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SUSTAINABLE CHANGES IN SUGARCANE INDUSTRY AND AGRICULTURE CLIMATE ANALYSIS IN KARNATAKA

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Abstract

Sugarcane (*Saccharum officinarum* L.) is an important crop for sugar and bioenergy worldwide. The increasing greenhouse gas emission and global warming during climate change result in the increased frequency and intensity of extreme weather events. Climate change is expected to have important consequences for sugarcane production in the world, especially in the developing countries because of relatively low adaptive capacity, high vulnerability to natural hazards, and poor forecasting systems and mitigating strategies. Sugarcane production may have been negatively affected and will continue to be considerably affected by increases in the frequency and intensity of extreme environmental conditions due to climate change. The degree of climate change impact on sugarcane is associated with geographic location and adaptive capacity. In this paper, we briefly reviewed sugarcane response to climate change events, sugarcane production in several different countries, and challenges for sugarcane production in climate change in order for us to better understand effects of climate change on sugarcane production and to propose strategies for mitigating the negative impacts of climate change and improving sugarcane production sustainability and profitability.

Introduction

A combination of long-term change in the weather patterns worldwide (i.e., global climate change), caused by natural processes and anthropogenic factors, may result in major environmental issues that have affected and will continuously affect agriculture. Atmospheric CO_2 concentration ($[CO_2]$) has increased by about 30% since the mid-18th century due to increases in combustion of fossil fuels, industrial processes, and deforestation [1]. Projections indicate that atmospheric $[CO_2]$ would increase to about 550 ppm in a low emission scenario or could double (800 ppm) from current levels in a high emission scenario by the end of the 21st century. Global warming is directly associated with increasing atmospheric [CO_2] and other greenhouse gases (GHG). Global surface mean temperatures had increased from 0.55 to 0.67°C in the last century and are project to rise from 1.1 to 2.9°C (low emission) or 2.0 to 5.4°C (high emission) by 2100 relative to 1980–1999, depending on GHG emission level, region, and geographic location [2].

Increases in atmospheric [CO_2] and air temperature can be beneficial for some crops (especially C_3 plants) in some places [3, 4]. Climate variability and climate change are projected to result in changes in sea levels, rainfall pattern, and the frequency of extreme high- and low-temperature events, floods, droughts, and other abiotic stresses [5, 6] as well as tornados and hurricanes [7]. High temperatures accompanied by drought stress have been two of the major issues influencing agricultural production and economic impacts in many regions of the world. The challenges, faced by the agricultural sector under the climate change scenarios, are to provide food security for an increasing world population while protecting the environment and the functioning of its ecosystems [8]. For most countries that are highly dependent on rainfall with limited or no proper irrigation conditions and/or that have poor mitigation systems, these challenges may be amplified [9].

Agriculture is vulnerable to climate change through the direct effects of changing climate conditions (e.g., changes in temperature and/or precipitation), as well as through the indirect effects arising from changes in the severity of pest pressures, availability of pollination services, and performance of other ecosystem services that affect agricultural productivity. Reduction of crop productivity is universally predicted in most status reports on effects of climate change [10]. Climate change poses unprecedented challenges to agriculture because of the sensitivity of agricultural productivity and costs of improving growth environmental conditions. Adaptive action offers the potential to manage the effects of climate change by altering patterns of agricultural activity to capitalize on emerging opportunities while minimizing the costs associated with negative effects.

Sugarcane Response to Climate Change Events

Water availability at different growth stages of agricultural crops is crucial for obtaining a normal yield. A correlation analysis of yield vs. kharif and rabi season rainfall was conducted for the five dominant rainfed crops of Karnataka. It is evident from the analysis that the correlation between yield and rainfall varies across districts and seasons. The results obtained in this study for correlation between yield and rainfall are in concurrence with those reported by Revadekar and Preethi (2012), wherein the correlation between kharif rainfall and yield was reported to be stronger than that between rabi rainfall and yield. This is because the yield of crops grown during the rabi season is dependent on not only the kharif season precipitation but on the northeast monsoon as well. A similar correlation analysis was conducted for yield vs. summer maximum temperature for the top five crops. However, no correlation was found for any of the crops. Jacoby et al. (2011), Guiteras (2007), and Schlenker and Roberts (2006) have also reported that the effect of temperature on crop yield is generally non-linear, as found in this study. Notably, many of the Karnataka districts were affected by droughts and floods during the period 2007–08 to 2017–18. About 63 lakh hectares of cropped area is reported to have been affected by natural disasters as of 25/03/2019 (Disaster Management Division, Ministry of Home Affairs). The Karnataka districts are prone to two extreme calamities—droughts and floods. Drought has been recorded in several districts of the state since 2001. In 2019, the Karnataka districts faced the dual wrath of droughts and floods, with 16 districts bearing the impact of both climate extremes.

