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Effect Of Global Change And Possible Ways To Reduce Its Adverse Impact On Agriculture In The Overall World: A Review

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Abstract

Climate changes devastation and damages may be seen all around the world, but especially in South Asia, where populations are particularly vulnerable to climate change and climate change adaptation and mitigation understanding is exceedingly poor. Pakistan's low adaptive capacity has been a constant threat to the ecosystem, biodiversity, and human communities due to the country's high poverty rate, limited financial resources, and lack of physical resources, as well as constant extreme climatic events such as varying temperature, continuous flooding, melting glaciers, lake saturation, earthquakes, hurricanes, storms, avalanches, droughts scarcity of water, pest diseases, human healthcare issues, and seasonal and lifestyle changes With local animal species such as lions, vultures, dolphins, and tortoises facing extinction regardless of generating and contributing minimally to global GHG emissions, the likely effect of climate change on common residents of Pakistan in comparison to the rest of the world and they, 're per capita impact of climate change are high, with local animal species such as lions, vultures, dolphins, and tortoises facing extinction. The average world temperature is steadily rising and is expected to climb by 2 degrees Celsius by 2100, resulting in significant global economic losses. Increased temperature offsets this effect by increasing crop respiration rate and evapotranspiration, higher pest infestation, a shift in weed flora, and reduced crop duration. Increased CO2 concentration, which accounts for a large proportion of greenhouse gases, has led to higher growth and plant productivity due to increased photosynthesis; however, increased temperature offsets this effect by increasing crop respiration rate and evapotranspiration, higher pest infestation, a shift in weed flora, and reduced crop duration GHG emissions, according to the review's findings, create climate change, which has impacted agriculture, livestock, and forestry, weather trends and patterns, food, water, and energy security, and world forum. This paper examines the data gathered from the literature on climate change, its possible causes, its near-term projections, its impact on the agriculture sector as a result of its influence on plant physiological and metabolic activities, and its potential and reported implications for plant growth and productivity, pest infestation, and mitigation strategies, as well as their economic impact. According to the findings, government intervention is necessary for the country's long-term growth, as evidenced by stringent resource accountability and regulations imposed in the past for developing state-of-the-art climate policy.

