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Review Article

Climate and Weather in Agriculture

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Abstract

Global agricultural methods and results are significantly impacted by the complex interplay between climate and weather. The climate, which is defined by long-term climatic factors like humidity, temperature, precipitation, and wind patterns, impacts the agricultural terrain. The short-term variations in these factors that affect daily farming activities are represented by the weather.Extreme weather events and climate variability have a major impact on rural livelihoods, food security, and agricultural output. Strong difficulties to agricultural systems are posed by heat waves, storms, floods, and droughts, which can result in yield losses, degraded soil, and unstable financial situations for farmers. In addition, the continuous modifications in climatic patterns brought about by man-made elements such as greenhouse gas emissions are changing customary agricultural methods and raising questions about crop appropriateness in different areas.

Keywords: Climate Change Impacts; Agricultural Practices; Adaptation Strategies

Weather and climate are two basic elements that have a big impact on agricultural output and practices. For farmers and other agricultural participants to make educated decisions about crop selection, planting dates, irrigation, pest control, and general farm management methods, they must have a thorough understanding of the nuances of the environment and weather patterns. An overview of the significance of weather and climate in agriculture is given in this introduction, with particular attention to how these factors affect different facets of agricultural productivity [1].

21st-century agricultural has several problems, chief amongst them being global warming and extreme weather occurrences including periodic droughts and floods. A changing climate requires farming communities to adapt globally. In addition to making sure that natural resources are used sustainably, they must simultaneously enhance the amount of food available to feed the world's expanding population [2]. Agriculture is not only the cause for a rise in emissions of greenhouse gases in this process, but it is also a victim of temperature rise and harsh weather events. Utilizing ad hoc crop varieties and animals can reduce farming's environmental effect, and improved management practices can encourage soil conservation, making agriculture a valuable partner in the fight against climate change [3]. These agricultural programs that are put in place will determine whether agriculture has a good or negative influence on the effects of climate change mitigation and adaptation efforts. It will also rely on how well the relationships between the environment, weather, and farming operations are understood. Gaining this comprehension won't be an easy feat. The topics being studied are extremely multidisciplinary and complex. They need the knowledge of climatologists and meteorologists, as well as the abilities of plant pathologists, agronomists, ecologists, and geographers, to name a few professionals who have worked on studies examining the connection between weather, climate, and agricultural practices [4].

Effects of climate change on agriculture

Climate change affects agriculture in various ways, many of which make it more difficult for farming operations to ensure global food security. Due to lack of water brought by extreme heat, drought, and flooding, rising temperatures along with shifting weather patterns frequently result in reduced crop yields. Additionally, a number of insects and diseases of plants are predicted to either proliferate or expand to new areas. Many of the same problems, such as increased heat stress, insufficient animal feed, and the development of parasite and vector-borne illnesses, are predicted to affect livestock around the world as well [5].

In addition to increasing the already uncommon possibility of multiple regions experiencing simultaneous crop failures, the effects of climate change might have a major impact on the world's food supply [6].

A great deal of research has been done on how climate change affects specific crops, especially the four basic crops that account for about two-thirds of human energy intake (both of which directly and indirectly through animal feed): maize (also known as maize), rice, wheat, and soybeans [7]. However, there are still a lot with other significant unknowns. These range from the linked but essentially distinct problems of loss of soil including groundwater depletion to projected population expansion, which will only raise the world's food need for the foreseeable future [8]. However, during the 1960s, a series of advancements in agricultural yields known as the "Green Revolution" have increased harvests for every hectare of land area by 250% to 300%, and part of that growth may be anticipated to continue [5].

Impacts directly related to changing weather patterns

Observed variations in adverse weather

Because agriculture is weather-sensitive, significant occurrences like heat waves, droughts, or heavy rains—also referred to as low high rainfall extremes—can result in significant losses. For instance, the El Nino weather in Australia is predicted to cause losses for farmers, and the 2003 heat wave in Europe resulted in uninsured agricultural losses of 13 billion euros [9]. Heatwave duration and intensity are known to increase with climate change, and precipitation is known to become erratic and more susceptible to extremes. However, since the field of environmental attribution is still relatively new, it can be challenging to link specific weather conditions and the shortcomings that they lead to climate change rather than natural variability [5].

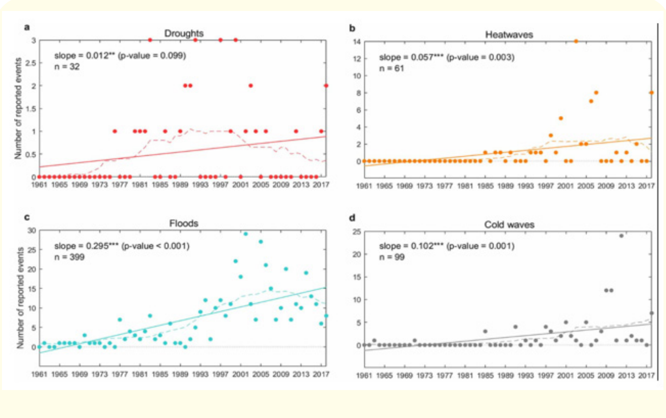

Figure 1: The noted rise in severe weather occurrences in Europe between 1964 and 2015 [23].

