy and suggests proper measures to adjust these issues through relief activities (Chaudhary, 2017). The framework views Pakistan's 2016 Intended Nationally Determined Contributions (INDC) document as a significant stride in addressing climate change challenges and integrating them into the decision-making processes at both the national and sub-national levels of policymaking. The document shows an environment

friendly development path. This document also highlights the preparation of Nationally Appropriate Mitigation Actions (NAMAs), National Action Plan (NAP), future National Communications to the UNFCCC, and a detailed plan of sub-national adaptation actions (Chaudhary, 2017).

The developing countries are at the utmost risk since they lack resources, strategies, and capacity to adapt to the measures which address climate change. Such a climate change would also affect Pakistan's ecological diversity. Pakistan's landscape includes arid deserts, high mountains, plateaus, forests, and river deltas and flood plains. All these ranges depend on different ecosystems on which local livelihood of people depends. It is estimated that 67% of the total labor force in the rural areas and 42% of the total workforce of Pakistan is directly or indirectly involved in the agriculture sector of the country. It is observed that climate change conditions have hit the agriculture sector in a disastrous way, affecting the communities dependent on this sector (Lal, 2011). Given local resource constraints and very limited capacity of the local communities, the situation even seems more alarming. The findings of this report may be considered as a basic vulnerability baseline which would be helpful for researchers, policy-makers, academics, and development practitioners. The report may be taken as a basis for further research to overcome the food security challenges due to climate change in the world, in general and Pakistan in particular.

Agriculture Sector and its Importance to the Economy of Pakistan

Pakistan's agriculture sector has been a significant contributor to the country's development since its inception in 1947. Initially playing a leading role in the economy, it has now receded to second place due to various environmental, social, climatic, and political factors. The agriculture sector accounts for around 21%of the national GDP (A. Niaz, personal communication, January 11, 2021) and employs approximately 21% of the total labor force (A. Niaz, personal communication, January 11, 2021), with a significant proportion of the rural population depending on it for their livelihoods. Despite its strong linkages with the rest of the economy, these connections often go unnoticed in official statistics. According to World Bank estimates (Javed et al., 2014), in 2009, Pakistan's' total GDP was $161.99 billion or 5,475,716 million in PKR. The agriculture sector provides raw materials to the industrial sector, contributes to exports, and serves as the largest market for industrial goods. Its focus has shifted from

self-reliance to commercialization, aiming to maximize profits and transform farming into a commercial business. Major crops, such as cotton, rice, wheat, and sugarcane contribute 6.5% of the total GDP (Javed et al., 2014), with cotton being a significant raw material for textiles and Pakistan ranking fourth in global cotton production. Minor crops, livestock, and fisheries also contribute to the sector's output. The livestock sector, supported by government policies, plays a vital role in Pakistan's economy, particularly in dairy production. The milk produced has a total worth of Rs. 177 billion, which is the largest product of the agriculture sector of the country (Khan & Tahir, 2018). However, there is significant untapped potential in the fisheries sector, which currently accounts for only 1% of the national GDP. The government aims to increase the share of the fishery sector in order to drive economic growth, reduce poverty, and enhance food security. However, as against vast aquatic resources, the fisheries sector makes only 1% of the national GDP. The government aims to increase this share as fisheries can play an important role in the growth of the state economy by helping to reduce poverty and increase food security (Ahmed & Schmitz, 2011).

Relationship between Climate Change and Agriculture in Pakistan

The relationship between agriculture and climate change is very complex. Climate change affects the agricultural production in the country. For the production of edibles, different crops go through a proper cycle of photosynthesis which needs proper heat, nutrients, and water. The survival of crops and an increase in their productivity depends on a certain degree of rainfalls, temperature, and CO2. CO2 is necessary for fertilization in all types of crops. However, CO2 also gives birth to different insects and bugs, in addition to the crops. Besides, extreme events, such as periods of frost, spells of heat, and irregular patterns of rainfall are major threats to agriculture production in the country. The researchers used the most common economic tool, that is, the partial equilibrium analysis also called as Multivariate Ricardian model which analyzes the impact of various socioeconomic and biophysical variables on farm revenues. These models don’t permit complete tuning to climate change conditions by the farmers. Indeed, any model can only highlight the effects which are part of the data analysis and cannot provide a complete picture of the entire economy. Additionally, the increasing global warming greatly affects the production of different crops. The temperature component takes lead over the

