QLANTIC
JOURNAL OF
SOCIAL SCIENCES

Unravelling the Effects of Climate Change on Agriculture of Pakistan: An Exploratory Analysis

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Abstract: *The agricultural sector of Pakistan, the backbone of the economy, has experienced extreme changes in climate over the past years. Varying temperatures, rainfall patterns, and carbon emissions have drastically affected the country's agricultural productivity. This study focuses on the exploratory analysis of various factors of climate change in the agricultural sector of Pakistan and involves a descriptive analysis of three variables: temperature, rainfall, and carbon emissions. Time series data on monthly temperature and rainfall was taken from the World Bank from the year 1990 to 2018. At the same time, carbon emissions were studied on a yearly basis. The analysis showed that the country had experienced an increase in temperature and carbon emissions during the period of analysis. However, the decreasing trends of rainfall during most of the months explored the deteriorating agricultural production and food insecurity in the country. Therefore, the government should employ innovative techniques to harvest rainwater for agricultural development, aiming to reduce carbon emissions.*

Key Words: Climate Change, Carbon Emissions, Agriculture, Global Warming, Exploratory Analysis

JEL Classification: Q54, Q1

Introduction

According to UNFCC, climate change means the change of climate, which is attributed directly or indirectly to human activity altering the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Ali et al. (2017) have also defined climate change as an average change in weather conditions over a long period of time, affecting numerous natural factors with variations in temperature. With the Earth's temperature estimated to rise at the rate of two degrees Celsius by the end of 2100, crop productivity, water shortage, forestry, rainfall patterns, precipitations, floods and droughts are counted as highly affected factors (Malhi et al., 2010; Srivastav, 2021; Mushtaq et al., 2024; Dutta et al., 2024). Additionally, sea levels are expected to rise by the end of a century, making hurricanes even stronger, and emerging temperatures have caused glaciers to melt at higher speeds, resulting in water scarcity. Changing ecosystems force humans and many species to move in search of survival, and many species are likely to go extinct due to the absence of the required temperature (Javed et al., 2014; Upadhyay, 2020). For instance, species like polar bears, snow leopards, giant pandas, sea turtles, penguins and many others are under the threat of climate change, which has already exacerbated water scarcity, and farmers worldwide are struggling to keep up with the required amount of water for cultivation (Lodhi et al.,2023). Water, which is a precondition to life on earth, is under huge threat imposed by climate

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change (Javed et al., 2014). The contingency theory of climate change has also forecasted the everlasting impact of the increased rate of carbon emissions on a global level (Alves et al., 2017; Lodhi et al., 2023).

It is predicted that globally, nine million people will be food insecure by the end of 2050 due to changes in rainfall patterns, floods and droughts affecting food productivity (Ali et al., 2017). Due to the 0.6-degree Celsius increase in global temperature, the Asian region is expected to lose 50% of its wheat productivity (Khan et al., 2016; Sirba and Chimdessa, 2021; Aryal, Machanda and Sonobe, 2022).

Moreover, constant increases in Greenhouse Gas emissions are imposing threats to food productivity and water availability across the globe (Gomez-Zavaglia, Mejuto, & Simal-Gandara, 2020). Increasing heat is melting glaciers, raising sea levels and causing shifts in rainfall and precipitation patterns, resulting in mass evacuation for both livestock and humans (Khan et al., 2020). Climate change encompasses not only the rising average temperature of the Earth but also the extreme weather, causing noticeable shifts in rainfall patterns, floods, droughts and crop productivity. All these outcomes are the result of human anthropogenic activities enforcing the increment of greenhouse gases in the atmosphere (Khan et al., 2020; Kabir et al., 2023; Arif, 2024).

Climate change in Pakistan over the past few years has forced displacement of the population at large scale, leaving many in hunger and poverty (Khan et al., 2016; Salik, Shabbir and Naeem, 2020; Ajani, and Van der Geest, 2021). Intense droughts, floods, and rainfall are a few of the worst effects of climate change in Pakistan, which has made nearly 40% of the population vulnerable to natural disasters. Evidence of this can be gathered from tsunamis and earthquakes from the years 2004 and 2009, respectively, which displaced almost 25 million people from their houses, resulting in a loss of 9.5 billion rupees and 2 million hectares of agricultural land (Khan et al., 2016). Similarly, floods in 1992-93 brought down the GDP to 2%, falling from 7% in 1991-92, marking negative agricultural growth (Khan et al., 2016). According to Alves et al. (2017), due to extreme weather events such as droughts, floods, and hunger, industries and companies across the globe are suffering financially.

Compounded by the outcomes of climate change, Pakistan ranks 12th on the list of most affected countries (Awan and Yaseen, 2017). With agriculture as the backbone of its economy, it contributes almost 19.8% to GDP by providing employment to 45% of labour. The agriculture sector, therefore, is the most climate-sensitive sector of the economy (Ali et al., 2017). In the past, recurrent spells of floods, droughts, irregular rainfall patterns, cyclones, heatwaves and exacerbating temperature and precipitation rates have taken a toll on both human life and property. Glaciers

feeding the rivers are now melting at high rates on an annual basis, causing floods and cyclones in some parts of the country (Ali et al., 2017). Water resources are also under threat due to climate change, causing a change in the behaviour of melting glaciers, and the country is likely to be water-stressed in the coming years. With the floods and droughts imposing threats to livestock and fisheries, the country's condition is worsening on an annual basis (Khan et al., 2020). The contingency theory of climate change also focuses on the reduction of carbon emissions by balancing the supply chain process inside industries. Otherwise, it is nearly impossible to achieve any of the initiatives taken (Alves et al., 2017).

Emerging food prices, on the other hand, are making food unaffordable for the deprived population. Rising temperatures in some parts of Punjab are costing it millions of tons of cotton each year. Wheat and rice production is also influenced due to irregular rainfall patterns and high precipitation rates. The geographical location of the country has made it highly exposed to climate change effects, causing wide-ranging effects for many, including humans, livestock, and crops. With the change in climate, human activities are expected to disrupt life on Earth, leaving long-lasting repercussions on land agricultural productivity (Khan et al., 2020).

This study considers the trends of three variables, including temperature, rainfall, and carbon emissions in metric tons per capita. The main objectives of this study are to explore yearly trends of carbon emissions and fuel imports that affect agriculture in Pakistan and to explore the monthly trends in temperature and rainfall, which are considered major determinants of change in agricultural output. Another important objective of the study is to establish a link between contingency theory and climate change disturbing agriculture in Pakistan.

Most of the studies learning the impact of climate change on agricultural growth of the economy involve some statistical or econometric tool. Only a few researchers have studied it descriptively. In this paper, an exploratory analysis of climate change on agriculture has been done using trend line charts with the help of data from the World Bank. Moreover, this research paper also focuses on the descriptive study of variables causing change in climate and agriculture.

The significance of climate change is not confined to a single place or country. It is, in fact, affecting every aspect of our lives, including food, transport, livelihoods and social and economic health. The author's purpose in writing on these issues is to raise a voice for the inconvertible loss from past and upcoming losses, which we can prevent from happening. Furthermore, with the rise in food prices in the past few years, a large portion of our population has been forced below the poverty line (Ahmad, 2012). Food security issues and rising concerns about water scarcity are a few major environmental problems. Especially in the case of Pakistan, where agriculture has a great potential to produce various types of food directly involving almost 60% of its population dependent on food production (Awan and Yaseen, 2017). However, the intensity and severity of climate change have left 702 million people in hunger and extreme poverty due to reduced production of food (Ullah, 2017). Therefore, studying climate change phenomena must be our top priority, and this is one major reason why the author sheds light on climate-related issues inside our country.