Winter extremes have decreased in Europe between 1950 and 2019, whereas heat extremes have increased in frequency and likelihood of occurring consecutively. Simultaneously, the Mediterranean region began to face increased drought, while most of Northern and Eastern Europe was discovered suffered extreme precipitation more frequently [10]. Comparably, it was discovered that within a 50-year span, the impact of heatwaves and droughts on crop production in Europe tripled, going from 2.2% losses in 1964–1990 to 7.3% losses in 1991–2015 [11]. Heat waves in the latter half of 2018 significantly decreased average yield in different regions of the world, particularly Europe. These heat waves are likely related to climate change. More crop failures in August contributed to an increase in food prices worldwide [12].

Projected effects from temperature increase

The locations that are appropriate for farming will change as a result of changes in weather and temperature. Due to their great heat sensitivity, many staple crops die when temperatures climb beyond 36 °C (97 °F), and maize pollen becomes lifeless [13]. Currently, warmer winters along with longer frost-free days in some areas can be disruptive since they can lead to a phenological mismatch between plants' flowering times and pollinator activity, which might compromise the viability of those plants' reproductive efforts [14].

Heat stress in livestock

Pets should generally be kept in environments with temperatures from 10 to 30°C (up to 50- and 86-degrees Fahrenheit). But global warming and increasingly frequent and severe heatwaves will undoubtedly have detrimental effects and significantly increase the likelihood that livestock will experience heat stress. "Cattle, sheep, goats, pigs, and poultry in low-latitude regions will face 72–136 more days per year of severe stress due high heat and humidity", according to SSP5-8.5, the climate change scenario with the most emissions and greatest warming [15].

Livestock in those areas would benefit from warmer winters, just as climate change is predicted to improve general quality of life for people living in the world's coldest regions [16].

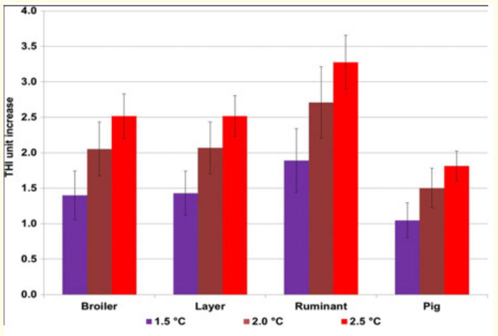

Figure 2: The thermal heat index of Jamaican farm animals rises even more with increased global climate change severity. One of the more commonly used markers of heat stress is a high thermal heat index [24].

Effects of increasing CO2 and methane levels in the atmosphere on plants

There are several methods that more atmospheric carbon dioxide impacts plants. By accelerating photosynthetic rate and reducing water loss due to stomatal closure, elevated CO_2 enhances crop yields and growth. Plants that experience the carbon fertilisation effect, also known as the CO_2 fertilisation effect, have a decrease in leaf transpiration and an increase in photosynthesis. Elevated environmental carbon dioxide (CO_2) levels cause both processes. The kind of plant, the temperature of the air and soil, and the availability of nutrients and water all affect how much carbon fertilisation occurs. NPP, or net primary productivity, may react favourably to the carbon fertilisation effect. However, research indicates that increased rates of photosynthetic in plants brought on by CO_2 fertilisation may not necessarily result in increased plant growth and, thus, increased carbon storage [17]. 44% of the rise in gross primary production (GPP) since the 2000s has reportedly been attributed to the carbon fertilisation effect. Vegetation patterns associated with rising atmosphere CO_2 levels are studied and interpreted using Earth System Designs, Land System Models, and Dynamic Worldwide Vegetation Models. Nonetheless, modelling the ecological mechanisms linked to the CO_2 fertilisation impact is difficult because they are still unknown [18].

Increased yields from CO_2 fertilisation

156 unique plant species will see an average 37% increase in growth in response to a twofold of CO_2 concentration, according to a 1993 analysis of scholarly greenhouse research. By species, the response differed dramatically; some showed substantially larger increases, while others showed a loss. A 1979 study conducted in a greenhouse revealed that forty-day-old cotton plants doubled in dry weight when the CO_2 concentration was doubled, whereas 30-day-old maize plants only had a 20% rise in dry weight [19].

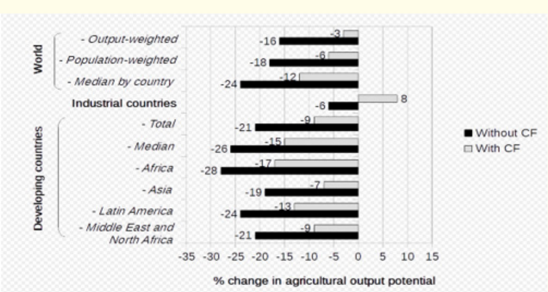

Figure 3: According to IPCC estimates from 2007, agricultural productivity is far less affected cumulatively by CO_2 fertilization (grey) than by its absence (black) [25].

