Impact of Climate Change on Rainfed Crops

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Climate change due to increasing concentrations of green house gases in the atmosphere since the pre-industrial times has emerged as a serious global environmental issue and poses a threat and challenge to mankind. The Fourth Assessment report of Intergovernmental Panel on Climate Change (2007) concluded that 'there is high confidence that recent regional changes in temperature have had discernible impacts on many physical and biological systems'. The changes in the composition of atmosphere in terms of greenhouse gases, aerosols influence the properties of solar radiation and alter the energy balance of the climate system. Now it is evident from various studies that the human activities are contributing significantly for the change in climate compared to natural variability in climate. General circulation models predict temperature rises of 1.4-5.8°C by 2100, associated with carbon dioxide increases to 540-970 parts per million. The atmospheric concentration of carbon dioxide- the most important anthropogenic greenhouse gas increasing at alarming rates (1.9 ppm per year) in recent years than the natural range concentration growth rate. This could be due to enhanced usage of fossil fuel and changed land use pattern to some extent.

Climate model predictions of CO_2-induced global warming typically suggest that rising temperatures should be accompanied by increases in rainfall amounts and intensities, as well as enhanced variability. Both the number and intensity of heavy precipitation events are projected to increase in a warming world, according to the IPCC. The mean atmospheric temperatures of the globe have been on the increase and the last 12 out of 13 years recorded the highest temperatures in the last 100years. Many regions across the world started witnessing increased occurrence of extreme weather events. There have been events of increased number of intense cyclonic events and increase in occurrence of high rainfall events, even though the quantum of rainfall had not shown large changes. The frequency of occurrence of heat and cold waves is on the increase. Significant changes in daily maximum and minimum temperatures are observed.

More intense and longer droughts have been observed over wider areas since 1970's, particularly tropics and subtropics (IPCC, 2007). Increased drying linked with higher temperatures and decreased precipitation has contributed to changes in drought. Changes in sea surface temperatures (SST), wind pattern and decreased snow pack and snow cover have also been linked to droughts. Agriculture is one sector, which is immediately affected by climate change, and it is expected that the impact on global agricultural production may be small. However, regional vulnerabilities to food deficits may increase. Short or long-term fluctuations in weather patterns - climate variability and climate change- can influence crop yields and can force farmers to adopt new agricultural practices in response to altered climatic conditions. Climate variability / change, therefore, has a direct impact on food security. Monsoon rainfall is an important socio-economic feature of India, and climate models suggest that global averaged temperatures are projected to rise under all scenarios of future energy use (IPCC, 2001), leading to "increased variability and strength of the Asian monsoon."

The climate sensitivity of agriculture is uncertain, as there is regional variation of rainfall, temperature, crops and cropping system, soils and management practices. The interannual variations in temperature and precipitation were much higher than the predicted changes in temperature and precipitation. The crop losses may increase if the predicted climate change increases the climate variability. Different crops respond differently as the global warming will have a complex impact.

Seasonal precipitation distribution patterns and amounts could change due to climate change. With warmer temperatures, evapotranspiration rates would rise, which would call for much greater efficiency of water use. Yields can be significantly enhanced by improved agricultural water management, in particular by increasing water availability through on-farm water management techniques such as water harvesting and supplemental irrigation, and by increasing the water uptake capacity of crops through measures such as conservation farming. In many circumstances, investments in improved water management in rainfed agriculture are catalytic, reducing barriers to the adoption.

Of the 1.5 billion hectares (ha) of cropland worldwide, only 18% (277 million hectare) is irrigated land; the remaining 82 percent is rainfed land. The importance of rainfed agriculture varies regionally, and is most significant in country like India where rainfed agriculture accounts for about 65% of the cropland and 70% of population main occupation. Under current water use practices, increases in population and changes in diet are projected to increase water consumption in food and fiber production by 70-90%. If demands for biomass energy increase, this may aggravate the problem. In addition, sectoral competition for water resources will intensify, further exacerbating the stress on developing country producers. Throughout the 20th century, global water use has increased in the agricultural, domestic and industrial sectors. Evaporation from reservoirs has increased at a slower rate. Projections indicate that both global water use and evaporation will continue to increase.

Rice, wheat, maize, sorghum, soybean and barley are the six major crops in the world and they are grown in 40% cropped area, 55% of non-meat calories and over 70% of animal feed (FAO, 2006). Since 1961, there is substantial increase in the yield of all the crops. The impact of warming was likely offset to some extent by fertilization effects of increased CO_2 levels. At the global scale, the historical temperature- yield relationships indicate that warming from 1981 to 2002 very likely offset some of the yield gains from technological advance, rising CO_2 and other non-climatic factors.

The potential effect of climate change on agriculture is the shifts in the sowing time and length of growing seasons geographically, which would alter planting and harvesting dates of crops and varieties currently used in a particular area. Also weed and insect pest ranges could shift. Perhaps most important of all, in addition to changing climate, there would likely be increased variability in weather, which might mean more frequent extreme events such as heat waves, droughts, and floods.

