
CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE

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GLOBAL WARMING, CLIMATE CHANGE AND ITS THREATS TO SUSTAINABLE AGRICULTURE

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Global warming, climate change and environmental degradation constitute the biggest threat to human civilization. Temperature measurement records on land and sea, shrinking polar ice sheets, recession in mountain glaciers, rise in sea level and ocean acidification are manifestation of global temperature increase, estimated at 0.8–1.0°C since 1880. The present day global warming is generally considered a consequence of the accumulation in atmosphere of greenhouse gases, notably CO₂, which result from burning of hydrocarbons in industry, power generation, vehicles and domestic use. Global warming would result in melting of glaciers and polar icecaps, unpredictable weather patterns, natural disasters (e.g., floods), disruption of existing communication systems and infrastructure, health issues, sea level rise and unmanageable threat to coastal regions. It can trigger the vicious circle of food insecurity, human migration and conflicts. Climate change can cause unpredictable changes in weather patterns, erosion of soil, desertification of cultivable land, disruption of existing irrigation systems, and reduction of tropical forest cover. Hence, it would have severe impact on agriculture sector, food security and its supply chain. Melting of the glaciers in Tibet and greater Himalaya would adversely affect the food security and life pattern of three billion people. To mitigate climate change and harness food security, diverse sustainable and environment friendly techniques, such as crop rotation, integrated pest management, hydroponics, cultivation of salt tolerant plants, and efficient irrigation techniques need to be employed. But, most importantly, the impending disaster of global warming can only be avoided by urgently controlling the emission of greenhouse gases.

Keywords: Global warming, climate change, sustainable agriculture.

Introduction

Climate change is an enormous threat to humanity and sustainable development. It is conceived to be characterized by extreme and unpredictable weather conditions, changes in precipitation pattern and overall environmental degradation. Hence, climate change and its causes have become the focus of research and heated debate. Although natural causes (e.g., solar flare ups, volcanism, floods, storms, meteorite falls) have been responsible for climate changes in the geological past. There is a general agreement that the present day global warming is rooted in anthropogenic activities. Here we describe briefly the causes and consequences of global warming and climate change, and their threat to agriculture and food security.

Evidence, consequences and mitigation of climate change

Increase in temperature over ocean's surface, on continents (weather stations data), near surface (troposphere 50 years satellite temperature) data), and in the heat content of the oceans, rise in sea-level, recession in glaciers and reduction in polar icecaps are striking evidences of global warming [1, 2]. Recorded data suggest that global temperature has risen by 0.8–1.0°C over the past 130 years, an alarming rate indeed (Figure, Left). Human activities empirically known to influence climate and ecosystem include burning of fossil fuels in industry, automobiles, power plants, and buildings, waste disposal, deforestation, urbanization, agriculture, and wastage of water. The consumption of fossil fuels results in the production and

accumulation of Green House Gases (GHGs), such as CO₂, CH₄, N₂O, and fluorinated gases, which take various lengths of time for removal from the atmosphere. CO₂, the principal GHG, takes flabbergasting one hundred years for its removal, and has increased significantly over the past century to 400 ppm (ca. 40 B tons).

The consequences of the climate change can be disastrous, long lasting, and even irreversible. Changes in patterns of rainfall and snow, increased likelihood of drought and severe storms, decline in ice cover, melting of glaciers, increase in floods (including GLOFs), landslides, rise in sea level, higher humidity, changes in animal and plant behavior, faunal extinction, bleaching of coral reefs and dying of the African iconic baobab trees are the feared scenarios. Climate change would impact infrastructure, steady supply of energy, patterns of livelihood, and standard of living, leading to a vicious socioeconomic burden. At the present rate of global warming, around 75% of world's population will be exposed to deadly climate conditions by 2100. Water borne and water related diseases, such as malaria, dengue, diarrhea, dysentery and typhoid, are likely to become epidemic. Global warming is projected to cause approximately 20,000 heat-related deaths among the elderly in 2030. There would be severe impact on agriculture sector, food security, food, supply chain, and fresh water, which will initiate human migration and social conflicts.

Global response to climate change started as early as 1992 under an international treaty aka Framework Convention on Climate Change (UNFCCC). This has led to significant progress and the Paris Agreement 2016 was adopted as an

implementation plan to combat climate change. This policy demands global commitment to keep the temperature increase below 2°C, preferably not more than 1.5°C by the end of this century. More than 180 countries have pledged to limit carbon emissions as part of Intended Nationally Defined Contributions (INDC) to keep temperature from rising. Use of renewable, environment friendly energy sources are to be given priority while traditional energy sources dependent on fossil fuel are to be replaced. These INDCs are not legally binding on any country, and no end timeline is set forth for the task. The Paris agreement also lays an added emphasis on the financing and budgeting of the losses; damages caused by climate change and for the infrastructure change that is required for curbing emissions. It looks difficult to achieve these targets; therefore, there is an urgent need for devising a more effective long term plan to control the temperature rise to the recommended limits by the end of this century.