The impact of elevated CO_2 in naturalistic settings is being studied in the field and by satellite observations in addition to traditional greenhouse research. In natural field plots, plants are cultivated in free-air atmospheric carbon dioxide enrichment (FACE) studies, where the ambient air's CO_2 content is intentionally increased. In comparison to the greenhouse investigations, these trials often employ lower CO_2 levels. They demonstrate less growth than studies conducted in greenhouses, with the growth mostly reliant on the species being studied. An average increase in crop output of 17% was reported in a 2005 assessment of 12 studies conducted at 475–600 ppm. Legumes generally responded more strongly than other species, while C4 plants generally responded less. The experiments' own shortcomings were also mentioned in the review. The majority of the studies were conducted in temperate regions, and the CO_2 levels under study were lower [20].

Decreased crop nutritional value

There is a possibility that some crops, like wheat, will lose some of their protein and mineral content due to variations in atmospheric carbon dioxide. C3 plants, such as wheat, oats, and rice, are particularly vulnerable to reduced protein and mineral content, such as zinc and iron. Food crops may have a 3–17% decrease in the amount of protein, iron, and zinc they contain. Food grown under anticipated atmospheric carbon dioxide levels in 2050 is likely to provide this outcome. The writers examined 225 distinct staple foods, including maize, maize, rice, and wheat. vegetables, roots, and fruits, using data gathered by the Food and Agricultural Organization of the United Nations as well as other open sources [21].

The impact of elevated atmospheric carbon dioxide levels on the nutritional value of plants extends beyond the crops and nutrients listed above. According to a 2014 meta-analysis, crops and plant life exposed to high carbon dioxide levels at different latitudes have decreased mineral densities for magnesium, a mineral zinc, and iron, and potassium [22].

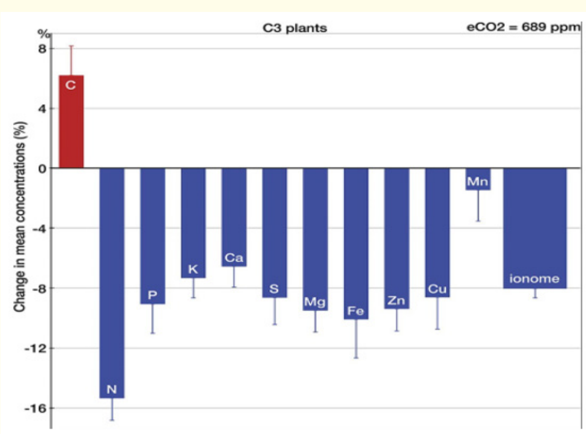

Figure 4: A systemic review was used to reconstitute the average decline in micronutrient density over a variety of crops at high CO_2 concentrations from several research. Although this figure's heightened concentration of 689 ppm is more than 50% higher than present levels, it is anticipated to be approached under "mid-range" change in climate scenarios and exceeded in high-emission ones [26].

Changes in the extent and quality of agricultural land

A more active hydrological cycle, with more intense rainfall episodes, is predicted as a result of the rising air temperatures seen over the previous few decades. Degradation of the soil and erosion are more likely. Global warming would have an impact on soil fertility as well. Anthropogenic influences can lead to higher rates of erosion in agricultural landscapes, which can result in loses of up to 22% of the soil's carbon in 50 years. Warming soils will also be a result of climate change. This could thus result in a sharp 40–150% rise in the size of the soil microbial population. The composition of the bacterial community would change as a result of warmer circumstances favoring the growth of some bacterium species. Increased soil microbial and plant growth rates in response to elevated levels of carbon dioxide would slow down the soil ecological cycle and favor oligotrophs, which grow more slowly and efficiently use resources than copiotrophs [23].

Conclusion

In conclusion, the complex interactions between climate and the weather have a big impact on agricultural practices and productivity all over the world. A farmer's regular processes are immediately impacted by short-term weather fluctuations, but long-term climate factors, such as precipitation, temperature, patterns of winds, and temperature, set the environment for agricultural activities. The unpredictability of the environment and extreme weather conditions like heat waves, droughts, floods, and storms provide a difficulty since they negatively impact agricultural yields, the condition of the soil, and farmers' ability to make a living. Additionally, as a result of human-caused variables like greenhouse gas emissions, the climate is continuously changing, which is changing conventional agricultural methods and casting doubt on the appropriateness of certain crops in various places.

In order to mitigate the effects of the changing climate on agriculture, proactive adaptation measures must be taken. These include diversifying crop types, improving water management strategies, incorporating cutting-edge technologies into agricultural systems, and putting resilient farming principles into practice. Policymakers, academics, farmers, and other stakeholders must work together to develop and implement sustainable solutions that improve agricultural resilience to changing weather patterns and climate. In the end, a coordinated effort is required to protect environmental sustainability, rural livelihoods, and global food security amid continued climate change and its effects on agriculture.

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