Literature Review

Climate change is termed a global phenomenon or long-term change in weather patterns emerging due to escalated greenhouse gas emissions because of human activities and major shifts in weather patterns with an overall increased temperature of the world. Greenhouse gas emissions involve 90% of carbon and methane emissions due to the burning of fossil fuels such as coal, oil, and natural gases (Awan and Yaseen, 2017). Accelerated temperatures, water scarcity, stunted agricultural growth, Frequent floods, droughts and cyclones have affected the worldwide production of crops and livestock, resulting in famine and poverty as it distorts food accessibility across Africa and South Asia. For instance, altering rainfall patterns, emerging temperatures, and emissions rates can plunge food production, resulting in a spike in food prices and making it unaffordable for many (Kiran and Qurat-ul-Ain, 2017). Developed countries are considered major contributors to global greenhouse gas emissions.

According to recent statistics, 600 million people will experience water stress by the end of 2050, and an annual loss of 12 million hectares of land will cause displacement for millions in Asia and Africa (Kiran and Qurat-ul-Ain, 2017). Moreover, irregular rainfall patterns have marked a 19% decrease in the production of Rabi crops during the year 2016 (Khan et al., 2020). Underdeveloped countries apparently suffer more due to climatic changes since they have fewer mitigation techniques and policies because of financial constraints to avoid any sort of damage (Zahra et al., 2016). However, the uneven distribution has made the lower-income countries suffer more. Food and agricultural organizations have declared around 795 million people malnourished (Ali et al., 2017). There is a lack of research on the fact that most of the cultivated food from underdeveloped countries is exported to various parts of the world to fulfil the needs and desires of the upper class. Marx's theory of social class and structure focused on the very same thing. Social classes and structure play a key role in understanding the mode of production. Class, which is primary in terms of the dynamics of capitalism, is the only class that has the right to rule society. Very similar is the case with our lower working class, who are vital in running the economy, yet they are paid the least.

Food security and water availability, on the other hand, are highly unguarded factors, with 75% of the Himalayan glaciers already melting at a high-speed rate. Since the food and every sector in Pakistan has been subjected to the adverse consequences of climate change due to its geographical location. Food security has been shown to have a direct relation with agricultural productivity since it increases with the increase in agricultural productivity inside the country. Floods in Pakistan have caused an irreparable loss to the country's economic conditions. Five consecutive floods from 2010 have caused a loss of nearly 25$ million in the agricultural, irrigation, health, public infrastructure and industrial sectors of the economy (Zahra et al., 2016).

South-Asian region, the most climate change-affected continent, is counting the hungriest population in the world. Another study by Ali et al. (2017) has claimed a 50% reduction in wheat production by the end of 2050 and declared farmers highly unprotected professions because of the occurring floods, irrigation, high precipitation rate and rainfall patterns. Flooding in case of economic loss contributes at a high rate. Moreover, with the change in rainfall patterns generating water, capital, land and global resource availability issues, climate change will threaten food availability for almost nine million people (Ali et al., 2017).

With climate change taking place across the globe, Pakistan falls among the first ten countries to be highly affected, and it is taking a toll, too (Kiran and Qurat-ul-Ain, 2017). Prolonged floods, irregular rain patterns, rising temperature, water scarcity and floods are the key

counting factors in this regard. Floods and droughts from 2010 and 2011 have given a boom to the already crippling condition of the agricultural sector of the economy. During the year 2010, a loss of 5$ million was faced by Pakistan. Around 3000,000 were displaced, and 20 million were severely affected (Ali et al., 2017). Posing various developmental, economic and investment challenges and crises, the agricultural sector of the country is proclaimed to be the most defenceless sector, and acting as a major contributor to the country's economy, the agricultural sector also stumps up to 20% annual increase in the anthropogenic emission of the greenhouse gases (Awan and Yaseen, 2017and Arif, 2024).

Water scarcity is another emerging issue since Pakistan lacks a proper system to store them for the future. Tons of water go waste into canals and rivers, causing floods and forcing people to evacuate (Javed et al., 2014). This study has been designed to scrutinize the relationship between different variables of climate change affecting the overall performance of Pakistan's economy and highlight the agricultural sector. Over the past few decades, Pakistan has faced an immense loss of livestock and fisheries due to unexpected floods and droughts (Ali et al., 2017). Water shortage and mismanagement issues have compounded hardships for this sector, and crop productivity is shrinking on an annual basis. The mountainous area of the country is home to about 180 million people, and all of them are at high risk due to climate change threats and rising sea levels, causing floods and forcing people to evacuate (Ali et al., 2017).

One of the leading reasons for Pakistan being on a list of highly affected countries due to climate change is its geographical location. Where the entire region is prone to the threat of rainfall during floods and monsoon season. Pakistan is now tackling the peculiarity of climate change both at the economic and social level and seems to take no ample cudgels in this regard. The economic impacts of climate change are not limited to water and food insecurity, but sundry sectors such as livestock, fisheries, forests, transport, and industries are also at an ultimatum. In the wake of increasing climate threats and population rate, water scarcity is already reaching the threshold level of 1000 cubic meters, marking 5600 cubic meters per capita in 1950 and a decrease of 1200 cubic meters in 2003 (Khan et al., 2016).

Karachi, the largest city in Pakistan, accommodates about 10% of the whole Pakistani population, with 40% of its energy production units inside it (Khan et al., 2016). The city will face an energy crisis with a shortage of water in the coming years, causing displacement for many. Jeopardizing job opportunities for many, the climate change phenomenon could cause a high inflation rate in the future, making food and necessities inaccessible to the poor. Rural residential areas are more prone to flood threats, as they vanish in no time. Adverse social impacts on health can be a cause of loss of income for the working class of society. Experts have warned the authorities against poverty and hunger due to water shortages in several areas in the coming years. Climate change is striking one of the world's poorest populations (Khan et al., 2016).

The rising issue of water scarcity and the reduction of land productivity agitates climate change, leaving disastrous impacts on humans. Being a water-rich country with rivers and an irrigation system, Pakistan has contributed a lot to the agricultural sector of the economy by corroborating food security for millions and reducing poverty. Yet experts have suggested that the crops be short in duration in order to mitigate the loss. Despite not being a major contributor to releasing emissions, the country is facing a major threat. 19.8% of our GDP belongs to the agricultural sector, bestowing 42.3% to the labour force and providing means of income to almost 62% (Ali et al., 2017). The prime objective of the agricultural sector of any economy is to reduce poverty and hunger by boosting productivity. Due to its demographical features,

Pakistan is pre-disposed to the threats being imposed due to climate change. The country requires almost 6- 14$ million to mitigate the loss of the nature-gifted climate change threats such as droughts, rainfall patterns, floods and cyclones. With an economic loss of 6% during the 2010 floods, Pakistan ranked number 7 on the list of highly unprotected countries due to climate change (Zahra et al., 2016). Also, 500 glaciers in Pakistan are recoiling faster than the recoiling rate of any other country. The major food crop consumed on a large scale in Pakistan is wheat. Rice, sugarcane, and maize are some other highly contributing and ingesting crops of the country. With about 31.9% contribution to the economy, these crops marked a boom of 3.2% over the years 2010-11. Wheat, since the 1960s, has been one of the major contributors to the GDP of a country. Wheat, being a cheap source of animal food and the most extensively used crop, is emphasized in Pakistan. In the past year, Pakistan has been marked by a discernable change in precipitation patterns, droughts, water availability, weather-induced natural disasters, and the intensity of heat waves. Despite not contributing majorly to greenhouse gas emissions, the country is now on the radar to face repercussions.

