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Agriculture and climate change

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Abstract
Climate change includes higher temperatures, changes in precipitation, and higher atmospheric CO_2 concentrations. The Greenhouse effect may be important for agriculture in three different ways (1) by increasing atmospheric CO2 concentrations which may effect directly on the growth rate of crop plants as well as weeds (2) CO2-induced changes of climate may alter levels of temperature, rainfall and sunshine which manipulates plant and animal productivity and (3) increases flood area by rises in sea level. Climate change is the most serious environmental threat that negatively affects the farm produce. In agriculture, Green House Gas (GHG) emission is much more because of large number of cattle and poor manure management, rude use of agro-chemicals and land mismanagement. Nitrous oxide (N_2O) and methane (CH_4) are two of the main potent non-CO_2 GHG, which contributes about half of the global emissions of the world. Emission of nitrous oxide (N2O) arises directly from nitrogen (N) applied to the soil or indirectly from nitrates, whether it may be in the form of fertilizer, manure, crop residues or nitrogen fixation. There are two processes, Nitrate leaching or ammonia volatilization which will be successful measures to reduce farming emissions. India has wide range of variations in climate, ranging from tropical to temperate and alpine in the Himalayan. As the temperature and resource availability varies between different countries it results in variation of agricultural contribution to climate change. In present paper we are concerned with the contribution of Agricultural Activities to Climate Change, its causes, impact as well as mitigation strategies. Therefore, contribution of agricultural activities to climate change, its causes, impact as well as mitigation strategies need to be addressed for sustaining agricultural productivity.

Keywords: Green House Gases (GHGs), Climate Change, Mitigation, Nitrous oxide

Introduction

Climate change and agriculture are interrelated processes, both of which take place on a global scale and their inter- relationship is of meticulous importance for those countries having higher initial temperatures and having marginal or degraded lands. The impact and consequences of climate change is the severe environmental threat that negatively affects agricultural productivity as the imbalance between world population and world food production increase. According to the Inter-governmental panel on climate change (IPCC), any change in climate over time, due to natural variability or as a result of human activity is termed as climate change. The contribution to climate change from agricultural sector varies from country to country which depends on available resources and temperature. In agriculture, Green House Gas (GHG) emission is much more because of large number of cattle and poor manure management, rude use of agro-chemicals and land mismanagement. Nitrous oxide (N_2O) and methane (CH_4) are two of the main potent non-CO_2 GHG, which contributes about half of the global emissions of the world. Emission of nitrous oxide (N2O) arises directly from nitrogen (N) applied to the soil or indirectly from nitrates, whether it may be in the form of fertilizer, manure, crop residues or nitrogen fixation. There are two processes; Nitrate leaching or ammonia volatilization which will be successful measures to reduce farming emissions. Agriculture sustains human life which is also in turn affected by climate change. Climate here in India is mainly influenced by its topography like the Himalayas, Thar Desert, Arabian Sea and Bay of Bengal. These natural agents control temperature as well as rainfall consequently affecting the agricultural production and productivity. Since the main cause of climate change is human activities, the term has become synonymous to the anthropogenic term global warming. Impact of cc becomes more serious in developing countries, due to high levels of greenhouse gases (GHGs) and is expected to increase the global average surface temperature by 1.5-4.5°C over the next 100 years. This will raise sea-levels, shift climate zones pole ward, decrease soil moisture and storms. Therefore, contribution of agricultural activities to climate change, its causes, impact as well as mitigation strategies need to be addressed for sustaining agricultural productivity.

2. Contribution of Agricultural activities to climate change

Direct and Indirect emissions are the two kinds created by agriculture. Fertilized agricultural soils and livestock manure contributes to Direct emission where as indiscriminate use of land, fossil fuels for mechanization, transportation, chemical and fertilizer production, leaching of fertilizer and runoff contribute to indirect emission.