Projected Climate Change in Karnataka

In this section, the results of a modelling analysis for temperature and rainfall over the future period of 2021–2050 (2030s) are presented and compared with the corresponding data for 1990–2019. The likely changes are also discussed. The results of this assessment form the basis for a climate risk analysis of three dominant crops grown under rainfed conditions in Karnataka, the details of which are presented in Section 5. Climate-related hazards manifest locally, and the impacts of climate risk need to be understood in that context. Climate risk creates spatial inequality, as it may simultaneously benefit some regions while adversely impacting others. In this context, an analysis of climate at the district level for Karnataka has been conducted to assess the emerging climate risks.

Approach and Methods

Data modelled by the Coordinated Regional Climate Downscaling Experiment (CORDEX) South Asia (Appendix 1) on rainfall and temperature have been analysed for districts of Karnataka. The ensemble mean values from bias-corrected 15 CORDEX simulations of 0.5° × 0.5° resolution are used for estimating climate change projections. All data in this analysis are first re-gridded to a common 0.25° × 0.25° resolution to agree with the resolution of IMD data. The analysis has been conducted for two of the four Intergovernmental Panel on Climate Change (IPCC) climate scenarios or representative concentration pathways (RCPs), namely, RCP 4.5 and RCP 8.5. These pathways refer to a range of future anthropogenic greenhouse gas emissions and their atmospheric concentrations.

• **scenario:** This scenario is described by the IPCC as an intermediate scenario with emissions peaking in 2040 and then declining. This scenario will quite likely result in a global temperatu re increase of 2°C.

• **scenario:** This is the worst-case scenario in which emissions continue to rise throughout the 21st century. This is likely to result in a global temperature increase of up to 2.6°C. Changes in temperature and rainfall during the projected period are computed as a difference between the model-simulated 15-model ensemble5 average values for the 30-year historical period and the projected 30-year period. District-level averages of climatic variables are obtained using outputs from the re-gridded 0.25° × 0.25° resolution data. The mean value for a district is obtained as the mean of the values for multiple grids that may cover a district. For this computation, only grids that fall fully within a district and those with >60% area falling within a district, are considered. If a district falls within only one grid cell, that single grid cell value is considered.

Projected Changes in Temperature

Summer maximum and winter minimum temperatures are analysed as they are crucial for agricultural crop growth and productivity.

. Summer Maximum Temperature An increase in the summer maximum temperature of 0.5°C–1.5°C is projected in the short term, considering RCP 4.5 and RCP 8.5 scenarios (Figure 9). Under the RCP 4.5 scenario, (for the 2030s), warming is projected to be in the range 0.5°C–1°C for the Western Ghats districts. In the northern districts, and some of the central and eastern districts such as Chitradurga, Tumakuru, and Davanagere, warming in the range 1°C–1.5°C is projected for the short term. Under the RCP 8.5 scenario, warming is projected to be in the range 0.5°C–1°C for the Western Ghats districts. For all the northern and eastern districts, warming is projected to be higher—in the range 1°C–1.5°C for the short term. An increase in the winter minimum temperature of 0.5°C–2°C is projected in the short term, considering the RCP 4.5 and RCP 8.5 scenarios Under the RCP 4.5 scenario, warming in the range 0.5°C–1.5°C is projected across the districts. The warming is higher in the northern districts—in the range 1°C–1.5°C. In the southern and central districts, lower levels of warming—in the range 0.5°C–1°C—are projected. Under the RCP 8.5 scenario, warming in the range 0.5°C–1°C is projected for the southern and eastern districts; 1°C–1.5°C for the central and western districts; and 1.5°C–2°C for the northern-most districts.

