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Climate Change Implications for Agricultural Productivity: A Comprehensive Analysis

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ABSTRACT

The impact of climate change on global agriculture has been noticeable in recent decades, with rapid trends affecting various agricultural regions. As we look to the future, concerns about food security arise, prompting questions about the potential effects on aggregate productivity. Numerous factors, such as population growth, income disparities, dietary preferences, disease incidence, and competing demands for land and water resources, will influence global food security in the coming decades. While studies indicate that the overall food supply worldwide may not be seriously jeopardized by projected climate changes, there is a growing consensus that food insecurity in Africa will intensify. The risk of hunger is expected to increase both in terms of percentage and absolute numbers throughout the century. Despite projections suggesting a relatively minimal impact on the global average supply of calories in the next few decades, ranging from close to zero to potentially 20% to 30% of overall yield trends, the complexity of the issue is underscored by significant regional variations. The global perspective on food security conceals nuanced changes at smaller scales, which could have substantial implications even if overall production is maintained. To mitigate uncertainties in understanding global impacts, this paper recommends improving estimates of global warming rates and the responsiveness of crop yields to both warming and increased carbon dioxide levels. The responsiveness of yields is intricately linked to various factors, including genetic improvements made to crops, making it essential to address these variables for a more accurate assessment of future scenarios.

Keywords: Climate Change, Agricultural Productivity, Food Security, Global Warming, Crop Yield Responsiveness

INTRODUCTION

The agricultural sector plays a pivotal role in shaping the socio-economic and industrial landscape of any nation due to its multifunctional nature [1]. Serving as a potential industrial and economic catalyst, agriculture holds the key to a country's development [2]. Particularly in developing countries, it remains the primary source of livelihood for rural communities, contributing significantly to employment and Gross Domestic Product (GDP). In Africa, where over 60 percent of the population relies on agriculture for livelihood, the sector contributes approximately 30 percent to the GDP [3]. Sub-Saharan Africa heavily depends on rain-fed farming, which covers about 97 percent of total cropland. This reliance exposes agricultural production to the challenges of high seasonal rainfall variability [4]. Nigeria, for instance, leans heavily on agriculture, serving as the main source of food and employment for 60-70 percent of its population [5]. Beyond its role in sustaining livelihoods, agriculture in Nigeria significantly contributes to the economy, supplying raw materials for processing industries and generating foreign exchange earnings [6]. Given that agriculture in Nigeria is predominantly rain-fed, any alterations in climate patterns are poised to impact productivity and, consequently, other socio-economic activities in the country. The impact of climate change on agriculture can be measured through its effects on crop growth, soil water availability, soil erosion, incidents of pests and diseases, sea level rise, and a decrease in soil fertility [7]. As such, understanding and addressing the implications of climate change on agriculture in Nigeria is crucial for sustainable development and the overall well-being of the population. The menace of climate change not only poses a severe threat to the sustainable development of socio-economic and agricultural activities within nations but also imperils the very essence of human existence [7]. As articulated by the United Nations Framework Convention on Climate Change (UNFCCC), the impact of climate change manifests as a rapid alteration in local climate variability, surpassing the adaptive capacities developed by

communities over time. The peril that climate change presents to agricultural production extends beyond crop cultivation, encompassing livestock and the entire agricultural sector. Livestock play a crucial role for African farmers, serving as a source of income, food, and various animal products. Climate change can exert both direct and indirect effects on livestock [8, 9]. Direct impacts arise from climate variables such as air temperature, humidity, wind speed, and other climatic factors that influence crucial aspects of animal performance, including growth, milk production, wool production, and reproduction. Moreover, climate change can influence the quantity and quality of feed resources such as pasture, forage, and grains, as well as the severity and distribution of livestock diseases and parasites [10]. Therefore, the holistic assessment of the agricultural sector involves a thorough examination of agricultural productivity, with rainfall emerging as the paramount element in Nigeria's climate change and water resources potential [7]. The northeast region of Nigeria is undergoing rapid aridification, marked by a yearly reduction in surface water, depletion of flora and fauna resources on land, and an escalating transformation into an arid environment [11]. The persistent decline in rainfall contributes to a reduced natural regeneration rate of land resources [12], compelling people to exploit previously untouched lands, resulting in deforestation and the proliferation of sand dunes and Aeolian deposits in the northern axis of Nigeria. Climate change stands out as one of the most pressing global challenges, surpassing even the threat posed by global terrorism [13]. In the traditionally high-rainfall southern areas of Nigeria, irregularities in rainfall patterns are being experienced, coupled with a gradual rise in temperatures in the Guinea savannah zone. Simultaneously, the northern zone contends with the menace of desert encroachment [14]. The repercussions of climate change extend to food and water resources, critical for livelihoods in Africa where a significant portion of the population, especially the impoverished, relies on locally sensitive supply systems. Disruptions to existing food and water systems carry severe consequences for development and livelihoods, exacerbating the challenges already posed by climate change for poverty eradication [15]. As indicated by [11], the sustainability of the environment, providing life support systems and materials for fulfilling developmental aspirations, hinges on the suitability of the climate, which is undergoing constant changes. The effects of these changes pose a significant threat to food security. This study examines the trends of agricultural productivity and assesses the impact of climate change on agricultural output.