Changes in natural vegetation and traditional land use, including deforestation and soil degradation are the most noticeable indirect emission. One of traditional land use practices which continuously involve disturbing the land is Intensive tillage that increases CO_2 emissions by transcending decomposition of SOM and soil erosion. According to the World Bank (Busari *et al*., 2015) [3], agriculture contributes about half of the global emissions of two of the most potent non-CO_2 GHG: nitrous oxide (N_2O) and methane (CH4). These non-carbon GHGs have powerful greenhouse effects and have greater longevity than CO2. Globally, agriculture contributes to 58 percent of total N_2O emission (Thornton and Lipper, 2013) [16]. It creates 4.5 million tons of nitrous oxide annually. Fertilizer application to methods of irrigation, tillage and cattle and feedlots are the various management practices in agricultural land that can lead to production of nitrous oxide. The use of synthetic fertilizer for agriculture is a major source of nitrous oxide emissions. Apart from this, large quantities of natural gas are used to make synthetic fertilizers because it is the main ingredient. The production process also takes a lot of energy so their impact on climate change is actually larger when we factor this in. Industrialized farming practices have worsened this loss and the result has been increase emissions. Continuous cropping may result in using of large chemical fertilizer. According to FAO (Smith *et al*., 2007) [15] report in developing countries there is a significant increase in GHGs emission from 2001-2011 (14%), the increase occurred, due to an expansion of total agricultural outputs.

Hence the agricultural activity could be a source and sink of GHGs, notably through the storage of carbon in the soil organic matter and in biomass and influenced by CC. And the study also reported that the farmers consider the negative effect of agro-chemicals only for their crops. This points out the fact that the farmers are only concerned about their crops and does not care about the environmental side effect of fertilizers. The most important source of nitrous oxide emission is agriculture. Another non-CO_2 GHG which has large contribution in agriculture GHGs emission is methane. Methane is produced by cattle as a part of their digestion, known as enteric fermentation. This sector is responsible for 47% of the world's methane emissions, in which manure management matters greatly. When the manure of livestock is not used as a fertilizer or left in fields during grazing. Many of these systems create conditions that are favorable for nitrous oxide producing bacteria. However, besides its primary role in producing food and fibres, agriculture performs also other functions, such as the management of renewable natural resources, the construction and protection of landscape, the conservation of biodiversity, and the contribution to maintain socio-economic activities in marginal and rural areas. Climate change could affects also this multifunctional role of agriculture (Klein *et al*., 2013).

Climate change affects agriculture in a number of ways; including through changes in average temperatures; rainfall and climate extremes with an important impact on soil erosion, changes in pests and diseases, changes in atmospheric carbon dioxide, changes in the nutritional quality of some foods, changes in growing season, and changes in sea level. Crop yields show a strong correlation with temperature change and with the duration of heat or cold waves, and differ based on plant maturity stages during extreme weather events. Modified precipitation patterns will enhance water scarcity and associated drought stress for crops and alter irrigation water supplies. They also reduce the predictability for farmers' planning. In an indirect way, a change in temperature and moisture levels may lead to a change in the absorption rate of fertilizers and other minerals, which determine yield output. According to Ignaciuk and Mason-D'Croz (2014) [8], climate change, decreases the yield of maize, rice, wheat, potatoes and vegetables and continue to reduce seriously by 2050 globally. Climate change is also likely to affect the livestock sector both by affecting the quantity and quality of feed and by affecting the frequency and severity of extreme climate events. There is a limited body of literature that deals with climate change impacts on livestock, but livestock sector may be particularly vulnerable to the effects of climate change.

The change in climate of a region is determined by the amount of energy received in that area by sun and the amount of energy lost to space. Any imbalance in it causes the changes in climatic conditions. Factors which can shape climate are called forcing mechanisms. While some forcing mechanisms such as oceans and glaciers affect the climate slowly, there are other factors that can cause a more rapid change in the climatic conditions of a region. These mechanisms can be divided into two parts namely internal forcing mechanisms and external forcing mechanisms. The changes in climate brought by components of biosphere, lithosphere, hydrosphere and atmosphere are known as internal forcing mechanisms. These include ocean-atmosphere variability, carbon and water cycle etc. Agriculture is one sector that is most harshly affected by climate change. The continuous change in climate quickly changes the category of vegetation and the most productive species that can thrive in the new ecosystem. Thus, any failure to adapt to the new climate can intensify the damage caused.