Projected Changes in Rainfall

Rainfall is analysed for kharif and rabi seasons separately. In addition to the total quantum of rainfall during a season, the variability of rainfall and extreme events—high-intensity rainfall and rainfall deficiency—are also projected.

Projected Changes in the Frequency of Occurrence of Extreme Events

According to IMD, a rainy day is defined as one receiving >2.5 mm rainfall. In Karnataka, an increase in the number of rainy days is projected for almost all the districts, under both RCP 4.5 and RCP 8.5 scenarios. The increase in the number of rainy days under RCP 4.5 and RCP 8.5 scenarios is ≥5 days annually in 4 and 16 districts, respectively. The following sections present an analysis of the number of days likely to receive high (51–100 mm/day) or very high (>100 mm/day) intensity rainfall during the 2030s, and the number of years likely to be rainfall deficient during the same period in comparison to the historical period of 1990–2019

Heavy Rainfall Events

For this analysis, rainfall events are categorized on the basis of the intensity of rainfall received per day: 100 mm (very high intensity). In this section, changes in the number of rainfall events—relative to the historical period—in the highland very-high-intensity categories are presented, as they have implications for crop growth and productivity. High-Intensity Rainfall (51–100 mm/Day)

Scenario

An increase in high-intensity rainfall events—relative to the historical period—is projected for all the Karnataka districts, except Vijayapura. The increase is in the range 1–5 events annually over the projected 30-year period. A higher increase in high-intensity rainfall events (3–5 events annually) is projected for the high rainfall districts of Dakshina Kannada, Udupi, Uttara Kannada, and Kodagu.

Scenario

An increase in high-intensity rainfall events—relative to the historical period—is projected for all districts in the state. The increase is in the range 1–7 events annually over the projected 30- year period. A higher increase in high-intensity rainfall events (4–7 events annually) is projected for the high rainfall districts of Dakshina Kannada, Udupi, and Uttara Kannada.

Scenario : An increase in very-high-intensity rainfall events—relative to the historical period—is projected for 25 of the 30 districts. The projected increase is in the range 1–2 events annually over the projected 30-year period. No change relative to the historical period is projected for Kolar, Ballari, Bagalkot, Vijayapura, and Udupi.

Scenario

An increase in very-high-intensity rainfall events—relative to the historical period—is projected for all the districts, except Gadag and Uttara Kannada. The increase is in the range 1–3 events annually over the projected 30-year period. The occurrence of high-intensity rainfall is an indicator of flood-causing rainfall events. More than 100 mm of rain/day may cause excessive runoff and even flooding, leading to crop damage. These high-intensity rainfall events could damage the soil and water conservation structures that may have been created.

Risks of Climate Change to Crop Production and Implications

Climate determines the growth and productivity of crops. The crop–weather relationship has been studied by several scientists (Varma et al., 2007; Sarkar, 2005; Sarkar and Thapliyal, 2003). Studies have also investigated the impact of droughts and floods on food grain production (Krishna Kumar et al., 2004; Selvaraju, 2003; Kulshreshtha, 2002) and the resulting impact on economy (Gadgil et al., 1999; Kumar and Parikh, 1998). The potential crop yields in the tropical and subtropical regions are projected to decline under increased temperatures. An increase in temperature, depending on the current ambient temperature, can reduce crop duration, increase crop respiration rates, alter photosynthate partitioning to economic products, and affect the survival and distribution of pest populations, developing a new equilibrium between crops and pests. Increased temperature coupled with reduced rainfall may lead to upward water movement, resulting in accumulation of salts in the upper soil layers (Xu et al., 2019). An increase of 1°C in global temperature would reduce the global yield of rice by an average of 3.2 ± 3.7%, maize by 7.4 ± 4.5%, and wheat by 6 ± 2.9% (Zhao et al., 2017). In their analysis of the impacts of global warming on farmers in Brazil and India, Sanghi and Mendelssohn (2008) conclude that by the next century global warming can reduce annual crop yield in India by 4–6%. Kumar et al. (2004) assessed the effect of monsoon droughts on the production, demand, and prices of rice, sorghum, pearl millet, maize, pigeon pea, groundnut, and cotton, and concluded that the greatest impact of drought is on the yield of pearl millet and sorghum. A drought of 10% intensity is projected to result in a decline in the pearl millet yield of 7.6%; sorghum, 6.8%; and maize, 2.8%. Similarly, heavy rainfall events that lead to stagnant flooding or flash floods restrict the growth of crops; growth is restored only after water removal. Thus, deviations from normal temperature and rainfall have adverse effects on crop growth, yield, and productivity. The impact of these events on crops is determined by the length of the growing period (LGP). LGP for a given district or region represents the climatically determined number of days during which a crop receives enough moisture from soil for its growth. Venkatesh et al. (2016) have determined the LGP for various taluks of Karnataka to range from 90 to