Introduction

Climate change is one of the most pressing issues facing the globe today. Significant changes in the average values of meteorological components such as precipitation and temperature, for which averages have been estimated over a long period, are classified as climate change (WMO.1992). Significant changes in global climate over the last few decades have been attributed to increased human activities that affected the composition of the global atmosphere (IPCC.2007). Since 1750, the concentrations of greenhouse gases like methane (CH4), carbon dioxide (CO2), and nitrous oxide (N2O) have increased by 150 percent, 40%, and 20%, respectively (IPCC.2014). Carbon dioxide emissions increased to 36.14 billion metric tons in 2014, up from 22.15 billion metric tons in 1990 (Sathaye et al. 2006). Since 1975, the average global temperature has risen at a pace of 0.15–0.20 degrees Celsius per decade (www.earthobservatory.nasa.gov), and is anticipated to rise by 1.4–5.8 degrees Celsius by 2021 (Arora et al. 2005). GHG emissions, primarily CO2 from fossil fuel combustion and non-CO2 GHGs including nitrous oxide, methane, and CFCs, contribute to global warming. The CO2 concentration in the atmosphere grew from 315.98 ppm in 1959 to 411.43 ppm in 2019 (NOAA. 2020). CO2 makes up the majority of greenhouse gases in the atmosphere, accounting for 65 percent from fossil fuels and industrial processes and 11 percent from forestry and another land usage, with methane (16 percent), nitrous oxide (6 percent), and fluorinated gases accounting for the remaining 6 percent (2 percent) (IPCC.2014). CO2 emissions from fossil fuels were minimal before 1750, but they skyrocketed with industrialization. The first part of the review paper depicts the growth in CO2 emissions from 1850 to 2020. Since 1751, the globe has emitted around 1.5 trillion metric tons of CO2. There are, however, regional differences in emissions. Europe, with roughly 514 billion metric tons of CO2 emissions, is the highest contributor, followed by Asia and the North American continent, each with 457 billion metric tons of CO2 emissions. The United States is the largest contributor to CO2 emissions (399 billion metric tons), accounting for 25% of all historical emissions since 1751. (200 billion metric tons). The European Union (EU-28), a group of 28 countries that sets collaborative goals, is responsible for 22% of CO2 emissions in the past. Due to low per-capita CO2 emissions, Africa produces only 3% of global CO2 emissions. However, nations with lower historical emissions, such as Brazil and India, contribute significantly to overall emissions in the current environment (CDIAC.2020) Because of the increased CO2 levels in the atmosphere, crop fertilization is boosted, and energy requirements are reduced as a result of warming. These are some of the positive effects of climate change, but climate change has a negative influence on water supplies. Climate change had a mostly good impact in the twentieth century. The majority of countries benefited until 1980 when the trend for the industrialized world remained the same, but Third-World countries suffered. Climate change will become a serious problem in the twenty-first century, with negative externalities affecting both developed and poor countries (Tol et al. 2013). In the second part, the increase in greenhouse gases has ramifications for the rising global temperature. These infrared active gases, primarily carbon dioxide (CO2), ozone (O3), and water vapor (H2O), absorb thermal radiation from the atmosphere and the earth's surface, warming the planet. The greenhouse effect is the name given to this phenomenon. The third part depicts the average worldwide temperature anomaly, which shows a considerable increase in global temperature when compared to the average temperature of the base period (1901–2000). Since 1850, the world average temperature has risen by 1–1.2 degrees Celsius. Nonetheless, because temperature changes on land are far more noticeable, the global land temperature has risen approximately twice as much as the ocean temperature. In comparison to the 1951–1980 average, land temperatures have increased by 1.32 0.04 C globally, while ocean surface temperatures have increased by 0.59 0.06 C. (excluding areas of sea ice). In addition, because the Northern Hemisphere has more landmasses, it has a greater average temperature than the Southern Hemisphere. Since 1850, the temperature in the Northern and Southern Hemispheres has increased by 1.31 and 0.91 degrees Celsius, respectively, with a global average of 1.11 degrees Celsius. Extreme temperature rises have been seen in the polar areas, with negative consequences such as glacier melting (Richie et al. 2020). As the global temperature rises, it is necessary to cut greenhouse-gas emissions to keep the temperature increase to 2 degrees Celsius below pre-industrial levels. Since 2005, affluent countries have contributed roughly 60–80 percent of global temperature rise, sea-ice loss, and upper-ocean warming, compared to 20–40 percent for poor countries (Wei T et al.2012;Hare B et al.2006). Shortly, climate change is expected to worsen. In Pakistan's Punjab province, the minimum and maximum temperatures are expected to rise throughout the Kharif and Rabi seasons. In simulations done for the next mid-century (2040–2069), the average maximum temperature and average minimum temperature are forecast to climb by 1–3.3°C and 2–3°C, respectively, during the Kharif season, and by 2.1–3.5°C and 2–3°C, respectively, during the Rabi season. There have also been estimates of rainfall fluctuations in the regions, most notably during the Kharif season (25–35 percent), although variations in the rabi season are minor (Bokhari et al.2017). According to PRECIS, temperature minimums and maximums in Punjab, India, are expected to climb by the middle and end of the twenty-first century (Providing Regional Climates for Impact Studies). Extreme hot temperatures (heat waves) from March to June and extreme cold temperatures (frost) from December to January are also expected (Kaur N et al 2016). With an extra 0.5°C of warming, extremes in meteorological parameters, such as minimum temperature, maximum temperature, and precipitation, are expected to occur more frequently and with greater intensity in China. Furthermore, if global warming stays below 1.5 degrees Celsius, weather extremes will be reduced (Chen H et al. 2018). The global precipitation anomalies for the base period (1901–2000), suggest that precipitation is changing in a positive direction, however, these vary by area. Between 1901 and 2015, there was an absolute change of 0.78 inches in precipitation over the planet (www.ourworldindata.org). Temperature and precipitation extremes, on the other hand, are more likely to occur soon as a result of global warming. Extreme precipitation events, such as severe rain or drought, are influenced by the geography of a place. Drought in southern Africa and South America will be less severe, but the increased average river flows due to persistent strong rains will be more likely in South and East Asia. The Indus River Basin's rainfall pattern is expected to demonstrate uneven regional and seasonal fluctuations. In the upper Indus basin, precipitation is expected to increase, whereas, in the lower basin, it is expected to drop. Furthermore, the upper basin is expected to warm faster than the lower basin (Rajbhandari, R et al.2015). In the northeastern United States, there is a chance of more warm extremes, fewer cold extremes, and stronger precipitation extremes in the future. Increased emissions will exacerbate these changes (Ning, L et al.2015). Increased precipitation intensity and frequency have an influence on soil erosion, which will be exacerbated in northeast China as greenhouse-gas emissions rise (Zhang, Y.G et al.2010). Anomalies in precipitation have a negative impact on agriculture, particularly in underdeveloped countries. It has a substantial impact on agricultural yields as well as cropland acreage. According to data, the nearly 9% rate of farmland growth in the developing world during the last two decades is due to dry anomalies, as farmers extend their acreage to compensate for production losses (Zaveri, E et al 2020 Climate change is known to have a negative impact on agricultural production, with maize and wheat production anticipated to decrease by 3.8 percent and 5.5 percent, respectively (Lobell, BD et al 2011). Plants are subjected to abiotic stresses such as salt, drought, heat stress, and cold stress as a result of climate variables (Malhi, G.S et al. 2020). Climate change has several negative consequences, including water scarcity, soil fertility loss, and pest infestations in crops (Baul, T.K et al. 2015). This study aims: (1) to bring together studies on the effects of climate change on crop yields, weed infestations, and economic consequences from 1998 to 2020. (2) Climate change mitigation and adaptation measures are examined to have a comprehensive grasp of their potential significance.

