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Review Article

Impact of climate change on agriculture production and strategies to overcome

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Existing research suggests that climate models with enhanced geographical resolution might improve future climate projections. Meanwhile, stochastic projections from several climate models are necessary to evaluate model uncertainty and establish risk management strategies. Water availability is predicted to increase in some parts of the world, with consequences for water efficiency and allocation. Crop yields can be boosted by extending or increasing irrigated areas, but this may hasten environmental damage. Climate change alters soil water balance, resulting in changes in soil evaporation and plant transpiration. As a result, agricultural growth cycles may shorten in the future, reducing water yield. Climate change is projected to affect crop output differently depending on latitude and irrigation. Crop yields will rise in certain areas, but fall in others. In recent decades, agricultural regions throughout the world have seen major climate change, as well as widespread increases in CO_2 and ozone levels. Climate change and rising CO_2 levels increase worries about food security, particularly the influence on global agricultural productivity. We explain how climate and CO_2 changes impact agricultural yields, as well as present historical and prospective estimates. The study focuses on grain productivity on a worldwide scale, but other issues of food security are also included. CO_2 trends in the future decades are predicted to drive a 1.8% increase in global yields each decade.

Keywords: *agricultural yields, climate projections, environmental damage, prospective estimates*

Introduction

One of the most crucial challenges of the twenty-first century is ensuring enough food for a growing population while preserving an already fragile ecosystem, which is made more difficult by climate change. Water availability, food security, hydropower, and human health have already been significantly impacted by climate change, mostly in African countries but also internationally (Gemeda et al., 2023). A variety of climatic models were included in crop growth models to investigate crop production and soil water balance. Meanwhile, one of the key elements affecting crop productivity from year to year is climatic unpredictability, especially in high-yielding and highly developed agricultural regions. The effects of climate change, which would increase unpredictability in food production, have received more attention in recent years. Another factor limiting agricultural output and food security will be water availability. While water demand is steady, there won't be a scarcity of water; however, if the irrigated area is enlarged at the current rates of irrigation efficiency, there will be a shortage of water (Arora & Nabi, 2022). Therefore, creating effective adaptation plans requires knowledge of how climate change affects water availability and food production. Examining how crop growth models and global climate models function will help researchers assess how crop growth, agricultural output, and soil water balance will be affected by climate change in a variety of future climate scenarios. It is meant to provide scientists and decision-makers the essential background knowledge they need to comprehend how a changing climate will affect irrigated crops and the availability of food, as well as how to develop appropriate adaptation strategies (Ahmed et al., 2022). Emissions of greenhouse gases (GHGs) include both non-CO_2 and CO_2 from the burning of fossil fuels. The majority of greenhouse gases in the atmosphere are caused by CO_2, which comes from 65% of energy sources including fossil fuels and manufacturing processes, 11% from forestry, and other land uses. However, CO_2 grew significantly with industrialization (Bhattacharya, 2019). The global CO_2 emissions since 1751 have been around 1.5 trillion metric tons. Regional differences exist in emissions, however. The twentieth century was mostly positively impacted by climate change (Blanc & Reilly, 2017). The main concern is whether, in comparison to other variables affecting productivity, climate change and CO_2 would have a significant effect on world food production. This query helps to contextualize the difficulty of climate adaptation. We prioritize cost-effectiveness above statistically significant consequences in order to achieve the targeted growth rates. Important sources of calories for humans, including wheat *(Triticum aestivum*) and maize (*Zea mays*), are commodities that are traded globally, with pricing based on supply and demand (Alasti et al., 2020). The impact of individual places on the global supply is the only thing that matters. All sectors aren't, nonetheless, completely included in international marketplaces. Many places that are food insecure and impoverished lack the institutions and infrastructure needed to compete in local and international marketplaces. When studying global food security, it is important to take into account both local and regional effects, even if these regions are more global markets. Local supply and local pricing are more strongly correlated due to transportation expenses. For readability, this update concentrates on topics related to the whole world. The crops to be evaluated in climate impact assessments must be specified (Kuriachen et al., 2022).