Remedial steps on global scale and changes in lifestyle are touted as major ways of effectively fighting climate change. The remedial steps include use of clean energy, removal of CO₂ from atmosphere, increase in forest cover, replacement of coal by gas in power generation, and geo engineering. Changes in lifestyle, which would help reduce environmental degradation, include expanded use of renewable energy in buildings, reducing waste, avoiding unnecessary use of vehicles, eating less meat, and spatial planning and infrastructure to accommodate green and environment friendly infrastructures.

Climate change and agriculture sustainability

Agriculture is vital for human survival and is probably the most vulnerable human enterprise to

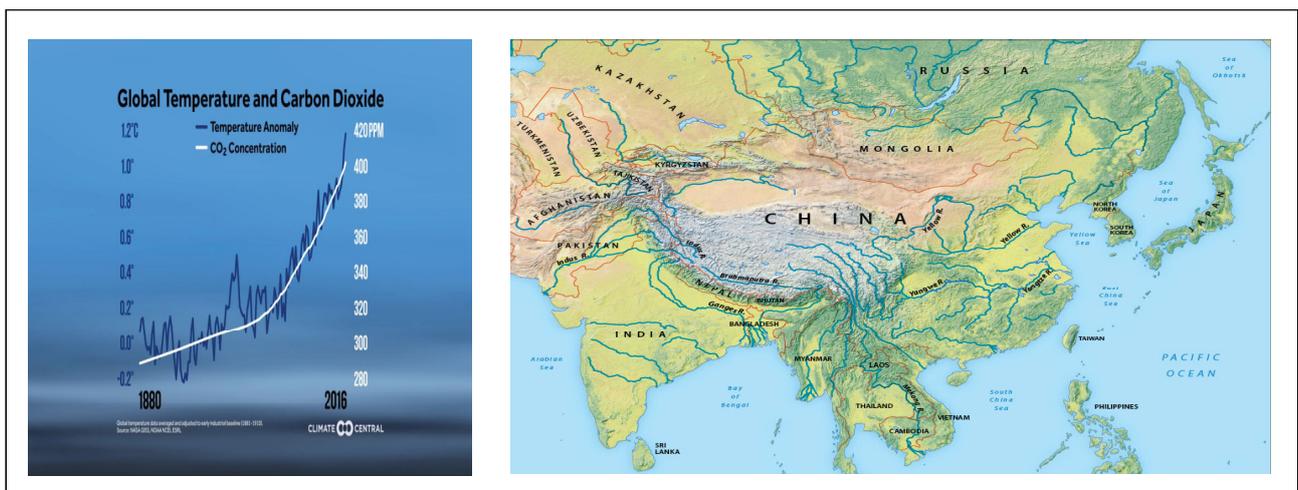


Figure Left: Degree of temperature increase and CO₂ accumulation in the atmosphere from 1880 to 2016 (NASA GISS, NOAA, NCEI, ESRL). Right: Himalaya-Karakorum-Tibet glacier-fed major rivers

changing climate which will impact agriculture in a complex and interconnected fashion. Water resources in particular will be the most affected natural ecosystem due to climate change and increasing need of ever-growing population. Continued global warming will cause melting of the polar ice caps and mountain glaciers, leading to sea level rise and increase in water-related disasters such as flash floods and cyclones. Global warming would be particularly disastrous for agriculture activities in the southeastern half of Asia that depends heavily on river waters drawn from the glaciers of Himalaya, Karakoram, Pamir, Hindu Kush, and snows of the Third Pole, i.e., Tibetan Plateau (Figure Right). This region, with the largest irrigation system and alluvial flood plains, provides nourishment, hydroelectricity, and transport facility to approximately two billion population. Melting of polar ice caps and glaciers, and heavy rains would also lead to GLOFs, flash floods, rapid erosion of soil cover, sediment-filling of water reservoirs, disruption of waterways and irrigation systems, and coastal areas inundation. The rise in sea level (hence greater surface area) and rising temperatures would likely result in greater evaporation and higher global humidity, but its overall impact on green gas house effect and quantity of rainfall are not clear.

