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Effects of Urbanization and Green House Gases on Sugarcane Growth

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Sugarcane (Saccharum officinarum L.) is planted all over the world and is an important crop for sugar and bioenergy. Increases in both the frequency and severity of extreme weather events have been attributed to climate change and the release of greenhouse gases. Climate change is expected to significantly damage sugarcane output worldwide, especially in poorer countries. This is because our ability to adapt is quite low, we are highly susceptible to natural disasters, our forecasting systems and our mitigation strategies are poor, and so on. Probably already having a detrimental effect on sugarcane production, climate change-induced increases in the frequency and intensity of extreme weather events are expected to have further negative consequences in the future. How much of an effect climate change will have on sugarcane is conditional on both where it is grown and how well it can adapt to its new environment. To better understand the effects of climate change on sugarcane production, we analyzed sugarcane reaction to climate change events, sugarcane production in numerous different nations, and obstacles for sugarcane production in climate change. We also provided strategies to lessen the impact of climate change and increase the long-term viability and financial viability of sugarcane farming.

Keywords: Green House Gases, Urban Heat Island, Sugarcane, Urbanization.

Introduction

Long-term changes in global weather patterns (i.e., global climate change) may result in major environmental challenges that have influenced agriculture and will continue to do so in the future. Since the middle of the 18th century, the amount of carbon dioxide ([CO_2]) in the atmosphere has increased by around 35% due to increased use of fossil fuels, industrial activity, and deforestation [1]. In a high emission scenario, atmospheric [CO_2] might quadruple (to 850 ppm) by the end of the twenty-first century from current levels, whereas in a low emission scenario, it could rise to roughly 570 ppm. Increases in [CO_2] and other greenhouse gases in the atmosphere are causing the planet to warm (GHG). Depending on the degree of GHG emissions, the region, and the location, it is anticipated that global surface mean temperatures will rise by 2 to 3.1 C (low emission) or 2.7 to 5.9C (high emission) by 2100 compared to 1980-1999 [2].

Increases in atmospheric [CO_2] and air temperature may be advantageous for some crops [3]. High and low temperature extremes, floods, droughts, and other abiotic stresses, and even tornadoes and hurricanes are all predicted to be affected by climate variability and climate change [4]. In many places of the world, agricultural output and economic implications have been negatively impacted by extreme heat and drought stress. Under climate change scenarios, the agricultural sector confronts challenges in meeting the needs of a growing global population for safe and nutritious food. Countries with poor irrigation systems or ones that rely heavily on rain may have it much tougher [5].

Changes in temperature and/or precipitation are the most obvious effects of climate change on agricultural output, but there are also secondary effects, such as shifts in pest pressure, availability to pollination services, and the efficiency of other ecosystem services. A decrease in crop productivity is predicted by the vast majority of existing evaluations of climate change's consequences [6]. Due to the fragility of agricultural output and the high cost of enhancing growing conditions, climate change presents agriculture with challenges never before experienced. Costs associated with these unfavorable consequences can be mitigated through the use of adaptive measures, and agricultural activity patterns can be adjusted to take advantage of emerging advantages. As a result, we will be better able to mitigate climate change.

Impacts of Climate Change Sugarcane

A major industrial crop, sugarcane is a source of both sugar and bioenergy. It is one of the most widely cultivated, and it thrives in warm, humid climates. Especially in many third-world nations, sugarcane harvests are highly dependent on weather and climate elements such as temperature, precipitation, and other harsh weather. According to Chandiposha, temperature and rainfall changes may have detrimental effects on sugarcane cultivation in Zimbabwe [7]. Extreme weather events, such as drought and tropical cyclones, have been linked to fluctuations in sugarcane and sugar production [7]. In 1994, Fiji set a new world record for sugar production with 516,529 metric tons, thanks in large part to the country's favorable climatic conditions. However, sugar production fell by 47%, 50%, and 43% from 1994 levels due to drought conditions in 1997, 1998, and 2003, respectively [7].