Crop responses to global change

We briefly examine how each of these processes affects crop physiology. Crop water stress will rise when agricultural droughts occur more frequently (Eitzinger et al., 2010). Irrigation may be expanded in certain parts, but many lack infrastructure and water supplies might be limited during severe droughts. Plants with shallow or medium groundwater depth can reach under the surface to avoid drought. Crop plants often close their stomata and decrease carbon absorption in response to low soil moisture, leading to increased canopy temperature and associated heat-related effects (Fischer et al., 2002). Additionally, fluctuations in rainy season timing, especially in tropical places, can make it difficult for farmers to establish ideal planting dates. Intense rainfall can cause floods, saturated soil, and agricultural damage. Rising CO_2 concentrations can mitigate the detrimental effects of rising temperatures and diminished soil moisture. Elevated CO_2 reduces stomatal conductance, improving water efficiency in C_3 and C_4 crops. However, the comparative advantage of this impact differs between research and is currently being debated in the scientific community (Gornall et al., 2010). CO_2 fertilization may degrade crop nutritional quality, particularly in low-in nutrients cropping systems, as it reduces nitrate absorption and lowers protein concentrations in harvestable yields (Habib-ur-Rahman et al., 2022).

Systematic agriculture and crop-specific adaptations to global change

Cropping systems will be affected differently by global change because of regional variances in day and night warming rates, changes in fertilizer timing and intensity, and being exposed to O_3 and pollutants from air sources. Farm management, including crop selection and input levels, varies greatly by area and significantly impacts weather and climate change. Even if atmospheric CO_2 levels rise globally, the impact on crops and moisture conditions would vary by area (Hatfield et al., 2011). This section highlights key differences in cropping practices that influence net consequences, rather than providing a comprehensive evaluation of actual or projected effects. Rice and sugarcane are more irrigated than other crops, which contributes to their low susceptibility to heat. Rice benefits from increased T_{max} until it causes direct heat damage, while higher T_{min} can be hazardous. Rain-fed crops in rainy locations perform similarly to irrigated ones (Ishaque et al., 2023). CO_2 sensitivity varies across C_4 grains (least sensitive), C_3 grain (more responsive), and root/tuber crops. The geographical distribution of crop yields in relation to optimal temperature is a crucial component in determining regional or global yield responses (Jat et al., 2016).

Climate change's impact on agriculture yield

Climate variables associated crop productivity is anticipated to have a significant impact on both local and global food production. Crop growth model simulations or experimental data may be used to forecast the expected effects of climate change on agricultural production (Kalra et al., 2007). Crop models are essential tools for predicting how future events may affect crop yield. Examples of these models are CERES-Maize (Crop Environment Resource Synthesis), CERES-Wheat, and SWAP (Soil-Water-Atmosphere-Plant). Recent studies have examined the effects of climate change on agricultural production using agricultural growth models (Karki et al., 2020). The majority of the study on wheat output and climate change is focused on future CO_2 concentrations. Wheat germplasm that can withstand high temperatures is essential for reducing climate change since it may decrease efficiency in hot climates. The effects of climate change on wheat output in southeast Australia were predicted using CropSyst version 4, and the results indicate that rising CO_2 levels may cause a 25% decrease in median wheat yield (Koli et al., 2019). The impacts of climate change on wheat output were investigated using the CERES-wheat model under four different climatic conditions. The results indicate that increased crop yield in this study area is still mostly due to the CO_2 influence. Researchers looked at how climate change affected wheat yield using DSSAT 3.5. All CO_2 levels in Southern Australia are simulated by CERES-Wheat until the 2080s (Lal et al., 2005). The results indicate that wheat output will rise regardless of CO_2 levels, with drier locations being better suited for wheat farming but probably having lower-quality wheat. The effects of climate change on rice and other grain crops are discussed in the following sections. According to the research, there will be an approximate 45% and 30% increase in rice yields, respectively. In China's major rice-producing areas, the impacts of CO_2 levels on rice production were examined using the CERES-Rice model (Leisner, 2020). The results show that rice output increases with CO_2 and decreases otherwise. Using the generic large-area model (GLAM), Challinor & Wheeler (2018) examined how climatic uncertainty affected peanut production and discovered that fixed-duration simulation might increase yield by 10–30% (Lobell & Gourdji, 2012).