Three major challenges faced by Pakistan are related to floods, drought, and sea intrusion, which cause harm to food and water availability, health issues, and the livelihood of many. For the past 15 years' smog has been rising, deteriorating the air quality, affecting crops and forests and causing population displacement in several regions of the country. Almost 95% of the irrigated land is at risk due to the melting Himalayan and Karakoram glaciers, increasing the water flow in rivers (Kiran and Qurat-Ul-Ain, 2017). Climate change is instigating extreme temperatures in some parts of Pakistan, making diarrheal and vector-borne diseases more prevalent. Moreover, less water availability by the end of 2035 will inflame food insecurity, leaving many hungry. Water availability in Pakistan is controlled by the amount of rainfall during the monsoon season and the glaciers flowing all the way into the rivers. The amount of water wasted in Pakistan each year is more than the water stored in their dams. Moreover, 60% of water is wasted during the transmission process in fields, and 30% is lost at the water cost level (Khan et al., 2016).

Climate change has dampened agricultural growth by harming many activities, and rising temperatures have played a key role in deteriorating the climatic conditions of the country, with greenhouse gases leading to climatic threats (Javed et al. 2014). High temperature and rainfall patterns are also expected to be witnessed in upcoming years, vandalizing South and East Asia's seasonal crop productivity at a large scale. The upper basin of the Indus River is projected to face increased precipitation compared to the lower basin, which will have decreased precipitation. Considering the temperature variability, having been sown in winter, the wheat crop is harvested in summer. In the years 2013-2015, wheat production plunged by 1.9% (Ali et al., 2017). Climate change does not only affect crop productivity but the cropland areas are also hampered. Moreover, less availability of water causes soil infertility, which is one of the severe consequences (Malhi et al., 2010). Increased temperature and precipitation rates have added fuel to the collapsing condition of crop productivity. With tons of kinds of wheat and other food crops produced each year, the agricultural sector of Pakistan has failed to secure its position in the global poverty ranking, with millions falling below the poverty line each year. Escalating temperature and rainfall patterns are two factors determining Pakistan's agricultural growth. In early Pakistan, 70% of the agricultural production was solely dependent on rainfall (Awan and Yaseen, 2017). Based on irrigation, Pakistan has almost one-third of its total cropped area under rainfall. Due to the direct exposure to climate change, developing countries like Pakistan are more susceptible to climate change threats, as most of them are agriculturally based economies and are more likely to be influenced by climate change (Ullah, 2017).

Depending upon the nature of the crop, rainfall affects them differently. Short-term increased temperature has already become an inevitable challenge for Pakistan, where tons of food and millions of hectares of land have already gone to waste, limiting food access. Rising temperatures are affecting the lives of rural and urban areas of the country. Also, declining production has been shown to increase prices, which makes food non-affordable for the lower-middle class and poor class of society. However, with the warning of experts, no changes or progress are to be seen in the country. Most of our water still goes to waste, destroying land and crops. Despite all those years of disastrous experience, the country has failed to manage itself as a dam to reduce the water crisis (Zahra et al., 2016).

Regardless of fluctuating temperatures and precipitation, glaciers across the country are melting due to sedimentation and sliding. Contaminated water has given a boom to freshwater demand among the rich.

The rising warm temperature of Earth would cause an increment in surface-water temperature, lowering the duration covered ic and resulting in overall lower water levels. With the constrained amount of water supplies, natural disasters across the globe are alarming the already stagnant agricultural growth. In 2010, the economic loss exceeded almost 9.6$ billion (Zahra et al., 2016). Human behaviour like deforestation, overhunting, and urbanization are some of the leading factors in this catastrophic situation. Climate change at the initial stage left positive externalities on crops, yet the constant cumulating temperatures are now hampering the conditions, causing welfare loss. Mitigation strategies are required in order to pause threats. Booming yield productivity is said to increase in areas with high latitudes, while areas with lower latitudes are said to face lower yield. Expanded temperature in mountainous areas will give rise to the damaged potential (Malhi et al., 2010).

Additionally, alterations in climate change and roaring temperatures are alarming the situation by threatening the agricultural productivity of the land. Yet some areas of Pakistan, such as Punjab, have marked growth due to climate change. Providing job opportunities to 45% of our labour, agriculture contributes to 21% of the economy. However, agricultural facilities have caused 20% of the local greenhouse gas emissions by allowing anthropogenic activities and releasing gases like carbon dioxide, methane and nitrous oxide (Awan and Yaseen, 2017). Pakistan is prone to changes in the increased rate of temperature and precipitation, which raises vulnerabilities to the agricultural sector, water resources, and forests. The country is highly vulnerable to climate change and geographical diversity, causing climatic catastrophes (Ullah, 2017). Climate change is more likely to have adverse effects on a country's productive resources; surging temperature is one of the major factors that count in this regard. The impact of climate change on the agricultural sector due to changes in rainfall patterns includes the shortening of growing season length and increased water requirements. Pakistan's agriculture over the past few years has flunked to keep its position in the performance sector regardless of its highest contribution to the country's GDP. Lower water availability has made the annual agricultural productivity poorer by augmenting temperature and irregular rainfall patterns. Being dependent on rainfall due to the water shortage sector's performance is exacerbated (Khan et al., 2020). Agriculture falls among the list of most affected climate-sensitive sectors of the economy because it requires all those inputs, such as temperature, soil, rainfall and precipitation, which are related to climate change ultimately. The temperature in Pakistan in 2060 is also expected to rise by 3.7 degrees Celsius in South Coast; a study by the Global Facility for Disaster and Recovery organization summarizing the fact that Pakistan will face the unpropitious consequences of weather changes (Zahra et al., 2016). Starting with 0.07 degrees Celsius, the mean temperature in Pakistan has increased up to 0.6 degrees Celsius (Climate Risks and Food Security Analysis: A Special Report for Pakistan, 2018). Wheat production in Pakistan is sensitive to high temperatures. Wheat fulfils two-thirds of the human caloric intake. High temperatures in the country have caused lower rainfall, affecting wheat and rice production. High food prices have forced many individuals to be selective in their nutritious food choices, spreading diseases like typhoid, cholera and diarrhoea. The livelihoods of many residents in the southern part of Pakistan are affected by climate change, which, if not addressed early, can cause displacement of many. People in some parts of Pakistan have switched their earnings to industrial labour rather than merely depending on agriculture. Climate change targets agricultural productivity at a large scale because it is dependent on climatic conditions, and due to the poor environment, productivity lessens, reducing the number of crops produced on a yearly basis. Intense cyclones can cause a risk to life and property in coastal low-lying areas, which are more prone to such threats, especially in Sindh, Pakistan. Climate change can also inflame the threat to our biodiversity since the demographical features are changing gradually due to human activities (Ali et al., 2017).