precipitation component. Climate change is witnessed as the most important factor in crop production in Cameroon. Moula, in 2008, employed Ricardian cross sectional approach in which he surveyed 800 farms (Kurukulasuriya & Mendelsohn, 2007). It was found that the incomes of these farms have decreased due to an increase in temperature and the consequent decrease in precipitation. The agriculture sector in Pakistan plays a vital role in addressing and ensuring food security by contributing almost 19% to the national GDP. The agriculture sector employs almost 40% population of the country. Most of the time, the sector grew at 3.46% per annum. Pakistan produces two major crops, that is, Kharif and Rabi. The Kharif crop is sowed from April-June and harvested from October-December. The Rabi crop is sowed in winter and harvested in April and May (Government of Pakistan, 2019a). Rice and wheat are the two major staple foods in Pakistan. Water is the most important contributor in the agricultural production and its shortage sharpens the attack of bugs and other diseases in the plant. "Wheat and rice are the two major crops and staple food grown in the country. Water is an important factor of agriculture system as dry climate causes its production to decrease and increase the number of bugs and infecting diseases in the plants" (Government of Pakistan, 2019a). Both cropping seasons in Pakistan requires sufficient water. According to the economic survey of Pakistan 2016-17, the availability of water for Kharif crops increased by 6.4% than the normal routine (Government of Pakistan, 2017b). However, the availability of water for Rabi crops decreased by almost 19%. This situation has greatly affected the production pattern and yield of different crops. Roundabout 140.9mm of monsoon rainfall was recorded for Kharif crops in 2016 which was 25% more than the normal rainfall, R 2016-2017. However, the Rabi season of the same year received 8% less rainfall.

Since, Pakistan is located in a geographical region where temperature rise and fall is comparatively higher as compared to other countries in the world with a warmer climate, therefore it is more vulnerable to climate changes. Climate change is a global threat affecting all regions and continents. The climatic variability in Pakistan poses serious threats to crop availability and adaptability. Since Pakistan is an agricultural country, the change in climate has catastrophic effects for this sector, which, in turn, affects the food security. An increase of 0.6C was measured during the first half of the 21st century as against a total increase of 0.76C during the entire 20th century. This situation is very alarming and catastrophic (IPCC, 2017).

The IPCC has predicted an increase of 1.4-5.8C by the end of the 21st century. This alarming rise in temperature would have a severe impact on sea level, ecosystem, global hydrological system, and crop production. The rise in temperature would severely affect the natural ecosystem of Pakistan (Khan & Tahir, 2018). It would destroy the natural output of several sectors, with agriculture being the most affected. Moreover, it would also affect the overall quality of life in Pakistan.

Management of the agriculture sector is the necessity of the time owing to the average rise in temperature by 0.74C during the last hundred years. Innovations in the agriculture sector have always been necessary and owing to the increase in temperature it has become even more vital. Focused policy responses are need of the hour. The frequency of natural disasters in Pakistan and due to change in climate conditions has made suitable mitigation strategies a necessity of time. The intensification of social inequality of resources due to climate change and its effects would lead to conflicts, instability, changes in irrigation patterns, and displacement of people. The climate change would also alter the life cycles of animals and plants, for instance, many plants and herbs would grow earlier and last longer than the normal practice. Animals are migrating to other areas and regions as a result of climate change.

Agricultural Production Affected by the Change in Climatic Conditions

Agriculture sector's contribution to national GDP is almost 19%. Additionally, it employs almost 40% of the total labor force in the country. The total area under different crops is around 23.4 million hectares which represents around 29% of the total reported area. The irrigated areas comprise 18.63 million hectares, with Punjab 77%, Sindh 14%, Khyber Pakhtunkhwa 5%, and Baluchistan 4%. A total of 3.8 million hectares are under sailable/Rod-Kohi, Barani farming systems and riverine which is also called the spate irrigation system of farming. An estimated 6.935 million hectares are under potential spate irrigation system, 0.862 million hectares in Khyber Pakhtunkhwa, 4.68 million hectares in Baluchistan, and 0.551 million hectares in Sindh with 0.571 million hectares in Punjab (Siddiqui et al., 2012).

There are two major crop seasons in Pakistan, that is, Rabi and Kharif. The season of Rabi crops starts in autumn (October-November-December).