According to Marin et al. [8], who relied on crop simulation models to draw their conclusions, sugarcane productivity and water consumption efficiency have both increased over a wide range of Brazilian locations as a result of climate change. Their projections indicate that cane yields could increase by as much as 59% on average by the year 2050. Studies have shown that sugarcane's photosynthesis, water use efficiency, biomass, and yield were all improved by exposure to high [CO2] in a controlled setting [9]. Sugarcane's increased water consumption efficiency in high [CO2] conditions is mostly attributable to a decrease in stomatal conductance [10]. Although these results from the lab are crucial for comprehending the physiological responses of sugarcane plants to increased [CO2], they may not be indicative of the actual interactions between [CO2] and other climatic conditions[11]. The biggest benefit would be a longer growing season, especially in places like Louisiana in the United States, where the growing season is rather short because of frost. However, before reaping these benefits, it is essential to do a thorough analysis of the potential long-term negative effects on nutrient levels, soil moisture, water availability, and other factors. In the tropics, where cold winters are necessary to delay plant development and promote sucrose storage, rising temperatures may have a negative effect. It is predicted that the rising sea level caused by climate change would have the largest impact on Australia's sugarcane crop [12].

Sugarcane is primarily cultivated in areas close to the coast. Any rise in sea level would make farming these areas difficult, and a significant rise would necessitate abandoning substantial swaths [13]. The situation is analogous in the southern part of Florida, USA.

Climate change-induced increases in temperature in northeastern Brazil will lead to higher evapotranspiration rates, which in turn will decrease soil water content and make it harder to plant sugarcane, while also dramatically increasing irrigation demand [14]. In their study of the effects of climate change on sugarcane production in Swaziland, Knox et al[15]. found that future forecasts for cane output were on the decline unless irrigation was factored in. The results of a crop model suggest that a doubling of [CO2] might reduce sugarcane yield in the South Caribbean by 20-40% [15]. Increasing water stress due to the warmer environment was mostly responsible for the lower productivity. Sugarcane production is extremely vulnerable to climate change due to an increase in the frequency and intensity of extreme weather events such as drought, heat, flooding, typhoon, and frost [16]. This is because increases in atmospheric [CO2] and air temperature may benefit sugarcane growth and biomass accumulation in some regions of the world.

How sugarcane grows and develops in response to climate change-related drought relies on the sugarcane plant's developmental stage, the intensity of the water deficit stress, and the length of the stress. Cane productivity, and thus sucrose production, is generally reduced during the early and middle stages of drought. The amount of sugar in the stalk can be increased by experiencing moderate dryness throughout the late growth period. More than 80% of the sugarcane grown in China relies on rain for irrigation, making drought the single greatest threat to the industry [17]. In 2005, a severe drought in Guangxi, China, reduced cane output by 18% [18]. Due to optimal rainfall distribution and other favorable growing circumstances, sugarcane yields in Guangxi were exceptionally high in 2009. With a cane harvest of 86 t ha-1, 7.6 Mt of cane and 9.5 Mt of sugar were obtained. Very low temperatures, rain, and freezing temperatures in the region from January to February of 2009 caused significant damage to the majority of the sugarcane crop. Because of the high frost temperatures (4.5 to 6.5 C) that reappeared in December 2009, sugarcane productivity dropped drastically during the early growing season (January to June) of 2011. The growing seasons saw a decline in cane yield, cane output, and sugar production, with totals of 56 t ha1, 56 Mt, and 6.8 Mt, respectively [19].However, the sugarcane harvest in record years was reduced by 16-46% due to drought in 1984 and 2003 and tropic cyclones in Fuji in 1998

[20]. Another common condition that severely limits organisms' ability to thrive is water blocking.

The duration of water logging, the stage of plant growth, and the cultivars all played a role in the 18-64% decline in sugarcane output that was observed [18]. Several pests and weeds that reduce sugarcane yield will evolve in response to climate change [15]. Smut illness, is one such condition that is expected to spread more widely as a result of the rising temperatures, as noted by, for example, Matthieson [21]. The symptoms of ratoon stunting are made worse by the prolonged dry weather. Sugarcane rust infections may fluctuate over time as a result of climate change, however the bacteria is responsible for leaf scald, can spread rapidly during hurricanes and other intense storms. As overwintering pests (weeds and insects), disease pathogens, and extreme weather events have increased due to climate change, the input costs for minimizing these risks have increased to maintain a constant sugarcane production. The degree of rusting depends on the cold temperatures and relative humidity in the area. Farmers used fungicides to lessen the impact of rusts on yields, but the three split applications (per hectare, over the course of a growing season) costed 3 tons (Mg). According to the Florida sugarcane industry, the state would have gained roughly $63 million in 2013 if orange rot had been eliminated from the region.