120 days. During this period, any deviation in temperature and rainfall from the normal will impact crop growth. For example, a temperature increase for a short period around pollen formation can lead to partial or complete sterility of the rice crop (Endo et al., 2009; Horie et al., 1996). An increase in temperature would also lead to increased evapotranspiration, which may result in lowering of the groundwater Crops also need adequate moisture, especially during critical stages of germination and fruit development. In Karnataka,

Policies and Programmes for Rainfed Agriculture and Crop Insurance

Many policies are in place for rainfed agriculture both at the national and state levels. The Department of Agriculture, Cooperation & Farmers Welfare of India, under the Ministry of Agriculture, has a division—Rainfed Farming System—that specifically works on the development and/or rejuvenation of the rainfed agriculture sector in India. Further, under the National Action Plan on Climate Change, one of the eight missions is the National Mission for Sustainable Agriculture (NMSA). This mission focusses on integrated farming, soil health management, and resource conservation synergy. Among the many schemes under NMSA, Rainfed Area Development Programme (RADP) is aimed at enhancing productivity and minimising risks associated with climate variabilities. Appendix 2 provides district-wise achievement details under RADP in Karnataka for the FY 2019–20. Below we present policies and programmes relevant to rainfed agriculture at the national and state levels

. • The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), with the motto of 'Har Khet Ko Paani', is a scheme that focusses on creating sources for not only assured irrigation but also protective irrigation by harnessing rainwater at the micro-level through 'Jal Sanchay' and 'Jal Sinchan'9.

• The On-Farm Water Management (OFWM) programme is focussed on enhancing water use efficiency by promoting efficient on-farm water management technologies and equipment. This programme emphasises effective harvesting and management of rainwater, and provides assistance for adoption of water conservation technologies, efficient delivery and distribution systems, etc.

• The Climate Change and Sustainable Agriculture: Monitoring, Modelling and Networking (CCSAMMN) programme is aimed at bidirectional (land/farmers to research/scientific establishments and vice versa) dissemination of climate-change-related information and knowledge by way of piloting climate change adaptation/mitigation research/model projects in the domain of climate smart sustainable management practices and integrated farming systems suitable for local agro-climatic conditions. 6.1. Karnataka State—Rainfed Agriculture Schemes Karnataka framed a rainfed farming policy in 2014. The salient features of this policy relevant to rainfed farming are as follows:

• Focus on small and marginal farmers who account for 76% of the holdings and operate 40% of the area • Increasing public investment in rainfed agriculture

• Preserving the germplasm of dryland crops and developing resource conservation technologies

• Developing systems for efficient medium- and long-term prediction of weather

• Market intelligence and price forecasting ahead of the sowing season.

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Conclusion

The government of India recently announced that it is planning to re-evaluate crop planting across the country to align agricultural practices with changes in climate and rainfall patterns. This requires a better understanding of the risks posed by climate change to agriculture in general, and more importantly for different crops at the state or district level. This study is an effort in that direction.

Risks of climate change have been analysed for only the three dominant rainfed crops—maize, sorghum, and groundnut—grown in Karnataka. There is a need to expand this analysis to all the rainfed crops grown in Karnataka. There is also a need for more information on actual yield losses due to variability and climate change. Further, changes in rainfall will need to be looked at in conjunction with other physiographic characteristics such as soil quality and slope to quantify the risks of climate change in the districts of Karnataka. However, on the basis of changes in temperature and rainfall projected for the short-term period of 2030s (2021–2050), several strategies could be implemented at the district level, considering the crops and projected risks due to climate change in the projected period.

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