These crops are harvested in (March-April-May). Wheat is the main Rabi crop which is sown in a vast area in the country. Kharif crops are sown in summer. The season of Kharif crops is generally longer than Rabi crops in Pakistan. Sugarcane sowing starts in February, cotton starts from March-May, Rice in May-June-July, and Maize in July-August. The major patterns include: (i) coarse grain-wheat (ii) rice–wheat, (iii) cotton–wheat (iv) maize–wheat, (v) sugarcane– wheat, and some other minor patterns. Crops grown under spate farming system and in irrigated areas are both very sensitive to temperature variability and the quantity of water available. According to some estimates, the production of agriculture sector would decrease by 8-10% with a rise in temperature (+0.50-20C) by 2040 in Punjab (Siddiqui et al., 2012). This situation is very alarming. Different simulation studies conducted in Pakistan have estimated a sharp decrease in the productivity of major crops, that is, wheat and rice in four major agro-climatic zones. The model predicted a decrease of 14 days for 10 centigrade rise in temperature in the length of the wheat growing season in northern areas as compared to southern areas in Pakistan. The current study also observed a 6% reduction in the yield of wheat crop and an 18% decrease in the basmati rice productivity in all agro-climatic zones except northern areas. It was also noticed that the yield of wheat crop is affected by various socioeconomic and agronomic factors, such as water availability, labor supply, pesticides, and household characteristics. Summer rainfall is essential for the productivity of Rabi crop. The International Institute for Applied Systems Analysis (IIASA) Austria Punjab (Siddiqui et al., 2012) predicts that by 2080, the yield of all major crops would decrease and wheat crop would be the most affected. The reduction of wheat yield is rather alarming for Pakistan and needs serious policy interventions. The maize yield has decreased due to bug attacks. Multinational companies have introduced some pesticides which are quite costly and beyond the reach of some farmers. The government should provide a subsidy on it. The prices of other inputs, such as fertilizers and oil should be reduced and controlled by the government. The government failure to provide funds for research in new cotton seeds has affected the quality of the output (I. Sial, personal communication, January 8, 2021).

Livestock Sector

The rising temperatures impact the livestock productivity in a negative way, leading to increased heat production and energy loss. High

temperatures also affect critical factors, such as water availability, reproduction, animal health, and overall production. Additionally, the increase in CO2, temperature, and precipitation variability affects the quantity and quality of forage, resulting in decreased milk and meat productivity, stress on animals, reproductive issues, diseases, and reduced fodder crop production (A. Niaz, personal communication, January 11, 2021).

In Pakistan, livestock sector is the backbone of the agriculture sector since almost all the families involved in agriculture also rear different heads of livestock. Its contribution in the agriculture sector is almost 56.6% and to the national GDP 11.8%. Around 8 million families are directly or indirectly involved in the livestock sector in Pakistan. The emissions of the livestock sector form a major portion of the total emissions of the agriculture sector in Pakistan. Manure management constitutes around 90% of the GHG emissions of the agriculture sector. It amounts to 40% of the total emissions of the agriculture sector in Pakistan (A. Niaz, personal communication, January 11, 2021).

Vast pastures and rangelands in Pakistan support the livestock sector. According to some estimates, around 60% of land in Northern areas, Baluchistan, and arid and semi-arid areas of Punjab and Sindh is used as rangeland for the livestock. These pastures and rangelands support around 93 million cattle heads (Hamza, 2018). In Baluchistan, majority of the population is dependent on livestock sector. It is estimated that around 87% of the total population depends on livestock sector for their livelihood (A. Gilani, personal communication, January 7, 2021). Limited research and evidence exists in the literature regarding the impact of climate change on the livestock sector, unlike the extensive studies conducted for the agriculture sector. Even, the IPCC's AR5 study has limited data on the effects of climate change on livestock systems, particularly in Asia. However, it is generally assumed that climate change negatively affects the livestock sector through the degradation and depletion of grazing systems, temperature increases, land productivity loss, reduced fodder quantity and quality, and the spread of diseases. Given the significant contribution of the livestock sector to agriculture, there is a crucial need for research on the potential impacts of climate change. Studies conducted in Sub-Saharan Africa highlight the high costs and limitations associated with adapting livestock management practices to climate change. Investing in the

livestock sector in Pakistan can yield substantial returns (A. Gilani, personal communication, January 7, 2021).