Climate change and food security

The term refers to the four facets of food security, which are use, access, stability, and availability. The FAO states that biotechnology may help increase food security while reducing its negative effects on the environment (Mahato, 2014). In the meantime, crop varieties that have been altered to withstand drought, flooding, salt, and harsh weather conditions may expand agricultural planting areas, such as those on damaged soils, and ultimately boost future food supplies. Food quality will be impacted by climate change as temperatures rise and crop growth cycles become shorter (Malhi et al., 2021). They simulated evapotranspiration and available water on a field scale using the HadCM3, SWAP, and water-salinity basin models, which allowed them to determine the connection between irrigation depth, crop area, and food quality. Therefore, in order to enhance overall grain yield, agricultural areas must be enlarged; failing to do so would reduce food security. It also proposed a number of strategies to increase potential crop yield, including crop diversification and increasing the area of irrigated and rain fed agriculture (Müller et al., 2015). The effects of climate change on food quantity and security were examined using the ADAPT and SWAP models (Pareek, 2017). The assessment of China's agricultural production and water management practices for food safety brought to light the need of integrating food, energy, environment, and population considerations with climate change when examining future food security in China and throughout the world. There are a number of uncertainties associated with managing water and other water-related issues due to climate change (Pathak et al., 2012).

Historical climate and co_2 trends: estimating their impact

Global soybean and rice yields have remained relatively stable despite changes, with barley and sorghum yields provided for comparison. Since 1980, grain yields such as barley, maize, and wheat have grown dramatically, however not as much as if the environment had been consistent. Since 1980, food consumption has increased dramatically, thus slight supply variations have an influence on global pricing and food security. The research, which concluded in 2008, could not account for following climatic events such as the Russian heatwave in 2010 and the US drought in 2012, both of which had a significant influence on food availability and prices (Raza et al., 2019).

Future climate and co_2 trends: estimating their impact

Several studies have projected how climate and CO_2 increases may affect crop production in the future. Research suggests that the benefits of CO_2 on a global scale are exceeded by the harm caused by climate change and other greenhouse gasses. There is a lot of disagreement regarding when the net impact will become negative. From 1980 to 2008, climate trends had a negative net global impact. However, this study investigated actual warming, not only the amount of warming caused by greenhouse gases. The impact of warming and CO_2 on agricultural yields could range from -23% to +2% every decade, depending on the rate of change in temperature and CO_2 levels. To determine if 3% is a significant quantity, examine yield growth rates over the past few decades, which have averaged around 15% every decade (Reddy & Hodges, 2000). A linear continuation of previous yield in terms of absolute values, which causes a lower percentage growth of 8% each decade until 2050, excluding climate and CO_2 effects. Decreases or increases of 2% to 3% every decade might significantly impact past and future yield growth. Historically, policies for mitigating greenhouse gas emissions have been based on the net effect. The combined effect of CO_2 and concomitant climate changes is particularly relevant in this scenario. When considering policies for adapting to temperature and pressure changes, the impacts of climate change become more important than the possible advantages of CO_2. In adjusting for climate as well as CO_2 in productivity growth projections, it's important to consider how the effects change from decade to decade, as historical yield trends incorporate past climate as well as CO_2 trends (Reynolds, 2010).