Agricultural practices for sugarcane production must be modified to account for climate change, taking advantage of favorable conditions while mitigating their negative effects. Understanding the effects of these climatic and meteorological conditions on sugarcane output can also aid in the development of strategies for adaptation and mitigation, as well as the engineering of plant varieties to better satisfy human needs. Our goal in the next sections of this study is to assess sugarcane output in several countries, such as Brazil, India, China, Thailand, Pakistan, and the United States, to learn more about how climate change has affected sugarcane cultivation in these regions (developing and developed countries). We also provide strategies for easing the burden of climate change and improving the economic viability of sugarcane cultivation.

Out of 105 countries that cultivate sugarcane, they rank 25th, 53st, 26th, 20th, 33st, 36th, and 27th, correspondingly. Sugarcane output has increased linearly from 1973 to 2013 throughout the seven largest producing countries. Increases in sugarcane hectarage contributed more significantly to increases in cane output than did advances in yield, with the exception of Pakistan. Cane yields have increased by 60, 38, 59, 70, 58, 11, and 24% over the previous 41 years (1973-2013) in Brazil, India, China, Thailand, Pakistan, Mexico, and Colombia, respectively. Hectare rose by 500, 237%, 286%, 52%, 61%, and 61% in these countries, respectively. Acreage of sugarcane in the United States increased by 31% during this time period, while yield changed very little, by only 7.0%. (Table 2).

Further, when compared to the United States, most developing nations reported lower cane yields and a substantially larger yield variation (CV) across years. From 1973-2013 (a period of 41 years), average cane yields in Brazil (17.8% lower), India (21.0%), China (25.1%), Thailand (31.7%), and Pakistan (44.1%) were all lower than in the United States. (Table 2). Cane yields in the United States showed a greater range (5.7%-21.5%) over time than those in the other five countries combined (11.5-20.4% CV). (Table 2). Neither acreage nor yield plateaued when plotted against year in the top five sugarcane-producing countries, and the slope of the linear regression, which reflects the rate of increase in yield, varied from 0.49 (India) to 0.75 (Brazil) Mg ha-1 yr-1. Cane yields continue to rise in the vast majority of developing countries due to better cultivars and management practices, despite the fact that the influence of climate change on sugarcane production varies by location and degree of adaptability. Hence, in light of the current situation in these nations, it is still possible to grow both sugar-cane acreage and cane yield. Increasing sugarcane yields is especially important because of projected population expansion and land problems, which would make it impossible to grow enough sugarcane in most growing nations.

Manufacturing of Sugarcane

The majority of developing countries have limited adaptive capacity, high sensitivity to natural hazards, poor forecasting systems, and insufficient mitigation strategies, all of which contribute to sugarcane yields that vary significantly between years (Table 2) and locations with variable rainfall and temperature. As a result of high input costs, high production costs, and low cane prices, sugarcane growers' incomes tend to be lower than average in these developing countries. As a result of economic uncertainty, sugarcane producers in China's major producing regions (Guangxi, Yunnan, Guangdong, and Hainan) have diversified their crop selection. A 6% drop in sugarcane acres is predicted for the country's largest cane-producing area, Guangxi, in 2014-15 as farmers shift to industrial tree varieties that require less labor and grow more quickly. Hainan's cane acreage is expected to decline 11% in 2014–15 due to low profitability, according to provincial statistics. in addition to Profitability has been low due to low prices and high labor costs. More than half of the sugarcane hectarage is in hilly areas, making mechanized operation impractical. This means that more time and effort must be put into the planting, management, and harvesting of the crop by hand. The cost of manpower increased ($20/Mg cane), accounting for over 27% of the cane price ($71/Mg) in 2013/14. This had a considerable influence on sugarcane growers' revenues (Figure 1). (Figure 1). Owing to the low cane prices and high labor expenses, growers' net income drastically reduced in 2013–14. Revenues will rise while production costs fall under the present and future climate if more sugarcane products are used to make ethanol, cellulosic biofuels, and other coproducts.