Forestry Sector

Forests play a crucial role in maintaining the environmental quality. They increase air humidity, enhance soil fertility, and add organic matter that improves water-holding capacity and nutrient content. However, climate change has resulted in shifting forests northward, biodiversity loss, and increased frequency of fires due to rising temperatures. Erratic rainfall patterns hinder the forest regeneration, while changing ecology makes forests more vulnerable to deforestation, erosion, and land use changes. These negative impacts of climate change on Pakistan's forestry sector include disturbances, such as insect outbreaks, invasive species, and storms. Rising temperatures, CO2 levels, and precipitation changes can also affect forest distribution and productivity (A. Niaz, personal communication, January 11, 2021).

Forests play an important role in the context of rural livelihood. They provide fuel, wood, timber, habitat for wildlife, food, and various important ecosystem services, such as adjusting the CO2, and reducing and controlling storms and cyclones in the coastal areas. In Pakistan, forests cover an estimated 4.19 million hectares. It forms 5% of the total land area in Pakistan. Coastal mangroves cover around 132,000 hectares which represent around 3% of the total forest area in Pakistan. The Indus delta areas which are home to around 1.5 million people rear 97% of the total mangrove forests in Pakistan. People living in the delta areas are greatly dependent on mangroves for their livelihood (Siddiqui et al., 2012).

It is estimated that climate changes, such as SLR, change in precipitation and temperature, and increase in the intensity and frequency of extreme events adversely affect the forest sector. These changes are a major threat to the soil quality and biodiversity. In Pakistan, very limited research has been conducted on the impact of climate change on the forest sector which shows the lackluster attitude of different governments towards this sector. However, a study was conducted in northern areas on the impact of climate change on forest ecosystems which showed a sharp decrease in forest cover for some plants and trees. It also highlighted the migration of some species to a new forest biome. Moreover, it also showed an increase in the productivity of all the biomes by using the BIOME3 model. A total of nine

biomes or plant types were assessed in the study to determine the impact of climate change. Out of these nine biomes, three biomes, (grassland or arid woodlands, alpine tundra and deserts) showed depletion in the selected areas. Five biomes (temperate conifer or mixed forests, cold conifer or mixed woodland, warm conifer or mixed forests, cold conifer or mixed forests and steppe or arid shrub lands) showed a prominent increase in the selected area. The net primary productivity of the forests showed an increase in biomes.

Various Adaptability and Compatibility Strategies in Relation to Climate Change

Adaptation strategies to climate change conditions are vital, otherwise the issues related to climate change would worsen the impact on agriculture gradually (Kurukulasuriya & Rosenthal, 2003). Different climate models project high rainfall, more severe floods, and heatwaves in the future. Therefore, it is the necessity of time to incorporate the climate adaptation strategies in national agricultural policies. Adaptation is considered to enhance the capacity at the local level to adjust to the climate change conditions (Dessai et al., 2005).

Adaptation to climate change was emphasized in the Paris agreement in 2015. It was argued that mitigation strategies do not cater to the effects of climate change conditions merely. Resultantly, adaptation measures are emphasized around the world to tackle the issues of climate change (Dessai et al., 2005).

The adaptation strategies take precedence in Pakistan's policy response to climate change. For instance, Pakistan's national climate change policy is considerably focused on climate adaptation initiatives (Mumtaz, 2018).

Farmers in Pakistan are trying to adjust with the climate change conditions. Their agricultural activities have shown an adjustment to the changing climatic conditions as well. Most of the farmers have explored several ways to identify and introduce these strategies. For instance,

- The farmers are adjusting planting time and optimizing the plant populations to the required climate changing conditions. These adjustments play an important role in order to obtain the expected productivity and to secure the maximum potential of the crops (I. Ahmed, personal communication, January 2, 2021).