2. Whys and wherefores of Climate Change

The concentration of GHGs increased by temperature changes on earth due to anthropogenic activity and natural phenomena (Stern, D.I. e al. 2014). Anthropogenic activities trigger the release of greenhouse gases such as CO2, methane, and nitrous oxide, as well as other compounds that deplete ozone in the atmosphere (Montzka, S.A et al. 2011). Elevated atmospheric CO2 (463–780 ppm) can enhance nitrous oxide and methane generation from upland soil and wetlands, correspondingly, neutralizing the 16.6% emissions reductions effect suggested by boosting biological carbon sinks (Groenigen, K.J.V, et al. 2011). Services account for 15% of overall emissions, mostly in the form of methane and nitrous oxide. If dietary choices and food energy consumption remain constant at 1995 levels, worldwide emissions of non-agricultural greenhouse gases are expected to rise until 2055. Nevertheless, as people's priorities shift into high-value items like meat and dairy, levels are projected to climb even faster. Emission can be minimized through technology prevention, reduced meat consumption, or a combination of the two (Popp, A et al. 2010). The cattle sector is the largest source of greenhouse gas emissions, accounting for 8–10.8% of total emissions, according to the IPCC; however, based on lifecycle analysis, it might account for up to 18% of total emissions (Popp, A et al.2010). Enteric fermentation, N2O emissions, liming, fossil fuels, organic farming, and fertilizer manufacturing are the main contributors to greenhouse gases in the cattle sector (Lesschen, J.P. et al.2011). Greenhouse gas emissions are also induced by the utilization of nitrogenous chemical fertilizers (Kahrl, F et al 2010). N fertilizer use can be avoided by 38% with crop growth production management. Crop growth handling also results in an 11 percent reduction in input energy consumption and a 33 percent rise in yields, resulting in a 20 percent decline in greenhouse-gas emissions (Soltani, A et al.2013)