Climate change mitigation and adaptation

Furthermore, the number of individuals exposed to water stress will be reduced by mitigating measures, but those who are left will need to adjust as a result of the stress that is developing. Farmers may find it easier to use climate-resilient technology if they use conventional and agroecological management techniques including biodiversity, soil management, and water collecting (Rosegrant et al., 2008). By promoting greater soil health, quality, and carbon sequestration as well as reduced soil erosion, these management strategies build resilient soils and agricultural practices that will ultimately guarantee food security as the climate changes. Because they lack managerial tools and have financial constraints, farmers in African countries are also particularly exposed to the effects of climate change (Rosenzweig & Hillel, 1995). A number of agronomic techniques have been used to mitigate the effects of climate change, including modifying the dates of planting. In the northeastern zone, October 22–28 has been determined to be the ideal time to plant wheat.

In Sub-Saharan Africa, farmers that adopt sequential cropping methods and modify planting dates based on weather conditions have the least amount of crop production loss (Rosenzweig & Liverman, 1992). Nutrient mismanagement accounts for over 80% of the enormous economic losses associated with traditional agricultural development, underscoring the need of nutrient management. Many techniques, such as zai, stone bunds, half-moons, and nutrient treatment, have been shown to be effective in preserving food production and supporting small-scale farmers in semi-arid West Africa. In Punjab, Pakistan, climate-smart agricultural solutions were investigated and shown to increase cotton output while improving returns and resource efficiency. Farmers have shown a willingness to embrace climate-smart agricultural technology, which has the potential to improve the productivity of traditional farming practices (Shahzad et al., 2021). There is a lot of opportunity for both adaptation and mitigation with these measures. However, a technology's site fit, people's views, technical difficulty, and economic viability all play a role in determining them. Additionally, these tactics function best when several therapies are used concurrently.

The economic effects of climate change and climate-smart agricultural technologies

Although there were initially some benefits to climate change, the unchecked warming of the environment is a negative externality. More than a 3°C temperature increase is unfavorable, and more than 7°C might seriously impair wellbeing. The global social cost of carbon emissions is projected to increase at a pace of 2% per year and reach USD 29/tC (tonnes of carbon) in 2015 (Yohannes, 2016). Utilizing techniques to mitigate climate change will have a major positive economic impact on the fishing sector in the Solomon Islands. Agricultural markets will be significantly impacted by climate change, which will reduce global GDP by 0.26 percent. In the event that the 2080s climatic projections come to pass, household welfare is probably going to drop by 0.2-1 percent annually (Venkatramanan et al., 2020). It is predicted that global income will decline by 23% by 2100 if future mitigation efforts adopt the adaption of previous strategies, widening the already existing income disparity gap. Annual global economic growth is predicted to decline by 0.28%.

Conclusion

Climate change exacerbates the growing burden that agriculture bears in ensuring the world's food and nutritional security. The main climatic variables affecting insect infestations, soil fertility, irrigation resources, physiology, and plant metabolism are temperature, precipitation, and greenhouse gas emissions. Techniques for adaptation and mitigation are anticipated to boost farmer revenue while maintaining the sustainability of agricultural output. The unpredictability of climate change and its effects makes mitigation and adaptation plans more difficult. This involves developing climate-resilient technology using an interdisciplinary approach that is tailored to the area. Planned agronomic management, crop pest control, and the development of suitable cultivars are all necessary to adapt to changes in the environment. Farmers need to be trained in the effective use of climate-smart technologies in the field.

Author contributions

All authors contributed to the study's conception and design. Author Muhammad Khizar Hayat was responsible for creating the study and writing the protocol. Muhammad Khizar Hayat and Saqib hanif handled the preparation of the materials, data collection, and analysis. Muhammad Khizar Hayat wrote the first draft of the manuscript, and Malaika Zaheer provided feedback on earlier iterations. Authors Hassan Raza, Qurat Ul Ain, Amara Razzaq the literature searches and contributed a lot to Strategies Portion. The final part of the manuscript is Hinder Hunger written by Ariba Sehar and Ali raza. Qurat Ul Ain was in charge of managing the references and citations. All authors read and approved the final manuscript.

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