- Farmers are also using heat tolerant and improved seeds which are another important strategy to maintain or increase their agriculture productivity. The generation of improved and heat-tolerant plants is necessary to maintain the farm productivity in view of the changing climate conditions. It is expected that the farm productivity would increase by adopting these measures even under extreme temperatures and moisture stress. These strategies are identified as changing sowing dates, changing seed types, planting shade trees, and looking for new fertilizers. As a result of the application of these strategies, the farm productivity has increased exponentially. For instance, due to the rise in heat, a farmer's production was affected. He brought seed from some other area where the temperature was already high. These seeds were more heat-tolerant and they produced the desired results. His experience was replicated by other farmers in the area and, consequently, the production of all these farmers increased. This practice was not limited to Punjab only, however, farmers outside the province also replicated and applied it at their farms. Farmers living in the border areas of Khyber Pakhtunkhwa (KPK) and Punjab are learning from each other's experiences. These practices are again shared by farmer's community with the Khyber Pakhtunkhwa (KPK) province. The adaptation strategies applied in Punjab are not only limited to the Punjab province, however, are also copied and applied to other areas.

- Industrialization and the resulting poisonous gases have increased the global warming leading to the deterioration of environment. Plants are suffering from the abiotic stresses. In order to understand the responses of plants under various abiotic conditions, there is a need to explore genetic basis of these mechanisms. Some physiological and molecular challenges in plants need to be addressed for their better adaptation under abiotic conditions. Variations in rainfall spells and temperature fluctuations are the indicators of climate stresses on plants. Weather fluctuations have both positive and negative impacts but negative impacts are more critical than the positive ones. The imbalances in agriculture sector due to climate change are very difficult to overcome. The strategies to overcome these problems are still very ambiguous. The researchers should focus on optimization of plant growth and development of abiotic stresses (A. Niaz, personal communication, January 11, 2021). For crop resistance against biotic and abiotic stresses, propagating novel cultural methods, implementing various

cropping schemes, and different conventional and non-conventional approaches would be adopted to save agriculture in the future (I. Ahmed, personal communication, January 2, 2021).

- Climate resilient crops should be developed through different breeding mechanisms. They would better resist the heat and drought. Genome-wide association studies, genomic selection, and advanced genotyping identify genes for resilient crops under climate change. Future focus should be on eco-friendly genome-edited crops via CRISPR/Cas9 for climate change adaptation.
- High tech laboratories should be developed in agricultural research institutes. The climate mitigation strategies should be developed through research findings.
- Awareness campaigns should be launched.
- Training programs for farmers should be organized.
- Role of academia and enhancement of institutional capacity.
- Coordination among different departments.
- Adaptation initiatives and autonomous adaptation

Pakistan's national climate change policy states, "adaptation efforts are the focus of this document." Pakistan is among those countries which have the least adaptive capacity due to poverty and lack of adequate resources, financial as well as physical. Future trends in agriculture may include integrated crop management, biotechnology, zero tillage technology and genetic engineering (A. Niaz, personal communication, January 11, 2021).

The government has established different institutions, structures, and authorities which are conducting research to counter the effects of climate change in Pakistan. These include PDMA, NDMA, and different climate change cells. The Punjab province is the most vulnerable to climate change and its effects, such as floods and droughts. Therefore, a structure of Provincial Disaster Management commission and authority was proposed in 2006's National Disaster Management Ordinance. The role of provincial commissions is policymaking, while the Disaster Management Authorities' role was to implement and coordinate. The disaster risk management falls under provincial subjects, the provincial governments would have the

fundamental role in the implementation of disaster risk management policies and programs (Iqbal et al., 2018).

Short-term Measures to Overcome the Effects of Climate Change

i. Agriculture Insurance
ii. Farm Forestry
iii. Heat resistant and drought tolerant varieties
iv. Improve productivity and production management
v. New farm management practices
vi. Watershed management
vii. Change in cropping patterns and adjustment with water availability
viii. More share of land to oil seed crops
ix. Improved crop residues management
x. Better pest, disease and weeds control
xi. Change in land use

Long-term Measures to Overcome the Effects of Climate Change

i. Efficient Irrigation Management

- Implementation of advanced irrigation techniques, such as drip and sprinkler systems, to minimize water wastage and increase crop water-use efficiency.
- Utilization of soil moisture sensors and weather data to optimize irrigation schedules, reducing over-watering, and water runoff.

ii. Increasing Soil Health

- Adopt agro-ecological practices, such as cover cropping, crop rotation, and reduced tillage to enhance soil fertility and structure.
- Increase organic matter content through composting and using organic fertilizers, which can improve water retention and carbon sequestration.

iii. Reducing Livestock Methane Emissions

- Implementation of feed additives that can reduce methane production in livestock.