With 60% of its population directly involved in agricultural employment, Pakistan is the 12th largest country in the world, with agriculture as the backbone of its economy (Awan and Yaseen, 2017). Despite having a strong agricultural base, Pakistan is counting major numerical numbers to their undernourished population. Studies conducted by (Javed et al. 2014) have declared the low income level to be one of the leading reasons behind the non-affordability of food. With the sharp rise in climate shock and increased inflation rate, Pakistan is expected to have food shortage in many areas, and unemployment will soar to poverty in the country. According to (Javed et al., 2014), food security is a condition where a state provides and produces for human survival by feeding them. Pakistan, despite millions of tons of production of wheat, rice and other crops such as sugarcane, maize cereals, etc., on an annual basis, have failed to feed

its population. With higher prices in world markets, food is becoming unaffordable for local market consumers. Pakistan is no exception when it comes to the consequences of seasonal variation of extreme weather conditions, which are already increasing on an average basis. With one-third of its population below the poverty line, it is impossible for people even to buy necessities in Pakistan (Javed et al., 2014).

Additionally, Global wheat production due to climatic change is said to be reduced by 5.5%, imposing a threat to food security in future (Malhi et al., 2010). Due to climate change threats to the agricultural sector, people will face food insecurity and shortages in the future as the situation is more likely to aggravate. 3-5 million hectares of land in Pakistan have been affected by wind erosion, and almost 40% of our irrigated land has been destroyed due to waterlogging and salinity (Khan et al., 2016). Billion dollars are required to be incurred in order to regain the loss. Moreover, the risk of insects, pests and pathogens is also harmful to the increasing humidity levels. In Pakistan, the total cost of salinity and soil erosion is estimated to be 30-80 billion and 15 billion rupees per year, respectively (Khan et al., 2016). Food productivity is primarily more prone to the climate process since it is directly related to any alterations in climate. With an expected increase of 0.5 degrees Celsius in 2040, agricultural productivity will shrink with an 8-10% loss to the land crops (Zahra et al., 2016). In some parts of the country, the productivity of rice and wheat is declining due to increasing temperatures. Rainfall patterns are another hitting issue. Different part of the country receives different annual amounts of rainfall, such as northern areas having rainfall of 1000mm per year and drier Southern areas receiving only 200mm on an annual basis (Climate Risks and Food Security Analysis: A Special Report for Pakistan, 2018).

Furthermore, climate change is causing a disturbance in the socio-economic aspects of the economy. The water demand of Pakistan through the melting process of glaciers is being fulfilled due to its demographical and longitudinal features. However, the extreme weather conditions are giving rise to melting glaciers at higher speeds, causing rivers to overflow. The complex relationship between agriculture and climate is affecting food productivity across the country. In order to grow nourished crops, a specific amount of heat and water is required, but the rapid change in climate over the past few years has affected the crops by not providing them with a suitable environment to grow (Khan et al., 2016). Water plays an essential role in the production of agricultural food and sustained livestock. Decreased amounts of water can cause harm to the plants and crops. Crops all over Pakistan demand a significant amount of water to grow. According to the survey, Kharif crops have received water with a 6.4% increase, whereas a 19% decline for Rabi crops water has been marked since Kharif crops enjoyed more water from the monsoon season in the year 2016, marking a noticeable growth in fiscal year 2016-17 (Khan et al., 2016). On the other hand, Rabi crops experienced a loss of 8% and higher rainfall than normal crops (Khan et al., 2016).

Expected floods in 2050 will destroy most of the agricultural land, leaving thousands unemployed. Increased floods, low crop yields, droughts, and irregular weather patterns are all the results of global climate change that targets developing or underdeveloped nations. Since 2010, Pakistan has faced major floods followed by a monsoon season, destroying the agricultural sector specifically. A loss of 13.3 million tons of major crops, 1.2 million livestock and 2 million hectares of cropland were destroyed after those floods (Khan et al., 2016). In summary of this whole scenario, Pakistan, being one of the most vulnerable countries to climate change, will have to face several consequences in terms of water, food, energy, forests, crops, etc. Pakistan has the lowest ranking, about 135th number in releasing emissions on a per capita basis, yet it falls very high among the list of most affected countries due to environmental threats (Khan et al., 2016).

The increasing population is another factor adding fuel to the disastrous climatic change. Farmers from many areas have adopted environment-friendly measures to cope with the situation, yet they are not going to last longer since climate change in the northern part of Pakistan is hitting at a very fast speed. With the depletion of natural resources, a wide range of populations have been displaced from their places in many parts of the world already. Moreover, landslides and glacier outbursts in Sindh and KPK have taken a large part of the land, affecting many people's earnings and employment. According to State Food Security Pakistan, 25% of labour depends on agriculture as a source of income (Climate Risks and Food Security Analysis: A Special Report for Pakistan, 2018). Agriculture in Pakistan is a major and fundamental primary source of income. Those who do not work directly on their land have a labour force working for them, and climate change can cause both positive and negative effects on the livelihood of people depending on the

rate at which climate is affecting the employment level and imposing food threats. For example, the loss of 4 to 5 million tons of cotton production is marked by the annual one-degree Celsius rise in temperature (Climate Risks and Food Security Analysis: A Special Report for Pakistan, 2018).

Moreover, large population plays a vital role in economic progress by increasing human capital in economy. However, if increasing population is a blessing for the economy, it can also leave some non-desirable effects on it by depleting the natural resources, as they contribute toward omitting Greenhouse Gases, wrecking natural habitats for many species and consuming resources at a progressive rate (Zahra et al., 2016). Population growth is not the root cause of growing environmental threats if the resources are utilized and sustained accurately without being mismanaged. Since the relationship between population and environment is always analyzed based on the accurate number of resources. Summing up the whole situation, apart from human contribution, climate change is affecting food and energy productivity around the globe. In order to mitigate the loss and lessen the threats, Pakistan needs to adopt crucial measures and work on a framework that will provide them with a policy to implement in future to preserve the environment (Zahra et al., 2016).

Greenhouse Gas emissions are another major contributor to climate deterioration. Despite contributing at a very low rate in releasing carbon dioxide emissions, developing countries are at greater threat. South Asians earn mostly through agriculture and are now facing serious economic and social threats (Khan et al., 2016). Anthropogenic activities being conducted by humans are a reason behind the sharp increase in greenhouse gas emissions, which is likely to increase at an alarming rate by the end of 2055 (Malhi et al., 2010). One way to reduce these emissions is either by pausing anthropogenic activities or by reducing meat consumption. The loss of cropland in future can cause a decline of about 0.3% by 2100 (Malhi et al., 2010). The agriculture sector, therefore, is one of the most affected sectors of the economy, posing negative impacts on food productivity worldwide. The increasing population has increased crop production by ensuring food security, which has also jeopardized the worsening climate conditions in the economy. A prominent contribution to this regard is increasing temperature, rainfall and precipitations affecting the soil productivity and metabolic activities of plants. Being dependent on agriculture, livestock, and forestry, Pakistan's economy is vulnerable because of the GHG emissions from other developed countries.