3. Agriculture and Global change

Farming is by far the most exposed business to climate change due to its immense size and sensitivity to climatic conditions, resulting in massive economic implications (Mendelsohn R. 2009). Sensitive to climatic events such as temperature and rainfall have a substantial impact on crop productivity. The temperature rises, precipitation changes, and CO2 fertilization have differential influences depending on the crop, location, and magnitude of change in the factors. The impact of rising temperatures on yield is found to be reduced, whereas rising precipitation is anticipated to offset or lessen the impact of rising temperatures (Adams, R.M et al.1998). Crop productivity is influenced by environmental characteristics, as seen in Iran, and is dependent on adaptive abilities, crop type, climate scenario, and CO2 fertilization effect (Karimi, V. et al 2018). In Cameroon, a decrease in precipitation or an increase in temperature results in a large decrease in farmer sales income. This element, combined with poor administration, has resulted in low consumption for Cameroon's agricultural exports, producing national revenue volatility (Molua, E.L et al.2007). In Veracruz, Mexico, statistical evidence demonstrates that temperature has an impact on coffee yield. It was also determined that the coffee industry may not be financially sustainable for growers in the next years, as present production is expected to drop by 34% (Gay, C et al. 2006). The consequences of climate change on crop yields vary depending on the region and irrigation method used. Raising irrigated regions can boost crop production, however, this might harm the ecosystem (Kang, Y et al.2009). Temperature rises are projected to lower the production of many crops by shortening their growing season (Mahato, A. 2006). If both the subtropical and tropical regions warm by 2 degrees Celsius, total wheat, rice, and maize production is predicted to fall (Challinor, A.J. et al.2014). Changing climate has a bigger influence on tropical places when tropical crops are closer to their high-temperature optima and so, therefore, suffer from high-temperature stress at higher temperatures. In addition, insect pests and diseases are more common in humid and warmer climates (Rosenzweig, C. et al.1992). Many factors, such as humidity and wind speed, as well as temperature and rainfall, have an impact on agricultural yields, and without these factors, the cost of climate change could be overestimated. Furthermore, by 2100, climate change is expected to diminish wheat, corn, and rice yields in China by 18.26 12.13, 45.10 11.55, and 36.25 10.75 percent, respectively (Zhang, P..2017). Weather extremes have been extremely prevalent in Amsterdam since the 1900s, and they have had a considerable impact on wheat yields in the region. The magnitude of wheat yield decline was decided by the week in which a severe storms event occurred (Powell, J.P. et al.2016). Droughts are expected to become more common in the near future as a result of climate change in most parts of the world, with a projected increase in drought-affected land from 15.4 percent to 44.0 percent by 2100. Africa has been identified as the most vulnerable continent. By 2050, the output of staple crops in drought-prone areas is anticipated to drop by more than half, and by nearly 90 percent by 2100 (Bosello, F. et al.2021). Crop yield reduction can hike food prices and have an unsustainable impact on global agriculture wellbeing, with a 0.3 percent annual loss of projected GDP by 2100 (Stevanovic, M. et al.2016). However, (Bosello, F. et al.2005) discovered that while climate change has a minimal impact on global food supply, underdeveloped countries will suffer severe effects. Temperatures in India are expected to climb between 2.33°C and 4.78°C, with CO_2 concentrations doubling and heatwaves lasting longer, posing a threat to the agriculture sector (Kumar, R. et al.2014). Farmers in the dry region of Rawalpindi, Pakistan, will suffer an annual loss of INR 4180/acre by 2100 as a result of a 1°C increase in temperature, but net revenue can be boosted by INR 377.4 and INR 649.21, respectively, with an increase in rainfall of 8% and 14%. (Shakoor, U et al. 2011). With a 1°C increase in global mean surface temperature, yield losses in three cereal grains (rice, maize, and wheat) are expected to worsen by 10 to 25% (Deutsch, C.A et al. 2018). Climate change is expected to affect average crop yields by 6–24 percent in Sub-Saharan Africa (Waha, K. et al. 2013). The reaction of plants to climate change varies depending on the plant species and developmental stage. Many organisms have developed species-specific thresholds, and their reactions, such as root elongation, root growth angle disruption, and yield loss, differ between species (Gray and Brady. 2016). Reduced transpiration was observed in plants when CO_2 levels in the atmosphere increased, resulting in a 0.42 0.02 K increase in air temperature. This indirect physiological effect of increased CO_2, as well as a direct radiative effect, can result in a 3.33 0.03 K rise in land surface warming (Cao, L. et al. 2010). The harvestable product of crops is projected to grow as CO_2 levels in the atmosphere rise, and plant developmental modifications will vary depending on the type of crop. C3 crops are predicted to produce more, but in the absence of severe conditions, both C3 and C4 crops' water requirements are expected to be reduced. However, the positive effects of increased CO_2 are likely to be counterbalanced by rising temperatures and changing precipitation patterns (DaMatta, F.M et al. 2010). In some locations, however, climate change has a positive impact on crop production. However, these regional variations, whether they are increases or decreases, will not have a large impact, and they will be more noticeable in some low latitudes alone. However, if the temperature rises over the point when CO_2 is doubled, it can result in significant economic losses (Aydinalp, C et al.2005). Climate change will have a huge negative impact in developing countries' tropical regions, although it will be highly dependent on the region's climate scenario. Agriculture would suffer massive losses in the drier north and east of Sri Lanka, contrasted to the cooler central highland region, where output is predicted to stay the same or even increase as temperatures rise (Seo, S.N et al.2005). Climate change impacts dictate the cost of adaptation, therefore environmental policies must be dynamic and executed with adaptability and flexibility (Zilberman, D. et al. 2004). Wheat and rice yields in northwest India could increase by 28% and 15%, respectively, at double the CO_2 levels, according to a sensitivity analysis using CERES (crop estimation through resources and environmental synthesis); however, increased thermal stress due to elevated temperatures associated with high CO_2 nearly cancels out the positive impact. Furthermore, if the current irrigation scheduling is followed, rice and wheat yields will improve by 21% and 4%, respectively, even with the combined effect of increasing CO_2 and thermal stress. However, even with the good effect of increased CO_2, rice and wheat yields are expected to drop in the future if there is a severe water scarcity combined with temperature stress (Lal, M et al.1998). Increased CO_2 concentrations can compensate for crop yield losses caused by higher temperatures and decreased soil moisture (Long, S.P et al. 2006). The increased CO_2 concentration reduces global yield losses significantly by reducing agricultural consumptive water consumption (4–17%). Furthermore, regional variances in agricultural yields are primarily due to varied crop growing circumstances (Deryng, D. et al. 2016). In non-leguminous C3 crops with high CO_2 levels, the concentration of nutrients (N, Fe, Zn, and S) found primarily in proteins is lowered (Uddling, J et al.2018). At an ambient air temperature of 29°C, increased CO_2 levels resulted in improved vegetative and reproductive development as well as increased seed output in rice fields; however, increased temperature resulted in decreased seed set (Madan, P W, et al.2012). The zinc and iron content of C3 grain crops and legumes is decreasing as CO_2 levels rise, which has negative consequences for human health. Protein concentrations in C3 plants and legumes are also shown to be lower, although C4 plants are unaffected by increased CO_2 (Myers, S.S et al. 2014). Climate change has an impact on the microbial population in the soil, as well as their enzymatic activities. The microbial population was found to be substantially higher in a temperature gradient tunnel with a 4–5 C higher temperature than in field circumstances. Under a wide range of temperatures, the population of nitrogen-fixing and P-solubilizers bacteria and fungus, as well as enzymatic activities, increased significantly, but the maximum parameters were obtained on or around the optimal temperature (Kaur, J. et al.2014). Endophytic fungus and plant growth-promoting bacteria, on the other hand, have a positive, negative, or neutral effect depending on the temperature range (Compant, S. et al.2010). Table 1 shows the influence of climate change on diverse agricultural productivity as assessed by several models.

Table 1: yield variation according to crops and their location.