- Utilization of improved breeding and genetics to develop livestock breeds that produce fewer methane emissions.

iv. Pasture-Based Livestock Management

- Shift towards pasture-based livestock systems that mimic natural grazing patterns, improving animal welfare, and reducing the environmental impact of concentrated feedlot operations.
- Managed rotational grazing can prevent overgrazing and soil degradation, enhancing carbon sequestration.

v. Protecting Farmland

- Implementation of land-use planning and conservation strategies to prevent the conversion of agricultural land into urban or industrial areas.
- Encouragement of restoration of degraded farmland and the reforestation of marginal agricultural areas.

vi. Supporting Farmers, Markets, and Local Food

- Promotion of local food systems to reduce the carbon footprint associated with long-distance transportation of food.
- Farmers, markets, and local food initiatives also support regional economies and contribute to community resilience.

vii. Renewable Energy

- Installment of renewable energy systems, such as solar panels, wind turbines, and biomass facilities on farms to reduce reliance on fossil fuels.
- Generation of clean energy to power farm operations and potentially contribute surplus energy to the grid.

viii. Organic Practices

- Transition to organic farming methods that avoid synthetic pesticides and fertilizers, reducing chemical runoff and enhancing biodiversity.
- Organic practices often lead to healthier ecosystems and more resilient crops.

ix. Keeping Agriculture Green

- Promotion of agroforestry practices, where trees are integrated into agricultural landscapes to provide shade, windbreaks, and carbon sequestration.
- Implementation of green infrastructure, such as buffer strips and wetlands to manage water runoff and prevent pollution.

x. Pushing for Climate-Friendly Policies

- Advocate for policies that incentivize sustainable agricultural practices and provide support for climate adaptation and mitigation efforts.
- Lobby for the integration of climate considerations into agricultural policies and programs at local, national, and international levels.

These long-term measures collectively address various aspects of agricultural practices, from resource management and emissions reduction to sustainable land-use and policy advocacy. By adopting these strategies, agriculture can play a significant role to mitigate the climate change while ensuring food security and environmental sustainability.

Revised Policies, Plans, and Programs for Future Agriculture

1. Enhancing Infrastructure: The development of modern storage and cooling facilities may help to reduce the post-harvest losses and maintain product quality. Upgraded infrastructure may also improve transportation and distribution, ensuring timely delivery of agricultural products to markets.
2. Improving Market Access for Inputs: Establishment of efficient supply chains for agricultural inputs, such as seeds, fertilizers, and machinery may ensure timely availability to farmers. Enhanced access can increase productivity and enable the farmers to adopt modern practices.
3. Increased Investment in Research and Development: Allocation of resources for agricultural research, innovation, and knowledge dissemination may help to develop sustainable and resilient farming practices. Support for research can also lead to the discovery of new technologies and methods that enhance agricultural productivity.
4. Promotion of New Crop Varieties: The development and adoption of crop varieties that are resistant to pests, diseases, and climate extremes

could prove beneficial. Diverse crop varieties can also contribute to food security and biodiversity.

5. Reduction of Post-Harvest Losses: implementation of appropriate technologies, such as improved storage, packaging, and transportation systems would minimize post-harvest losses. This can lead to increased food availability, reduced waste, and improved income for farmers.
6. Demand-Related Policies: Designing and implementation of policies stimulate demand for agricultural products, leading to increased income and growth in the sector. Market-oriented policies can create incentives for farmers to produce higher-value crops.
7. Focus on Education and Knowledge: Investment in farmer education and extension services would enhance their skills and capacity to adopt modern farming techniques. Knowledge dissemination can lead to improved productivity and sustainable practices.
8. Food Price Stability and Security: Development of policies to stabilize food prices would ensure affordability for consumers while providing fair returns to farmers. Establishment of food security measures would guarantee access to nutritious food for the population.
9. Diversification of Crops: Encouraging farmers to diversify their crop portfolios would emphasize minor crops with high-value potential. Diversification can reduce risks associated with mono-cropping and promote sustainable land use.
10. Effective Pricing Mechanisms: Establishment of transparent and fair pricing mechanisms for both, agricultural inputs and products. Fair pricing ensures that farmers receive reasonable compensation for their efforts.
11. Efficient Agricultural Markets: Improvement of the efficiency and competitiveness of agricultural markets through better infrastructure, information dissemination, and trading systems would provide better results. Efficient markets can enhance price discovery and market access for farmers.
12. Insulating Local Markets: Development of strategies to shield local markets from global market fluctuations would provide stability to farmers' incomes. This can mitigate the impact of external shocks on the agricultural sector.