Previous studies have blamed penetrating human activities as the reason behind the sharp increase in temperature. The world has claimed to emit about 1.5 trillion tons of CO_2 since 1751, with Europe as a major contributor, followed by Asia and then North America (Malhi et al., 2010). Climate changes have both positive and negative wallops. The world till the 20th century got to see the positive effects, with negative outcomes hitting only the underdeveloped countries, yet the 21st century will be showing severe impressions for rich and poor countries with uncontrollable water shortage and food insecurity issues posing negative externalities. With the increase in global temperature, the global emission rate of greenhouse gases needs to be reduced in order to restrict further increase in temperature. According to (Malhi et al., 2010), developed countries contribute almost 60-80% in anthropogenic activities, yet they are the least likely to face repercussions as the consequences trickle down to the underdeveloped states. If we keep the rate of global warming below 1.5 degrees Celsius, temperature variations shall be lowered, causing the situation to deteriorate any further (Malhi et al., 2010). With the speedy growth of climate change's adverse effects, countries are taking steps against the mitigation of loss. Pakistan, as discussed above, falls among the countries that are highly affected by this phenomenon. The immense economic and life loss has already plunged the country's economic status. An increase in annually varying temperatures has given rise to the increase in rainfall patterns, floods and droughts. Punjab and Baluchistan marked 24 degrees Celsius from the years (1981-2010), whereas the temperature in Northwest areas was 18 degrees Celsius (Climate Risks and Food Security Analysis: A Special Report for Pakistan, 2018).

The country needs to adopt environment-friendly policies because if we are to protect our economy, crucial measures will be required to generate policies to have a future safe from environmental threats (Khan et al., 2016). Households in Pakistan have looked for some innovative ways to cope with climate change, i.e., people are trying not to stay dependent merely on agriculture as their source of income, but they are heading towards the industrial sector for labour. Farmers are also adapting less water-required agricultural techniques in order to deal with the water shortage issue. In my opinion, switching to a free environment is beneficial for both humans and nature. Otherwise, nature will pay us back in notorious ways.

The consequences of climate change are the result of our enlightenment. Being a developing country, very few governments and private authorities have taken any initiative to mitigate agricultural loss. Furthermore, the political economy of agricultural taxation and subsidization from the government is a key to agricultural success; unfortunately, both are ignored in Pakistan. So far, Pakistan has failed to implement any policies to maintain sustainable development goals (SDGs), and an inefficient government has not yet introduced any policy to protect agricultural land, which is already expanding unemployment in the country.

Figure 1

Trend of sunshine for Pakistan,1989–2015
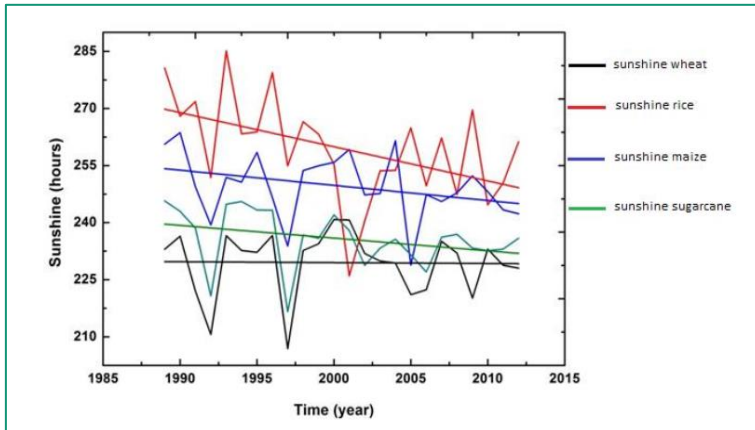
Attached above is the graph studied by Ali et al. (2017). Showing the impact of climate change on various crops (including wheat, rice, maize, and sugarcane) in Pakistan, graphs represent the decreasing trend lines over the years. Another study conducted by Zahra et al. (2016) determined that rising temperatures in Pakistan have already become an unavoidable challenge for Pakistan, where tons of food and millions of hectares of land have already gone to waste by limiting food access. The increase in temperature is also affecting lives in rural and urban areas of the country. Hence, we can conclude that the change in climate affects agricultural growth negatively.

With the second highest rate of malnourishment, around 82% of Pakistani children are deprived of one meal a day (Saeed and Roy, 2021). Around 18% of our children under the age of 5 years are victims of malnutrition, and more than 40% suffer from stunted growth (Saeed and Roy, 2021). In my view, good governance and effective leadership are things that Pakistan still lacks, and if we are to eradicate the food insecurity issue, the government should step forward and introduce policies to protect our agricultural land.

Summary of Few Studies Related to the Impact of Climate Change on Agriculture
Table 1

Author	Study	Results
(Awan and Yaseen, 2017)	Explored the impact of global warming on Pakistan's agricultural sector. Model ARDL	Significant (+)
(Ali et al., 2017)	Examined the effects of climate change on the major crops of Pakistan (e.g., wheat, rice, maize, and sugarcane).	Results reveal that maximum temperature adversely affects wheat production while minimum temperature is positive and significant for all crops (+ and –)
(Khan et al., 2020)	Studied climate change-induced loss of wheat and rice crop production	Loss in 2050 is 19.5 billion dollars on Pakistan's Real GDP, with an increase in commodity prices followed by a decrease in domestic consumption. (–)
(Torres et al., 2019)	Studied the effect of rainfall on agricultural productivity	Results showed that rainfall is an important determinant of agricultural growth. (+)

Methodology

Based on time series data from the years 1991-2020, temperature and rainfall patterns have been studied using line graphs. For this purpose, data from the World Bank was extracted. This research has explored the trends among temperature and rainfall on a monthly basis. Data on carbon emissions in metric tons per capita was also studied from the years 1960-2014.

Variables Defined

Table 2

| Variable	Source	Description
Temperature in degrees Celsius	World Bank Indicator	Temperature is a degree of hotness and coldness defined using a measurable scale. It is measured in degrees Celsius. Global temperature is termed as an average of air temperature recordings from weather situations from land and sea as well as some satellite measurements as well.
Rainfall in mm	World Bank Indicator	Rainfall can be defined as the amount of precipitation usually measured by its depth in unit inches.
Carbon emissions per capita.	World Bank Indicator	Emissions are something sent forth by emitting. Carbon emissions are defined as the release of carbon dioxide gas into the atmosphere.

Theoretical Framework

The contingency theory of climate change deals with the external context, which assists in restructuring the business with a reduced amount of released carbon emissions (Alves et al., 2017). Environment risk-reducing measures are vital to moderate the loss, and contingency plans are helpful in managing the impact of risks during the recovery plan (Beauchamp, 2018).

Contingencies are defined as events happening outside the control of the affected supply chain phenomenon by mounting the carbon emissions and causing displacement of the population (Alves et al., 2017). Theory on climate contingency is paramount in adopting fewer carbon-emissions techniques since it is difficult to measure or predict the outcomes directly (Alves et al., 2017). Contingency plans help to minimize the loss projected due to climate change and decrease the vast recovery time (Beauchamp, 2018). In this regard, structures for low-carbon management and mitigation techniques are vital to organizational survival. With companies reporting climate change affecting the process of the supply chain, reducing carbon emissions and monitoring them on a regular basis is now the centre of discussion (Alves et al., 2017). Adaptation techniques involve the change of action and behaviour because climate change brings new risks, which should also be considered while planning tools or ideas to mitigate the loss (Beauchamp, 2018).