Crops	Yield variation	Cause	Model used	Location	Reference
Maize, soybean cotton	Yield increase up to 29–32 ◦C −30–46% by 2100 −63–82% by 2100	Slowest warming scenario Rapid warming scenario	Hadley III model	United States of America	(Schlenker, W et al.2009)
Cotton, wheat	−2–9% by 2050	Medium-high and low GHG emissions	DAYCENT	California's Central Valley	(Lee, J. et al.2011)
Wheat Rice Maize	-6% 3.5% 7.4%	Each degree Celsius increase in world's mean temperature	Global grid-based, local point-based, statistical regression and field warming experiments	Multiple sites of the world	(Zhao, C et al.2017)
Rain fed corn	−23–34% by 2055	Increasing temperature and precipitation variability	Probability-based approach	Central Illinois	(Cai, X. et al.2009)
Maize	−24.5%	Increasing annual temperature	Multimethod analysis with statistical regression	Sub-Saharan Africa	
Rice	−3.7%	1 ◦C increase in mean growing season temperature	Regression, Kendall-tau statistic, Pearson correlation		
Wheat			SALUS crop model		(Ray, D.K. et al.2019)

Sorghum	−5–17% and −2–18% if occurred early in season	Increased frequencies of extreme weather events and warming		China	(Tao, F. et al.2006)
	−2.2%	Increasing temperature	County-specific multiple linear regression model		

Climate change is most likely to have an impact on pathogen development and survival (Elad, Y. 2014). The sensitivity of a crop to numerous pests, diseases, and weeds is projected to rise when the climate or weather pattern of an area changes. High and mid-latitude countries are expected to see higher yields, while lower-latitude countries will see lower yields (Rosenzweig, C et al.2001). However, a one-degree increase in temperature is expected to result in a 10–25 percent increase in losses owing to insect pest infestation (Shrestha, S. 2019). Climate change has the potential to increase insect populations and migration, posing a threat to agricultural production and even viability, as pest populations are mostly influenced by abiotic elements such as humidity and temperature. In Brazil, the infestation of coffee nematodes and leaf miners are projected to grow as the number of generations per month increases in comparison to 1961–1990 climatic circumstances (Ghini, R et al.2008). As a result of the pest invasion, pest management expenditures have skyrocketed. In contrast to a reduction in wheat in the United States, increasing rainfall and temperatures increased the costs of insecticides for crops such as corn, potatoes, and soybeans (Chen and McCarl, 2001). In the Had CM3-high 2050 scenario, the proportion of arable land affected by the European corn borer and the Colorado potato beetle is expected to increase by 43 and 48 percent, respectively, for the second generations, and the unoccupied areas of high altitudes are also found vulnerable to these pests (Kocmankova, E et al. 2010). According to the present global warming scenario, the suitable areas for wheat aphid (Schizaphis graminum) would expand to upper latitudes in the northern hemisphere by 2030, whereas the area in the northern hemisphere will decline (Aljaryian and Kumar, 2016). Insect outbreaks of 30 pest species are also projected to become more common. The rising temperatures in Sweden, it is likely to harm new locations, as well as the country's forestry sector (Hof, A.R. et al. 2015). When using GIS modeling to forecast the future of the potato tuber moth (Phthorimaea operculella), researchers found an estimated increase in the pest's harm potential in tropical and subtropical warmer climates, where the pest already exists. . It's also expected to spread in temperate and mountainous areas, with slightly higher harm potential (Kroschel, J. et al.2013). Increased temperature is expected to limit the life cycle of diseases like Puccinia striiformis f.sp. trictici, while an increase in atmospheric CO2 concentration is expected to create favorable conditions for Fusarium pseudograminearum (Luck, J. et al.2011). Climate change has an impact on population distribution and growth rates, as well as increasing the number of generations. Climate change has the potential to lengthen pest development seasons and alter crop-pest synchronization. It can also enhance the danger of pest invasion by migrating pests. Climate change is also expected to affect the effectiveness of plant protection strategies such as host plant resistance, natural enemies, transgenic plants, synthetic chemicals, or biopesticides (Reddy, 2013). Climate change and globalization may result in unforeseen interactions between farming systems, weather, and pests (Lamichhane, J.R et al.2015). Insect development and metabolic rates are anticipated to be affected by climate change, especially in temperate zones (Deutsch, C.A. et al.2018). As a result of climate change, the area suitable for pest infestation is expanding. Tuta absoluta, Ceratitis cosyra, and Bactrocera invadens, three of Africa's most abundant insect species, have increased habitat suitability across the continent, particularly in regions near to their most appropriate habitat (Biber-Freudenberger, L. et al.2016). Furthermore, rising temperatures and elevated CO2 levels are increasing the threat of late blight, blast, and sheath blight of rice, which might represent a severe threat to global food security (Gautam, H.R et al.2013). Climate change has an impact on crop weed infestation. Increased CO2 concentration causes C3 weeds to respond more strongly, with increased leaf area and biomass. In C4 plants, C3 weeds are a serious issue, while C4 weeds in C3 plants become less competitive (Korres, N.E. et al.2016). Weeds compete with agricultural plants for water and nutrients because they demand more nutrients than crop plants (Malhi, G.S. et al.1996). Climate change has an impact on crop–weed competitive dynamics. Climate change, in addition to weed growth, has a considerable impact on herbicide efficacy since it changes the herbicidal mode of action (Varanasi, A. et al.2016). Climate change is expected to have a positive impact on wheat weeds, which are critical to global food security (Bajwa, A.A. et al.2020). As a result of climate change, new geographical frontiers for weeds have opened up, and their control can only be accomplished if new management strategies are designed while climate change is taken into account. Insect infestations of various crops are expected to worsen as a result of climate change, as warmer and more humid temperatures are more conducive to pest reproduction. It will, however, differ from place to region and depending on the pests' capacity to adapt to climatic change.