13. Facilitating Local Market Access: Create avenues for farmers to easily access local markets, such as farmers' markets, community-supported agriculture programs, and direct-to-consumer sales. Direct market access can lead to improved income for farmers and stronger community ties. These revised policies, plans, and programs collectively aim to create a more resilient, productive, and sustainable agricultural sector that can address challenges, such as food security, income stability, and environmental sustainability. By focusing on these areas, policymakers can contribute to the growth and development of agriculture while ensuring the well-being of farmers and the broader population.

Policy Recommendations

1) In order to avoid water-logging, the inner surface of canals should be cemented. The land which is barren due to water-logging and salinity should be irrigated and reclaimed. To decrease salinity, tube wells should be installed. The government should address these measures on priority in order to avoid further loss and deterioration of land.
2) The issue of scarcity of water should be tackled on priority basis, as most of the land in Pakistan is barren due to scarcity of water. In order to increase the output of agriculture sector, the irrigation facilities should be extended to the far flung areas.
3) Fertilizers should be used in proper quantity in order to increase the productivity of different crops. Artificial manure should be used to enhance the productivity of the crops.
4) Loans should be given to the farmers on softer terms for good quality fertilizers, better quality seeds, and novel equipment. The government has extended the existing credit facilities to a large extent. The commercial banks also grant loans to the farmers but still there is a need for more facilities as our farmers are very poor. The farmers should be provided better quality seeds at the lowest price and at the right time. Better seeds will ultimately give better yield.
5) Different plant diseases destroy a major portion of the crops. The farmers have no effective control over these diseases due to the low quality pesticides. Therefore, the government must take measures to provide quality pesticides at the door steps of the farmers.

6) The yield of different crops can be increased by using modern equipments at cultivation stages.

7) Small holdings can be consolidated if farming is done based on mutual help and co-operation. In this way, the owners of small holdings can also use fertilizers and modern equipments jointly.

8) Increase of literacy ratio in rural areas, especially in agree-education, is the need of the day. The more educated the farmers would be, the better would be the results. Marketing procedures should be simplified and various marketing facilities should be provided to the cultivators.

9) The links between rural areas and markets of the country through road and railway should be established.

10) The government should keep farmers updated on weather conditions and climate change.

11) Climate resistant agriculture should be introduced in the country. Additionally, climate resistant seeds should also be developed and distributed to the farmers (A. Gilani, personal communication, January 7, 2021).

12) Latest and new seeds should be introduced, resistant to the climate change conditions. These seeds should be distributed by the ministry of agriculture of all the provinces. Hybrid seeds should be introduced in the wheat crop (A. Gilani, personal communication, January 7, 2021).

13) Soft-term loans should be provided to the farmers by the government. It would enhance their capacity to purchase and use latest equipments and machinery at their farms which would increase crop productivity.

14) Government should take some stringent measures to counter the water shortage in the country and must ensure timely availability of water for crops during the sowing season.

15) Agriculturists must be mobilized to play their active role in guiding and training the uneducated farmers to deal with climatic changes in order to avoid their adverse effects on productivity of different crops.

Conclusion

Climate change is a global phenomenon that directly impacts the agriculture sector, including Pakistan. The country heavily relies on agriculture and

changes in climate patterns, particularly rainfall, significantly affect crop production. Extreme weather events, such as heavy rainfall and flash floods, have already been observed in Pakistan, jeopardizing agricultural output.

Climate change impact the yield of major crops, such as rice and wheat, leading to shortages and hiked prices. This would likely require importing these commodities from neighboring countries which negatively impacts Pakistan's terms of trade. To ensure food security and support its growing population, Pakistan must revise its agricultural policy to align with the challenges posed by climate change.

In short, climate change poses significant threats to Pakistan's economy, particularly its agriculture sector. To mitigate these risks, government must prioritize agricultural policies and provide support to farmers, including awareness programs, financial resources, technological advancements, and capacity-building initiatives.

The current study offered policy recommendations based on tangible outcomes of the research. It also provided short-term and long-term measures to overcome the effects of climate change.

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