Figure 2

Yearly carbon emissions per capita, 1960-2014
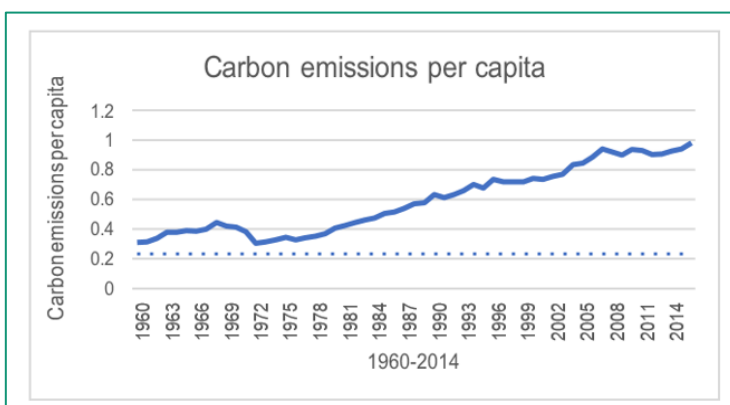
Table 3

Maximum CO$_2$ emissions (1960–2014)	Minimum CO$_2$ emissions (1960–2014)
0.100 metric tons per capita in 2014	0.04 metric tons per capita in 1972

The figure clearly represents the increasing trend line of carbon emissions in Pakistan per capita over the years. CO$_2$ emissions are an important indicator of climate change. Yearly data was taken to analyze the trend. Monthly data for carbon emissions was not available, so the trend was studied using the yearly data. 0.04 metric tons were the minimum amount of emissions during the year 1972, whereas 0.100 metric tons were the highest emissions of the country in the year 2014. Carbon emissions also play a major role in determining the agricultural growth and productivity of any country. And Pakistan, despite having no major contribution to its release, is on the radar to face upcoming repercussions (Kiran, 2017).

The major cause of carbon emissions is mass energy consumption. The world today has recorded an increase of 0.1 degree Celsius due to industrialization (Zahra et al., 2016). Transportation and industrial sectors of developed and developing countries consume oil and energy on a mass scale, and by the end, it all enters the environment in the form of released greenhouse gases such as carbon dioxide, nitrous oxide and other toxic gases (Denchak, 2018). Coal, oil, and gas in Pakistan have given rise to rising emissions. Moreover, agricultural land in Pakistan is being cut down due to industrial development. The industrial sector requires energy for growth, which has further caused environmental degradation in the country by emitting emissions. Researchers explored that the increased rate of carbon emissions is due to the constant economic growth in developed and developing countries (Khan, Khan, Rehan, 2020).

With an ongoing controversy over climate change, researchers believe it to be a trap for gathering scientific data. The public has declared scientific data for released anthropogenic and Greenhouse gases a fake collection of mathematical numeric because they consider that climate change is not happening in reality (Uscinski et al., 2017). However, the most alarming consequences are expected to be faced by those who deny the solutions to mitigate the loss, as they have falsified the idea of climate change. Despite scientists drawing a clear picture of the increased amount of carbon emissions in the air due to the burning of fossils, public opinion has polarized (Uscinski et al., 2017). With the conspiracy referring to actual terms, conspiracy theory refers to the accusatory perception of something to be true or false. Philosophers like Matthew Dentith argue that "it is not clear that conspiracy theory is prima facie unlikely, and therefore, it may be rational to entertain them (Uscinski et al., 2017)." Reality, which is not usually justified, is later categorized under the heading of conspiracy. For instance, some believe that climate change is a non-occurring phenomenon because not every claim made by scientists contains evidence, and they are accused of collecting funds in the name of research (Uscinski et al., 2017).

Research by Ali et al. (2017) explored that the change in climate affects temperature variations on a large scale. Moreover, globally, nine million people are predicted to be food insecure due to changes in rainfall patterns. Therefore, change in rainfall and temperature affects agricultural productivity massively. Due to the 0. 6-degree Celsius increase in global temperature, the Asian region is expected to lose 50% of its wheat productivity (Khan et al. 2016). In Pakistan, irregular rainfall patterns have marked a 19% decrease in the production of Rabi crops during the year 2016 (Khan et al., 2020). Irregular rain patterns, rising temperatures, water scarcity and floods are the key counting factors in deteriorating the climatic conditions of any country. Over the last few years, Pakistan has faced numerous changes in temperature and rainfall patterns.

Hence, the claim of conspiracy theory that scientist's consensus on climate change causing shifts in certain variables is a conspiracy to produce manipulated data does not hold true for Pakistan because the data used in methodology have shown fluctuations in variables– further proving that the environment inside the country is gradually deteriorating the climatic conditions.

Graphical Representation of Temperature

The data for temperature have been aggregated for 12 months and four seasons, following the study by Varadan et al. (2015). Pakistan has four major seasons. Cold and dry winter from December to February, a hot, dry spring from March till May, a summer rainy season from June till September and a retreating monsoon period of October and November. Maximum and minimum values for temperature and rainfall

were studied in these four seasons of Pakistan. 14.8, 29.1, 30.4 and 23.3 were the maximum temperature, and 7.3, 14.8, 23.6 and 9.8 were the minimum temperature recorded in degree Celsius during four seasons in Pakistan. Months from January to May– November and December showed a slight increase, as shown in Appendix A. Meanwhile, June, July, August, September and October showed a high increase in temperature, as shown below.

Table 4

Maximum and Minimum Temperature (1991–2019)		
Seasons	Maximum	Minimum
Cold and dry season (December– February)	14.8	7.3
Hot and dry season (March–May)	29.1	14.8
Rainy season (June– September)	30.4	23.6
Retreating monsoon (October and November)	23.3	9.8

Temperature–degree Celsius (Monthly Trends)