4. Extenuation and modification to Climate Change

Farmers' perceptions of the danger and seriousness of climate change are the most important motivators for voluntary mitigation. Adaptation, on the other hand, is contingent on the availability of relevant data (Semenza, J.C. et al.2011). Furthermore, mitigation techniques will reduce the number of individuals exposed to water stress, but the remaining people will require adaptation strategies due to their increased stress exposure (Vuuren, D.P.V, et al.2010). Farmers can embrace climate-resilient technologies by combining traditional and agroecological management approaches, such as bio diversification, soil management, and water harvesting (Altieri, M.A. et al.2017). Increased carbon sequestration, improved soil health, improved soil quality, and reduced soil erosion are all benefits of these management approaches, which result in more resilient soils and agricultural systems, assuring food security amid climate change (Lal, R. et al.2011). These educational interventions are the most effective in providing climate-change education for ecological development because they focus on local, tangible, and practical features that can be tracked by individual behavior (Anderson, 2012). Farmers were mostly in favor of adaptations, while only a few were in favor of GHG reductions, demonstrating the need to focus on treatments that combine adaptation and mitigation elements (Arbuckle, J.G et l.2015; Smith, P et al.2010). Resource-conservation technologies, cropping-system technology, and socio-economic or policy initiatives are the three main adaptation techniques for mitigation (Ventakeswarlu, B et al.2006). Due to a lack of information, small and marginal farmers are unable to cope with climate change, making them more vulnerable to losses (Baul, T.K et al.2015). Due to financial concerns and a lack of management measures, African farmers are also extremely sensitive to climate change (Biber-Freudenberger, L et al.2016). Many agronomic methods, such as shifting sowing dates, have been used to mitigate the effects of climate change. Wheat sowing dates in Punjab, India, have been determined to be October 22–28 in the northeast, October 24–30 in the central region, and October 21–27 in the southwest (Sandhu, S.S. et al.2019). Farmers in Sub-Saharan Africa who use sequential cropping methods and alter planting dates according to climate had the lowest crop yield loss (Verchot, L.V.. et al.2007). The agroforestry sector can help Kenyan small farmers adapt to climate change by reducing GHG emissions in the atmosphere. Alternate rice drying, mid-season drainage, improved cattle nutrition, increased N-use efficiency, and soil carbon are just a few basic ways to reduce GHG emissions. Climate change can be mitigated with simple adaptation methods such as adjusting planting dates and cultivars (Aggarwal, et al.2008). The spread of technology has a significant impact on how farmers respond to climate change. Market integration, public research assistance, and capacity-building are the top priorities (Lybbert, T.J. et al.2020). Conservation agriculture has the ability to reverse the years of soil degradation caused by conventional plowing by minimizing soil disturbance, increasing crop diversity, and maintaining soil cover. Furthermore, conservation agriculture reduces GHG emissions, reduces fertilizer consumption, and increases carbon absorption in the soil (Pisante, M. 2014). Conservation agriculture's basic concepts of minimal soil disturbance, crop rotation, and soil cover lay the way for sustainable agriculture approaches. Farmers in South Asia are switching to zero-tillage wheat-growing since it saves them 15–16 percent on labor costs. Furthermore, in wheat and maize, zero tillage produces higher yields with less variability (Erenstein, O et al.2012). No-till methods have also been promoted as a carbon-sequestering alternative to traditional tillage. However, the influence of no-till cultivation on climate change mitigation is exaggerated, as the additional organic carbon in no-till agriculture is relatively minor (Powlson, D.S. et al.2014). The adoption of conservation agriculture (CA) has been influenced by a number of factors, including farmer perceptions of individual benefits, functional market exchange techniques to supply the necessary resources for CA implementation, economic motivation for farmers, the development of farmer organizations to encourage local adaptation, and the creation of a suitable environment by farmer organizations and institutions (Brown, B. et al.2018). The major tools for adapting to climate change are improved farming techniques, which are heavily influenced by policy decisions tailored to climatic variability and extremes, as well as social, political, and economic factors (Smit, B. et al.2002). The traditional intensification of agriculture results in massive economic losses, over 80% of which are due to nutrient mismanagement, making nutrient management a crucial factor (Lu, Y. et al.2015). No-till farming, cover crops, manuring, nutrient management, agroforestry, and soil restoration can all help with carbon sequestration, or an increase in soil organic carbon (SOC). Furthermore, carbon sequestration has the potential to reduce global fossil-fuel emissions by 5–15 percent (Lal, 2004). When compared to transplanted rice, direct-seeded rice (DSR) emits fewer greenhouse gases. In comparison to transplanted rice, dry DSR and wet DSR had 76.2 percent and 60.4 percent reduced global warming potential, respectively. Furthermore, wet DSR yielded a yield that was 10.8% higher than transplanted rice (Tao, Y. et al.2016). Aerobic rice also has a big role to play in future climate change mitigation, as it saves 73 percent of irrigation water needed in field preparation and 56 percent of water utilized during crop growth. The use of micro-irrigation technology to cultivate aerobic rice is a viable option for long-term rice production. It also contributes to the reduction of methane emissions from rice fields (Parthasarathi, T et al.2019). There may be a lack of fresh water available for irrigation in the western United States, China, and south, west, and central Asia, resulting in the conversion of 20–60 million hectares of irrigation land to rainfed land and the loss of 600–2900 pcal food production (Elliott, J et al.2014). One of the irrigation strategies being advocated to mitigate groundwater overdraft and shocks caused by climate change is drip irrigation. It has the capacity to withstand climate change and reduce irrigation demand on groundwater. Farmers, on the other hand, are increasingly employing drip irrigation for intensive agriculture, resulting in increased groundwater extraction and the Jevons paradox (Birkenholtz, 2017). Sprinkler irrigation and drip irrigation, for example, can help reduce and adapt to climate change while also providing long-term economic benefits. However, due to water-pressure requirements, the added cost of mitigation in sprinkler irrigation is found to be the highest, ranging from USD 476.03–691.64/t, potentially increasing GHG emissions (Zou, X. et al.2014). Agricultural strategies based on site-specific data can help farmers use less nitrogen without sacrificing profit. As a result, precision agriculture is thought to be more profitable than field management