State of Agriculture in Sub-Saharan Africa

The pivotal role of agriculture in sustaining rural livelihoods and fostering economic growth is evident across much of Africa. Contributing between 20 and 30% of GDP and constituting 55% of the total value of African exports, the agricultural sector is a linchpin for the continent's economic dynamics [16]. With over 70% of the population residing in rural areas, and the livelihoods of approximately 85% relying on rain-fed agriculture and related rural activities, the sector is deeply interwoven with the fabric of African societies [17]. Rain-fed farming predominates in sub-Saharan Africa (SSA), covering a substantial 97% of total cropland, but this dependence exposes agricultural production to significant seasonal rainfall variability [18]. In contrast, irrigation systems are sparse, with only 4% of the production area under irrigation in SSA, compared to 39% in South Asia and 29% in East Asia [16]. Despite the high reliance on agriculture, productivity in SSA has witnessed a steady decline over the past five decades [19]. Notably, SSA's agriculture holds the record for the slowest productivity increase globally [20]. While Asia experienced a rapid surge in food production and yields during the green revolution in the late 1970s and early 1980s, SSA has seen a decline in per capita food production and yields [18]. This decline in agricultural performance is attributed to persistent issues such as a lack of demand for irrigated products, inadequate market access and supporting institutions, low population densities, limited incentives for agricultural intensification, challenging topography, poor-quality soils, and insufficient policy environments [21, 16]. This already challenging situation is poised to worsen significantly due to climate change and the increasing frequency of extreme events. The impacts of climate change on agriculture have the potential to exacerbate the living conditions of the rural poor and escalate food insecurity in the region

Implications for Food Security

During the World Food Summit (WFS) held in November 1996, the Food and Agriculture Organization (FAO) provided a comprehensive definition of food security, stating that it exists when "all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [22]. This definition encapsulates four fundamental dimensions of food security: food availability (encompassing production, distribution, trade, and exchange), food accessibility (considering affordability, allocation, and preference), food utilization (addressing nutritional and societal values, as well as safety), and food stability [22, 23,