When assessing agriculture and crop production systems, as well as climate change and its detrimental effects on crop production, many economic, environmental, and social issues must be carefully taken into account, including how to: (1) balance short-term and long-term goals; (2) increase productivity, profitability, and sustainability; (3) introduce new technologies and transfer them to growers; (4) comply with environmental regulations; (5) deal with contradictions between cl Indeed, these problems pose difficulties for sugarcane production systems.

Environmental Impacts on Sugarcane Yields

Worldwide sugarcane production has increased by a factor of three in the past 41 years in response to rising demand, despite the fact that the frequency and intensity of extreme weather events are on the rise as a result of climate change. Increases in cane production, yield, and acreage were already seen in the majority of developing nations. Under the current conditions and in the event of future climate change, there needs to be a much greater focus on increasing yield and boosting profits. The amount of sugar that can be extracted from sugarcane depends on a number of factors, including the plant's genotype, the pests, diseases, and environmental conditions that it is subjected to during cultivation, as well as the management techniques that are put into place (Figure 2).

Planting drought-tolerant varieties, investing in irrigation infrastructure, increasing irrigation efficiency and drainage systems, and enhancing cultural and management practices are just for lowering greenhouse gas emissions and adapting to climate change in Zimbabwe's sugarcane industry. Therefore, developing stress-tolerant, high-yielding sugarcane varieties is a crucial adaptation strategy in the face of climate change (Figure 2). Scientists working with sugarcane can use databases to plan for hybridization (within or between species), make use of growth and physiological data, and target specific needs. These traits are utilized in tissue culture, molecular biology, and gene-transformation technologies to enhance breeding and selection efficiency and to screen elite clones for resistance/tolerance to biotic and abiotic stresses. Some genotypes/cultivars have been shown to be superior to others in terms of yield, water stress tolerance, and cold temperature resistance

They found that the improvements in the yield component were mostly found in Florida's organic soils. Almost 69% of the increase in sugar yield can be attributed to a genetic enhancement associated with the Canal Point (CP) cultivar development programme, demonstrating the critical importance of cultivar development for the Florida sugarcane industry. Results from all three years combined revealed a positive and linear relationship between the year a cultivar was introduced and subsequent sucrose yield ($r = 0.77$). Cane tonnage ($r = 0.73$) was more strongly connected with the enhanced sucrose output of the recently introduced cultivars on Florida sand soils than commercially recoverable sucrose ($r = 0.17$). (Unpublished data, Figure 3). We also learned that some sugarcane genotypes are more resistant to stress environments than others by analyzing the large amounts of data on physiological, growth, and yield parameters collected during both pot and field trials. Hence, innovative sugarcane cultivars that can aid in climate change adaptation can be generated by finding and introducing desirable genes for agronomic trait development, applying fundamental breeding, physiological screening, and new molecular biology technologies. Improved sugarcane production, yield, and sustainability can help mitigate some of the worst effects of climate change.

The development of genetically modified (GM) sugarcane varieties with features including glyphosate resistance, drought tolerance, high sugar content, and disease resistance may be one of the important solutions for mitigating the adverse consequences of environmental stresses brought on by climate change. In the crystallized sugar from GM sugarcane plants, they detected no transgenic DNA or proteins. As a result of this discovery, the general public will have a more favorable impression of genetically modified sugar and its potential application in commercial sugarcane production in the future.

There are substantial differences in stress tolerance among plant species, cultivars, and cropping systems, so it is essential to have a diverse set of crops, cropping systems, and cultivars within a crop to lessen the negative effects of climate change, biotic and abiotic stresses, or other unpredictable extreme climate events. In 2000, 45 percent of Australia's sugarcane harvest came from the highly prolific Q124 variety. A new strain of orange rust virus decimated this variety, and the industry lost an estimated Aus$150-210 million due to the disease. As a result, having a wide selection of sugarcane types in a given area is essential for mitigating the effects of climate change, protecting the environment, and ensuring the crop's long-term viability. 12 primary cultivars were employed to harvest 172,100 acres of sugarcane in Florida during the 2012–2013 harvest season, creating a buffer between harvest time and the pressure of a labor shortage and milling capacity. Figure 4 displays the distributional frequencies of these cultivars across the Sunshine State of Florida. To lessen the impact of extreme weather events on sugarcane production and to lessen the likelihood of yield losses due to unexpected insects and diseases, it is recommended that each of the top sugarcane cultivars in a region not make up more than 25% of the total hectarage.