(Bongiovanni, R et al.2004). Farmers' improper fertilizer management has resulted in reduced nitrogen use efficiency in northwestern India. To enhance the time and fertilizer rate, a leaf colour chart (LCC) was shown to be highly useful. The resulting rice yield was on par with the recommended blanket dose of 120 Kg N/ha after fertilizer treatment when the LCC showed less than 4 shade (Singh, Y. et al.2007). Fertilizer application at LCC 4 reduced methane and nitrous oxide emissions by 11% and 16%, respectively, compared to standard N fertilizer administration in split doses. When compared to standard N fertilizer application, it resulted in 18% fewer nitrous oxide emissions in wheat (Bhatia, A et al.2012).. One strategy to cope with environmental pressures is to breed plants to create new types. This will necessitate germplasm selection, breeding cycle shortening, and multiplication trials to determine a variety's fitness for the target environment (Atlin, G.N et al.2017; Chhogyell, N. et al.2016). As the frequency and intensity of abiotic stress is expected to rise as a result of climate change, developing stress-tolerant cultivars is critical as a mitigation approach. The ability to incorporate the SUB1A gene into multiple high-yield rice varieties marketed in South Asian countries has been facilitated by the cloning of the gene in rice plants. After being submerged for 18 days, these submergence-tolerant types provide a better yield than the original variety (Gregorio, G.B. et al.2013). Climate smart agriculture (CSA) strives to adapt to climate change by including water-smart practices, nutrient-smart practices, weather-smart activities, carbon-smart activities, and knowledge-smart activities into its operations. Climate-smart agriculture increases resistance to climate change by accumulating evidence, improving the performance of local institutions, promoting climate-friendly agricultural policies, and tying agricultural funding to climate change (Lipper, L. et al.2020). Climate-smart solutions that either give nutrients or water, or support soil structure, are the most efficient. Some technologies, such as half-moons, stone bunds, and zai, as well as nutrient application, have been found to be suitable for maintaining food production and securing smallholder farmers in semiarid West Africa (Zougmore, R. et al.2014). In Punjab, Pakistan, climate-smart agriculture technologies were studied, and higher cotton productivity was observed, as well as higher returns and resource efficiency (Imran, M.A. et al.2018). The Indo-Gangetic plain is extremely vulnerable to climate change, which has a negative impact on the region's rice–wheat cropping. Farmers have expressed interest in adopting climate-smart agriculture technologies that can transform traditional farming practices into more productive practices. The eastern indo-genetic plains (IGP) farmers prefer laser land levelling (LLL), weather-advisory services, and crop insurance, while the western IGP farmers prefer direct seeding, LLL, zero tillage, crop insurance, and irrigation scheduling (Taneja, G. et al.2019). These mitigation strategies have a lot of potential for mitigation and adaptation. They are, however, dependent on a technology's suitability for the region, people's perceptions, economic viability, and technical complexity. Moreover, these strategies work well when a number of interventions are used together in solidarity with each other.