24]. It is crucial to emphasize that food insecurity is a multifaceted and intricate problem, extending beyond a simple lack of food availability. Beyond the impact of climate change, food security is intricately influenced by a myriad of factors, encompassing broader issues such as poverty, disparities in natural resources, governance challenges, corruption, inadequate infrastructure, conflict, market deficiencies, financial constraints, high disease burdens, unequal global trading arrangements, and internal inequities within countries [25]. According to the report from the Inter-Agency Standing Committee (IASC), climate change is poised to act as a multiplier of existing threats to food security, with the global performance of food systems now being more dependent on climate than it was two centuries ago [21]. The risks that climate change poses to food security become especially acute during times of elevated oil prices, surpassing $130 a barrel in May 2008 [26]. The surge in fuel prices amplifies the costs of agricultural production, impacting expenses related to fertilizers, irrigation, and transportation. In sub-Saharan Africa (SSA), climate variability and extreme weather events, such as droughts, excessive rains, and floods, emerge as prominent risks affecting agricultural productivity and, consequently, rural household food security [27]. The failure of the rainy season directly correlates with agricultural setbacks, reducing food availability at the household level and limiting employment opportunities in rural areas [27]. The impacts of climate change and extreme weather events extend across all dimensions of food security, from direct effects on crop production—such as altered rainfall patterns leading to droughts or floods, and shifts in temperatures affecting the length of the growing season—to broader changes in markets, food prices, and supply chain infrastructure [21, 28]. Specifically, climate change will reduce food availability, because it will negatively affect the basic elements of food production—soil, water and biodiversity. It will indirectly affect food availability through its impacts on economic growth, income distribution, and agricultural demand [24]. Without climate change, calorie availability is expected to increase in Africa between 2000 and 2050. With climate change, however, food availability in the region will average 500 calories less per person in 2050, a 21% decline [29]. Also, the continent can expect to have between 55 and 65 million extra people at risk of hunger by the 2080s under the HadCM2 climate scenario. Under the HadCM3 climate scenario the effect is even more severe, producing an estimated additional 70 million people at risk of hunger in Africa [30]. Access to food will be affected by climate change events in terms of direct impacts on agricultural zones affecting incomes, employment opportunities, macro economy and GDP which shape livelihoods in many ways, including forms of social protection [31, 32]. Sub-Saharan Africa (SSA) currently grapples with the highest prevalence of undernourishment, affecting around 32% of the total population who lack access to sufficient food [17]. The most substantial impact of climate change on the economic output of agriculture in SSA is anticipated to disproportionately affect the region already facing high levels of poverty and food insecurity, resulting in the most significant reduction of agricultural incomes [24]. By 2080, the consequences of climate change are predicted to lead to a reduction of Asia's agricultural GDP by 4%, while SSA's agricultural GDP could decline by up to 8% [17]. If the projected increases in weather variability materialize, there is a likelihood of a heightened frequency and magnitude of food emergencies. Unfortunately, neither the global food system nor the affected local food systems are adequately prepared to cope with such exigencies [21]. Furthermore, climate change and variability will severely compromise physical, economic, and social access to food. As agricultural production diminishes, food prices are expected to rise, leading to a decrease in purchasing power [26]. This, in turn, exacerbates the challenges faced by vulnerable populations, amplifying the risk of food insecurity in SSA. Food stability is intricately tied to the stability of crop yields and food supplies, both of which are susceptible to negative impacts from variable weather conditions and influenced by the temporal availability of, and access to, food [21]. Recent studies suggest that while the global food supply might not face severe threats from projected global changes in climate, the outlook for food security in Africa is grim. There is an anticipated exacerbation of food insecurity, leading to an increase in both the percentage and absolute numbers of the population at risk of hunger over the coming century [25, 32]. Climate change also poses threats to food utilization by impacting human health, contributing to the spread of diseases such as malaria, HIV/AIDS, and undermining livelihood capabilities, thereby affecting food security across various scales [33, 32]. However, the overall understanding of these dynamics is not conclusive. The IPCC fourth assessment report highlights that the causal contribution of climate change to food insecurity in Africa is still not fully understood, especially concerning the role of multiple stresses that enhance the impacts of droughts and floods, as well as the potential implications of future climate change. Nevertheless, there is a broad consensus that unabated climate change could result in an additional 30–170 million people suffering from malnutrition or under-nutrition globally by 2080,

with three-quarters of these individuals residing in Africa

CONCLUSION

The trajectory of growth in aggregate crop productivity until 2050 will predominantly hinge on technological and agronomic advancements, as it has for the past century. Even under the most pessimistic scenarios, it appears highly improbable that climate change would lead to a net decline in global yields. Rather, the crucial inquiry on a global scale revolves around the extent to which climate change might act as a headwind in the ongoing race to sustain productivity growth to meet escalating demand. In the broader context, the net effect of climate change and carbon dioxide (CO_2) on the global average supply of calories is anticipated to hover around zero over the next few decades, but it could potentially range from 20% to 30% of overall yield trends. It is essential to recognize that this global overview conceals nuanced changes at smaller scales, which can be profoundly relevant to food security, even if global production is maintained. To mitigate uncertainties in global impacts, there is a pressing need for improved estimates of rates of global warming and the responsiveness of crop yields to warming and CO_2, considering their combined effects. The responsiveness of yields will be influenced by factors such as the inherent characteristics of crops, including any genetic enhancements made to reduce sensitivity to temperature or enhance responsiveness to CO_2. Additionally, adaptive management changes by farmers, encompassing decisions on what, when, where, and how to grow their crops, will play a pivotal role. The impacts of changes in ozone (O_3) are currently less understood but could potentially exert a significant influence on a global scale. While measuring the precise effect of climate changes on global food production is inherently challenging due to the vast scale and continual evolution of agriculture, the best available scientific evidence related to climate change and crop physiology underscores that it poses a credible threat to sustaining global productivity growth at rates essential to meet increasing demand. To address this challenge, scaling up investments in crop improvement and intensifying the focus of these investments on global change factors will be crucial in sustaining yield growth over the coming decades.

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