Climate change would cause changes in agro-ecological conditions which, in turn, would impact crop yield, nutrition value and livestock productivity. Crop cultivation and harvesting, support pests, weeds and plant pathogens, with excessive precipitation and accumulation of GHGs affecting soil's biogeochemical cycle. Growth of crop plants is driven by interaction among CO₂, temperature, light and precipitation. Overall seasonal precipitation determines the yield over large areas, but stress and dry spells threaten productivity, even a few hours at critical growth stages. Increase in temperature will consequentially affect growth, nutritional value and required yield of the crop plants. The rise in warming condition may also affect the bee population, and pollination stage of the plants, leading to hindrance in development of fruit, fiber and grain and, in return, negatively influencing the crop yield. Growth of green and leafy vegetables would be severely hindered by rise in temperature. Negative effects of high night temperature on grain development are confidently and abundantly reported. Livestock is also affected directly and by lack of pasture and forage availability, and compromised quality as the agriculture production is affected. Livestock exposed to higher night time temperature are likely to have reduced milk, meat and egg production due to increased physiological stress.

The quality of soil and water, two key factors that have significant impact on the agriculture production, get affected by climate change directly or indirectly. Soil erosion is caused by floods which affect the cultivability of the land while soil nature is affected by carbon content. Changing climate will not only impact the quantity but also the quality of water that is available and accessible for irrigation use.

Another way through which agriculture is affected by climate change includes weeds, insects and disease re-emergence. Major losses to crop production globally are caused by weeds (estimated at 34%), insects (18%) and diseases (16%). Increase in temperature helps induce higher incidences of plant and livestock pathogens, and geographical distribution/relocation of insects and diseases [3]. It is important to note that the weed species can adapt to higher temperatures and CO₂ levels than the crop plants, providing them a competitive advantage. This re-emergence will cause increased use of pesticides and insecticides for the protection of agriculture and livestock health, which can lead to pesticide resistance and entrance of these chemicals into food chain, creating long-term implication for food safety and consumption.

Rapid population growth, increasing urbanization and natural habitat degradation have rendered the thickly populated South Asia a highly vulnerable region to climate change, thereby posing a serious threat to agriculture and food security. Some of the major challenges of climate change for agriculture in this region include increasing temperatures, availability of irrigation water, increased variability of monsoon, severe water-stressed conditions in arid and semi-arid areas, and extreme events, such as floods, droughts, heat waves, cold waves, and cyclones.

Temperature increase will negatively impact crops which are grown close to their temperature tolerance threshold (wheat, rice and maize, vegetables) in tropical and temperate regions of South Asia although individual locations may benefit [4]. It is important to note that the risk of food security and climate impact on agriculture is greater in low altitude areas. Indirect impact on agriculture is likely to emerge from changing soil moisture content, erosion of soil, disruption of existing irrigation systems, frequent occurrence of pests and crop pathogens.

Adaptation and mitigation options for sustainable agriculture

It is necessary to accelerate the research for climate change adaptation and mitigation in a multi-dimensional approach. The adaptation initiatives need to focus on development of new cultivars, innovations in plant protection, advances in biological engineer-

ing, enhancing productivity of horticultural crops, broadening the genetic diversity, and development of resource conservation technologies. The following adaptation measures are needed for sustainable agriculture development and food security:

A) Crops related measures, including alteration in sowing dates, use of new crop varieties, advance seasonal weather forecast, changes in irrigation methods, development of short duration, drought and heat-tolerant varieties, changes in cropping pattern, e.g. replacing high water requiring crops with low water requiring ones, and inclusion of legumes in all-cereal cropping pattern.

B) Water related measures, involving adapting water smart technologies like drip, sprinkler and sub-surface irrigation systems, rainwater harvesting, solar pumping and integrating irrigation with water sensitive growth stages of crops.

C) Soil related measures, entailing soil mulching to suppress evaporation and lower soil temperature, laser land leveling and improving soil drainage to prevent soil degradation.

The long-term response to climate change may include investing in creating new or improving existing infrastructure, e.g. water storages (through aquifers or dams), water harvesting structures, canal lining. The impacts of extreme events can be avoided, for example, through restricting development in floodplains and areas of increasing aridity. Adoption of clean energy and increase in forest cover are some of the viable options for climate change mitigation.

Conclusion

Agriculture and food security would be drastically affected under unrestrained climate change. Adaptation measures, such as conservation of water, use of organic fertilizer, cultivation of drought and salt resistant crop varieties, integrated pest control, hydroponics and, of course, reducing GHG in the atmosphere would be needed to protect agriculture from the negative impacts of climate change. Additionally, it is highly imperative that actions are taken in the areas of consumption and production trends, mass education and research, which will help to better understand climate stresses, economic losses and alternative methods and approaches.

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