5. Cost-effective Sway of Climate Change and Climate-Smart Farming Tools

Although climate change had some good effects at first, the unavoidable warming of the environment is a detrimental externality. A temperature increase of more than 3 degrees Celsius has net negative consequences, while a temperature increase of more than 7 degrees Celsius can result in total welfare loss. In 2015, the global social cost of carbon emissions is anticipated to be USD 29/tC (tonnes of carbon), rising at a rate of 2% per year (Tol, 2016). If climate change mitigation techniques are implemented, the net economic advantages in Solomon Island's fishery sector would be significant. Climate change will also have a significant impact on agricultural markets, resulting in a 0.26 percent drop in world GDP (Costinot, A. et al.2016). If the environment forecasted for the next few years materialises, household wellbeing is expected to decline by 0.2–1% per year. If the climate anticipated for the 2080s occurred today, there would be a projected annual loss of 0.2–1% in household welfare (Ciscar, J. et al.2011). With a 1°C increase in mean world temperature, both market and non-market damages are anticipated to cost 1.2 percent of GDP, or 1.2 percent of GDP (Ciscar, J.C. et al.2011). Table 2 shows the economic benefits of several climate-smart agriculture solutions.

Table 2: Incremental economic benefit by using climate-smart technology.

Crop	Location	Enhanced Efficiency	Climate-Smart Technology	Incremental Economic Benefit	Source
Wheat	Pakistan	Saving of 21% irrigation water and reduced irrigation time	Laser land leveling	INR 23,250/acre	(Wagan, S.A. et al.2015)
Many crops	Nyando basin of Kenya	Increased household income leading to household asset accumulation and investment	Stress-tolerant crop varieties	Increased HH income by 83%	(Ogada, M.J.. et al.2020)
Rice and wheat	Punjab, Pakistan	Higher water productivity, saving of irrigation water, and higher fertilizer use efficiency	Zero tillage and bed furrows	_	(Latif, A et al.2013)
Rice and okra	India	Reduced irrigation and preparation costs. Saving of irrigation water and electricity charges, reduced cultivation cost	Zero tillage and drip irrigation	Increase HH income by 16%	(Mishra, A.K.. et al.2016)
Wheat	Punjab, India	Saving of irrigation, lesser labor requirement	Direct-seeded rice	R 5050–INR 8100/ha over puddled	(Bhullar, M.S. et al. 2018)

Rice	Pakistan	This review has given a recent update on role of endophytes in improving rice plant	Fungal and bacterial endophytes.	transplanted rice (PTR)–Wheat _	(Muhammad U. U. k. et al.2021)

6. Conclusions and Views

As the world's population grows, so does the strain on agriculture to maintain food and nutritional security, which is exacerbated by climate change. Despite the fact that there are many unknowns about the future climatic scenario and its potential consequences, several studies have concluded that climate change will reduce agricultural productivity in the next years. Pest infestation, soil fertility, irrigation resources, physiology, and plant metabolic activities were all impeded by important climate elements such as temperature, precipitation, and greenhouse gases. To counteract the negative effects of climate change on agricultural sustainability, a number of mitigation and adaption measures have been developed. Water-smart practices (laser land levelling, rainwater harvesting, micro-irrigation, crop diversification, raised-bed planting, direct-seeded rice), nutrient-smart practices (precision nutrient application, leaf colour charts, crop residue management), weather-smart activities (stress-tolerant varieties, ICT-based agro-meteorological services), carbon-smart activities (zero tillage, legumes, crop residue management), and (agricultural extensions to enhance capacity-building). These solutions considerably mitigate the negative effects of climate change on crops and improve their climate suitability by reducing negative impacts. Climate change is expected to result in significant economic losses on both the micro and macro levels, which can be addressed by these actions. However, in order to improve their efficacy, these interventions must be planned at the regional or local level. Farmers' income is predicted to rise as a result of mitigation and adaptation techniques, without jeopardizing the long-term viability of agricultural production. Climate change's future and its consequences are very uncertain, making mitigation and adaptation planning a challenge. This involves the development of climate-resilient technology based on a regional multidisciplinary approach. Suitable varieties that can respond to environmental fluctuations, as well as planned agronomic management and crop pest control, must be created. Farmers must be educated about various climate-smart technology and given training to make their use in the field as simple as possible. Keynotes: 1. Global greenhouse-gas emissions raise CO_2 levels in the atmosphere, causing the global temperature to rise due to the greenhouse effect. Land masses, on the other hand, have experienced a greater rise in temperature than oceans. 2. The precipitation scenario has changed, and more extreme weather is expected to occur in the near future. 3. Agricultural productivity is expected to suffer as a result of climate change. The favorable effects of increased CO_2 on plants are most likely to be negated by increased temperature and changing precipitation. 4. Climate change has resulted in a warmer and more humid climate, which opens up additional opportunities for insect infestations. 5. To reduce climate change, technically sound and economically feasible climate-resilient innovations must be framed utilizing an interdisciplinary approach.

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