Most sugarcane illnesses are directly proportional to temperature and humidity levels. Sugarcane orange rust disease in Florida was substantially worse in the 2012 and 2013 growing seasons than in previous years due to warmer winters and greater humidity levels. Sugarcane smut disease was more devastating in sandy soils than organic soils due to the high temperatures and general dryness. Best management practices (BMPs) for pest control and enhancements in water and nutrient usage efficiency are also vital for the adaptation to climate change and the development of sugarcane output. In addition, breeding and variety development projects are creating disease-resistant cultivars.

Carbon sequestration, soil tillage, irrigation strategies and timing, drainage, nutrient monitoring, and fertilizer applications are all examples of best management practices. All of these have been the subject of extensive study in recent years, and researchers have discovered connections to both local climates and global warming. The sugar content of the stalks can be increased by allowing them to ripen and delaying irrigation until after harvest. Additionally, integrating accurate management tactics with seasonal climate projections may enhance sugarcane yield in many places. In order to increase sugarcane yields in China, experts have advocated for the adoption of specific methods of cultivar development and farm management. Plant growth regulators can be used to boost sugar production while also helping plants adjust to a wide range of environmental conditions. The tolerance to drought and other abiotic stimuli in sugarcane plants have been demonstrated to increase when seed canes or young plants are treated with low quantities of ethylene-producing compounds like ethephon at an early growth stage. Application of low concentration ethephon by foliar spray enhanced gas exchange properties, preserved relatively low osmotic rates of electrolytes and soluble sugar, raised proline content and water potential in leaf tissues, and stimulated the activity of cell protecting enzymes (such as peroxidase, catalase, and polyphenol oxidase). Cell membrane damage caused by water deficiency stress was minimized. The physiological and biochemical bases of plant growth regulator treatments and their beneficial effects on sugarcane development under drought conditions have been thoroughly. Topical use of ethephon in low concentrations can mitigate the negative effects of drought on sugarcane yields and growth.

Sugarcane's Effects on Local Climate\ Changes in farming practices and crop combinations may have a direct or indirect impact on a region's local climate features. Several countries routinely dispose of sugarcane byproducts in open fires either before or after harvest. The major difficulty with sugarcane farming is the emissions of greenhouse gases. Scientists have calculated that for every hectare of sugarcane grown, about 2.4 tons of carbon dioxide are discharged into the air. Sugarcane's primary contributors to carbon dioxide emissions came from three main activities: burning residue (44%), using synthetic fertilizers (20%), and burning fossil fuels (18%). Raising green harvest can consequently enhance soil organic carbon and minimize CO_2 emissions from sugarcane growing.

Their conclusions demonstrated that a thorough assessment of the costs and benefits of bioenergy-related land-use change must take into account potential implications on the surface energy and water balance in order to adequately address significant concerns for local, regional, and global climate change [11]. Sugarcane growth, according to its C4 carbon-fixing characteristics, can modestly boost carbon fixation and carbon sequestration. They came to the conclusion that the direct cooling effect of sugarcane boosts the indirect climatic benefits of this land-use option by integrating it with existing grassland and crops. By increasing air [CO_2] and surface temperature, sugarcane may consequently offer higher environmental protection than other field crops. The ways through which sugarcane can provide direct local cooling need to be investigated further.

Conclusions.

There is no question that the output of sugarcane has been impacted by and will continue to be impacted by climate changes. Extreme weather events, most notably drought, are becoming more common and severe as a result of climate change, posing serious threats to the sugarcane industry. With the help of the current adaptation mechanisms, many future effects can be reduced, but not all of them. Especially if greenhouse gas emissions continue to rise, the negative effects of climate change on sugarcane production are expected to worsen after 2050. Experts and policymakers in the agricultural sector need to collaborate closely to maximize sugarcane harvests and mitigate the potentially disastrous effects of climate change on the sector. There are a number of interrelated approaches that can be used to achieve this goal, such as the ongoing use of breeding and molecular biology to create new sugarcane cultivars, the improvement of best management practices, the promotion of new technology transfer, and the enhancement of productivity and profitability. To make sugarcane production systems more resistant to climate change, it is crucial to preserve vital natural resources like water and soil. By using sugarcane products more frequently for ethanol, cellulosic biofuel, and other coproducts, profits can be raised even further.

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