Figure 3
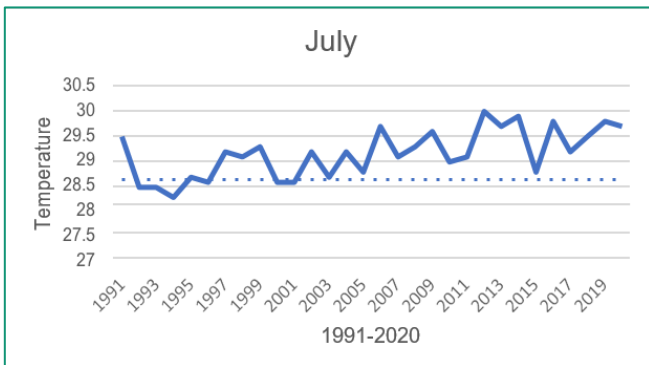*Monthly temperature in June*
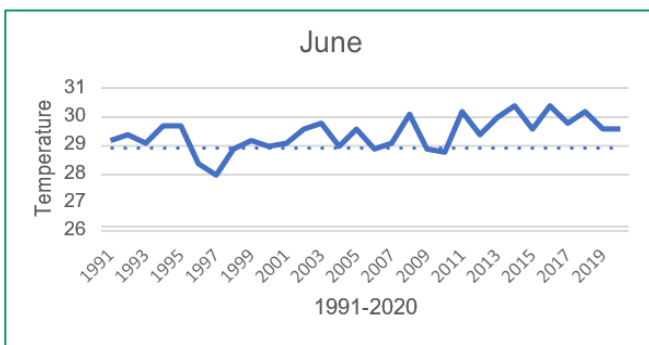
Figure 4
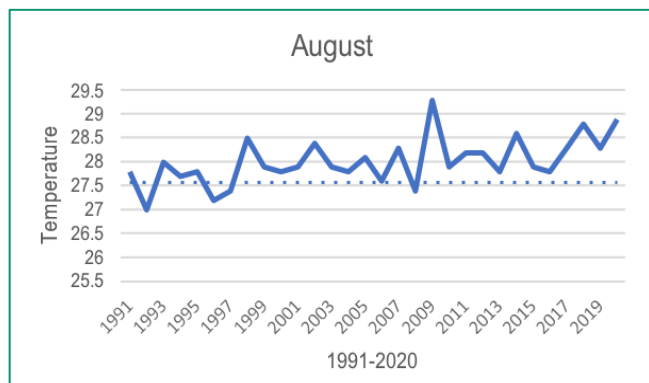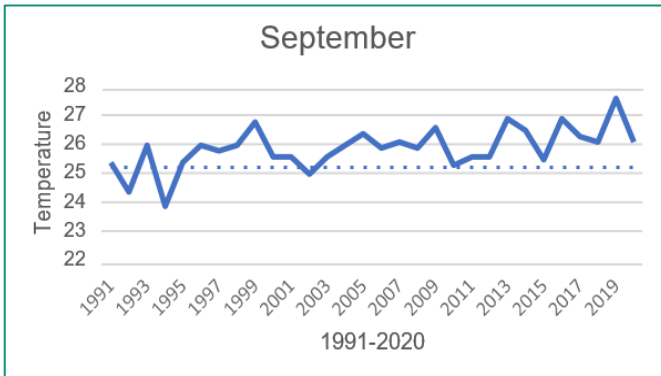*Monthly temperature in July*

Figure 5
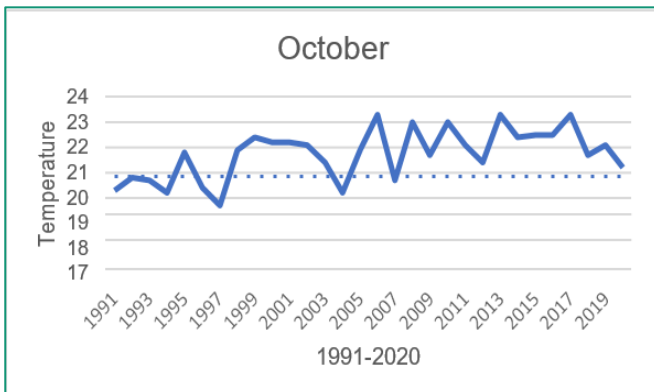*Monthly temperature in August*

Figure 6
Monthly temperature for September

Figure 7
Monthly temperature in October

Graphical Representation of Rainfall–MM

Data for rainfall was also graphed on a monthly basis. Results marked 52.6, 68.7, 107.3 and 23 to be the The maximum level of rainfall measured in millimetres (mm), and 0.5, 3.5, 5.2 and 0.3 was the minimum level of rainfall during the four seasons explored in Pakistan. Rainfall is an important factor in determining the crop production. A reasonable amount of rain decides when to grow a seed and when it is ready for harvesting. Rainfall mostly benefits cropland by increasing productivity and fulfilling water requirements. In some areas of Pakistan, agricultural productivity marked positive growth due to an increase in rainfall (Ullah, 2017). Similarly, rainfall and water level are important determinants when agricultural productivity is measured since crops depend upon water supply to grow and rip. Otherwise, underwater levels of land starve the crop, resulting in low yields because water is key to strong agricultural productivity. Torres et al. (2019) studied the effect of water and rainfall on partially irrigated agricultural land in Brazil and concluded rainfall is a vital determinant of crop production. Rainfall trends from January to July and October to December, with slight changes in the trend line, are illustrated in Appendix B. Meanwhile, the rainy and monsoon seasons during August, September, and November exhibited a rise in trend lines, as shown below.

Table 5

Maximum and Minimum Rainfall–MM (1991–2019)		
Seasons	Maximum	Minimum
Cold and dry season (December– February)	52.6	0.5
Hot and dry season (March–May)	68.7	3.5
Rainy season(June–September)	107.3	5.2
Retreating monsoon (October and November)	23	0.3

Rainfall–MM (Monthly Trends)

Figure 8
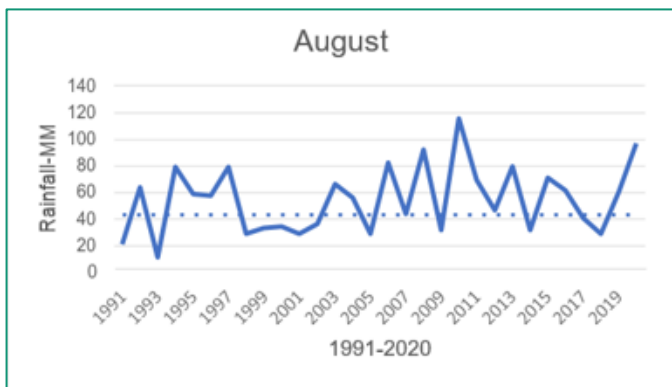*Monthly rainfall of August*

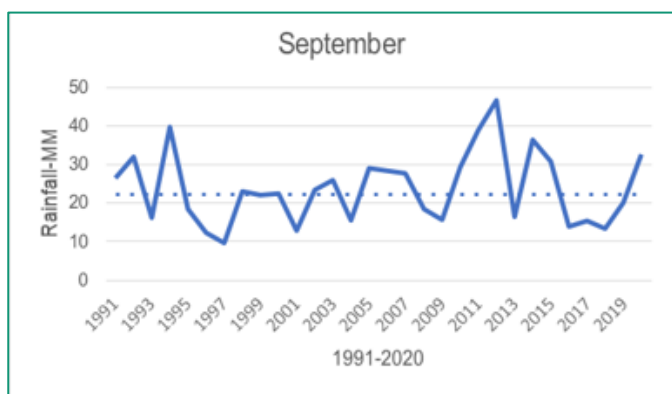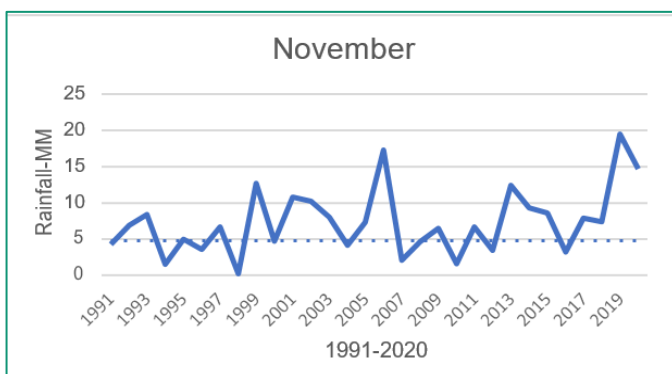### Figure 9
Monthly rainfall of September