The carbon dioxide level in the atmosphere has been rising and that this rise is due primarily to the burning of fossil fuels and to deforestation. Measured in terms of volume, there were about 280 parts of CO_2 in every million parts of air at the beginning of the Industrial Revolution, and there are 365 parts per million (ppm) today, a 30 percent rise. The annual increase is 1.9 ppm, and if present trends continue, the concentration of CO_2 in the atmosphere will double to about 700 ppm in the latter half of the 21^{st} century.

Carbon dioxide is the basic raw material that plants use in photosynthesis to convert solar energy into food, fiber, and other forms of biomass. In the presence of chlorophyll, plants use sunlight to convert carbon dioxide and water into carbohydrates that, directly or indirectly, supply almost all animal and human needs for food; oxygen and some water are released as by-products of this process. Voluminous scientific evidence shows that if CO_2 were to rise above its current ambient level of 365 parts per million, most plants would grow faster and larger because of more efficient photosynthesis and a reduction in water loss. There are two important reasons for this productivity boost at higher CO_2 levels. One is superior efficiency of photosynthesis. The other is a sharp reduction in water loss per unit of leaf area. By partially closing these pores, higher CO_2 levels greatly reduce the plants' water loss--a significant benefit in arid and semi arid climates where water is limiting the productivity.

There are marked variations in response to CO_2 among plant species. Most green plants, including most major food crops use the C3 pathway respond most dramatically to higher levels of CO_2. At current atmospheric levels of CO_2, up to half of the photosynthate in C3 plants is typically lost and returned to the air by a process called photo-respiration, Elevated levels of atmospheric CO_2 virtually eliminate photo-respiration in C3 plants, making photosynthesis much more efficient. Corn, sugarcane, sorghum, millet, and some tropical grasses use the C4 pathway, also experience a boost in photosynthetic efficiency in response to higher carbon dioxide levels, but because there is little photo-respiration in C4 plants, the improvement is smaller than in C3 plants. Instead, the largest benefit C4 plants receive from higher CO2 levels comes from reduced water loss. Loss of water through leaf pores declines by about 33 percent in C4 plants with a doubling of the CO_2 concentration from its current atmospheric level. Since these crops are frequently grown under drought conditions of high temperatures and limited soil moisture, this superior efficiency in water use may improve yields when rainfall is even lower than normal. When there was no stress, elevated CO_2 reduced stomatal conductance by 21.3 and 16.0% for C_3 and C_4 species respectively. The lowest response to higher CO_2 levels is usually from the CAM plants, which include pineapples, agaves, and many cacti and other succulents. CAM plants are also already well adapted for efficient water use.

The mean (average) response to a doubling of the CO_2 concentration from its current level of 360 ppm is a 32 percent improvement in plant productivity, with varied manifestations in different species. In crop plants, a distinction has to be made between the increase in total biomass and increase in economic yield resulting from an elevated CO_2 supply. When the dry mass production and yield increase of the world's ten most important crop species in response to elevated CO_2 was analyzed from different experiments, it was found that in some species the relative increase of total biomass and in others that of economic yield is greater. Cereal grains with C3 metabolism, including rice, wheat, barley, oats, and rye, show yield increases ranging from 25 to 64 percent, resulting from a rise in carbon fixation and reduction in photo-respiration. Food crops with C4 metabolism, including corn, sorghum, millet, and sugarcane, show yield increases ranging from 10 to 55 percent, resulting primarily from superior efficiency in water use. Tuber and root crops, including potatoes and sweet potatoes, show dramatic increase in tuberization (potatoes) and growth of roots (sweet potatoes). Yield increases range from 18 to 75 percent. Legumes, including peas, beans, and soybeans, show yield increases of 28 to 46 percent.

Field crops under drought often experience two quite different but related and simultaneous stresses: soil water deficit and high temperature stresses. Elevated CO_2 increase growth, grain yield and canopy photosynthesis while reducing evapotranspiration. During drought stress cycles, this water savings under elevated CO_2 allow photosynthesis to continue for few more days compared with the ambient CO_2 so that increase drought avoidance. Elevated atmospheric CO_2 concentration ameliorates, to various degrees, the negative impacts of soil water deficit and high temperature stresses.

Soils emit N_2O through biological and non-biological pathways and the agricultural lands are most significant sources of this GHG. The quantity of N_2O emitted from agricultural land dependent on fertilizer application and subsequent microbial denitrification of the soil. Emissions of N_2O from soils are estimated to be as much as 16 percent of global budget of N_2O. Various agricultural soil management practices contribute to greenhouse gas emissions. Agricultural soil management practices such as irrigation, tillage or the fallowing of land can affect the efflux of these gases. Level of N_2O emissions may be dependent on the type of fertilizer used, amount and placement depth of fertilizer, soil moisture and temperature. Tilling tends to decrease N_2O emissions; no-till and herbicides may increase N_2O emissions.

Agriculture is sensitive to climate change at the same time it is one of the major driver for climate change. Understanding the weather variables over a period of time and setting the management practices for better harvest is required for the growth of agricultural sector as a whole.