Figure 10
Monthly rainfall of November

Results and Discussions

Rainfall in any country can lead to severe climate incidents such as heavy floods and droughts, further hampering crop productivity and food security inside the country. Rainfall in Pakistan has uncertainly remained a challenge for farmers in coping with the loss of agricultural productivity. One major reason why Pakistan falls under the list of most vulnerable countries due to climate change is its geographical location. Where the entire region is prone to the threat of rainfall during floods and monsoon season (Khan et al., 2016). With an economic loss of 6% during the 2010 floods, Pakistan ranked number 7 on the list of highly unprotected countries due to climate change (Zahra et al., 2016). The season monsoon is experienced in many parts of the world; however, Asian regions are more prone to the threat of increasing floods and rains due to poor management. Unfortunately, Pakistan falls among the countries with high levels of rain and poor management during this season. In terms of agricultural and economic development, the summer

monsoon season is considered one of the best seasons. However, poor conditions of dams and rivers inside the country cause floods on a regular basis. Due to the poor drainage system of rainwater, crop productivity inside the country is harmed, affecting the growth of cotton, sugarcane, chilli and tomato (Ali et al., 2016). Heavy rainfall and floods are expected to disturb food productivity in Pakistan on a large scale in the upcoming years (Ali et al., 2017).

Wheat and rice production are more prone to the threats of heavy rainfall and floods, which Pakistan faces during the monsoon seasons, as shown in the graphs (Khan et al., 2020). Moreover, rainfall patterns in the graphs have shown variation with constant fluctuations on a monthly basis. Irregular patterns of rainfall can cause a drastic reduction in the fertility of soil, making it difficult for seeds to grow.

Additionally, trend lines of temperature have shown a constant increase on a monthly basis. Only the months of November and December marked slight movement due to seasonal change, with 17.6 and 12.9 maximum temperatures, respectively. Temperature is important to determine the agricultural growth of any economy. High temperature makes it difficult for a crop to grow. Wheat production in Pakistan is highly sensitive to extreme temperatures. Wheat fulfils two-thirds of the human caloric intake, and high temperatures in the country have caused lower rainfall, affecting wheat and rice production (Ali et al., 2017). Furthermore, some parts of the country have marked low productivity of rice and wheat because of increased temperatures. Rainfall patterns are another hitting issue. Different part of the country receives different annual amounts of rainfall, such as northern areas having rainfall of 1000mm per year and drier Southern areas receiving only 200mm on an annual basis (Climate Risks and Food Security Analysis: A Special Report for Pakistan, 2018). Hence, both temperature and rainfall play a significant role in increasing agricultural productivity.

Conclusion

In summary, industrial emissions and pollutants have played a major role in deteriorating the environment. Global warming has adversely affected the terrestrial and marine ecosystems, especially rainfall, which is a major component of food production. Changes in climate and extreme weather conditions in the past few years have significantly affected food production and prices. The world has marked 217,136, 125 and 107 per cent increases in the prices of rice, wheat, corn and soya beans, respectively. By 2050, climate change is expected to further increase the food prices of wheat and rice in the global market (Mazhirov, 2011). Maximum and minimum rainfall over the years have seen decreases in Pakistan, plummeting food production and resulting in a spike in food prices (Kiran and Qurat-Ul-Ain, 2017). Rainfall is an important factor in determining crop production. A reasonable amount of rain decides when to grow a seed and when it is ready for harvesting. Rainfall mostly benefits cropland by increasing productivity and fulfilling water requirements.

In some areas of Pakistan, agricultural productivity marked positive growth due to an increase in rainfall (Ullah, 2017). Similarly, rain is an important determinant in measuring agricultural productivity since crops depend upon water supply to grow and rip. Otherwise, underwater levels of land starve the crop, resulting in low yields because water is key to strong agricultural productivity. Torres et al. (2019) studied the effect of water and rainfall on partially irrigated agricultural land in Brazil and concluded rainfall is a vital determinant of crop production. Altering rainfall patterns, emerging temperatures and emissions rates in Pakistan are expected to plunge food production, resulting in a spike in food prices in future (Kiran and Qurat-Ul-Ain, 2017). Likewise, results from graphs showed heavy rainfall during the monsoon season. Pakistan, due to its poor management, has also faced the agricultural loss of a few crops, including sugarcane, tomato, wheat and rice (Ali et al., 2016). With the foremost objective of decreasing food insecurity and reducing poverty, the agricultural sector of Pakistan's economy serves as a source of livelihood for about 42.3% of the rural population (Ali et al., 2017).

In the past few years, countries have been extremely vulnerable to climate change contributions. During the last 100 years, the mean temperature on Earth has increased by over 0.74 degrees Celsius, alarming the situation for already melting glaciers (Javed et al., 2014). Companies have been initiating new techniques to mitigate the loss made by the released carbon emissions. In this regard, contingency plans play a vital role because they are helpful in reducing emissions (Alves et al., 2017). Graphical analysis of temperature has also shown a constant increase in temperature during most of the months. Taking into consideration the current situation of the country, Pakistan falls among the top affected developing

countries, and now the country is considering plans to reduce greenhouse gas emissions by 30% by the year 2030 (Sajjad, 2015). Climate change is mostly due to the increase in temperature, which has caused many human and anthropogenic activities. Pakistan is an agro-based economy where increasing temperature is constantly hampering crop agricultural productivity. Developed countries are the ones to blame for this since a major portion of received carbon emissions comes from them. Climate change, as well as intensified Gas emissions, are envisaged as one of the major driving forces behind accelerated temperature water scarcity and stunted agricultural growth, affecting worldwide production of crops and livestock (Kiran, 2017).

Policy Recommendation

The energy sector in Pakistan is the single largest source of carbon emissions, and the agricultural sector is the most vulnerable sector to emissions of greenhouse gases and increased temperature. Presently, Pakistan is a small emitter of greenhouse gases, but it is ranked high among the countries most affected by carbon emissions. Pakistan needs to focus on the reduction of carbon emissions and the preservation of rainwater for agricultural growth, especially during the monsoon season when an ample amount of rainwater is available. Monsoon season in Pakistan creates ideal conditions for plants to grow. Radish, Spinach, Sponge ground and sweet peppers are the few best vegetables to grow in Pakistan. Similarly, plum, apples, mangoes, and lychee are some famous monsoon fruits. It is suggested that Pakistan must harvest rainwater for agricultural sustainability. Rainwater Harvesting is a process of storing rainwater in natural reservoirs or tanks for later usage.

According to UNFCCC, the projected growth of industries, energy, and agricultural sectors has contributed to the increasing greenhouse emissions in Pakistan. Concerns have risen due to Pakistan's dependency on the coal energy sector. Emissions in Pakistan are projected to increase from 347 tons in 2011 to 4621 in 2050, and the increase is estimated due to the high contribution of agricultural, energy and large-scale manufacturing industrial sectors (Manjit and Surinder, 2013). Moreover, due to irregular rainfall patterns and poor preservation, plants are unable to grow properly. Graphs for rainfall, temperature and Carbon emissions were not studied on a regional basis due to lack of data. Data for Carbon emissions (metric tons per capita) was only available on a yearly basis. Therefore, no monthly trends were analyzed. Future researchers can use statistical and empirical analysis to come up with results that may help the policy framers adopt more applicable and results-driven policies.

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