3. Inter-relationship between Climate and Agriculture

Plants are highly influenced by certain ecological factors and these could either favour plant growth or hinder it which determines the yields. Field experiments can identify how a particular change in the climatic conditions affects a plant's yield. Since the conditions are varied by humans, it has a limit. Rational climate changes include higher temperatures, changes in precipitation, and higher atmospheric CO_2 concentrations. Though temperature rise can have both positive and negative changes, in a general scenario, it has been found that rise in temperature usually leads to a fall in yield. Increase in rainfall results in higher yield in dry or arid regions but can have a negative impact in the regions of excess rainfall. Similarly, a reduction in moisture content of the soil has reverse effects on the plant yield. A surrounding having larger concentration of carbon dioxide will result in higher net photosynthetic rate. Although higher concentrations can reduce the small opening in leaves through which CO2 and water vapour are exchanged.

An inter-relationship exist between climate change and agriculture processes as the effect of former can affect latter in a ways like through changes in average temperatures, rainfall, and climate extremes, changes in pests/diseases, changes in atmospheric carbon dioxide and ozone concentrations and changes in the nutritional quality of some foods are prominently among few. Agriculture largely contributes to climate change by (1) Man-made emissions of GHGs, and (2) by the exploitation of non-agricultural land for cultivation.

Climate change, the outcome of the "Global Warming" has now started showing its impacts worldwide. Climate is the primary determinant of agricultural productivity which directly impact on food production across the globe. Food production systems are extremely sensitive to climate changes like changes in temperature and precipitation, which may lead to outbreaks of pests and diseases thereby reducing harvest ultimately affecting the food security of the country agriculture sector is the most sensitive sector to the climate changes because the climate of a region/country determines the nature and characteristics of vegetation and crops. Climate change effect agriculture could be realized for (1) productivity of agricultural produce, (2) requirement of more resources such as water, herbicides, insecticides and nutrients etc., (3) leaching of minerals/nutrients, erosion of soil, loss of crop diversity, (4) change in holding of arable lands, (5) change in crop adaptability.

Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce final yield. The net impact of food security will depend on the exposure to global environmental change and the capacity to cope with and recover from global environmental change. Coping with the impact of climate change on agriculture will require careful management of resources like soil, water and biodiversity. To cope with the impact of climate change on agriculture and food production, India will need to act at the global, regional, national and local levels. Adaptation strategies are short and long-term changes to human activities that respond to the effects of changes in climate. In agriculture, adaptation will require cost-effective investments in water infrastructure, emergency preparation for and response to extreme weather events, development of resilient crop varieties that tolerate.

The net effect of climate change on world agriculture is likely to be negative. Although some regions and crops will benefit, most will not. While increases in atmospheric CO_2 are projected to stimulate growth and improve water use efficiency in some crop species, climate impacts, particularly heat waves, droughts and flooding, will likely dampen yield potential. Indirect climate impacts include increased competition from weeds, expansion of pathogens and insect pest ranges and seasons, and other alterations in crop agro ecosystems. The nature of agriculture and farming practices in any particular location are strongly influenced by the long-term mean climate state-the experience and infrastructure of local farming communities are generally appropriate to particular types of farming and to a particular group of crops which are known to be productive under the current climate. Changes in the mean climate away from current states may require adjustments to current practices in order to maintain productivity, and in some cases the optimum type of farming may change.

Higher growing season temperatures can significantly impact agricultural productivity, farm incomes and food security (Battisti and Naylor, 2009) [2]. For the coming century, Fisher *et al*. (2005) [6] simulated large gains in potential agricultural land for the regions such as the Russian Federation, owing to longer planting windows and generally more favourable growing conditions under warming, amounting to a 64 per cent increase over 245 million hectares by the 2080s. However, technological development could outweigh these effects, resulting in combined wheat yield increases of 37-101% by the 2050s (Ewert *et al*., 2005). Even moderate levels of climate change may not necessarily confer benefits to agriculture without adaptation by producers, as an increase in the mean seasonal temperature can bring forward the harvest time of current varieties of many crops and hence reduce final yield without adaptation to a longer growing season. In areas where temperatures are already close to the physiological maxima for crops, such as seasonally arid and tropical regions, higher temperatures may be more immediately detrimental, increasing the heat stress on crops and water loss by evaporation.

Water is vital to plant growth, so varying precipitation patterns have a significant impact on agriculture. As over 80 per cent of total agriculture is rain-fed, projections of future precipitation changes often influence the magnitude and direction of climate impacts on crop production (Tubiello *et al*. 2002; Reilly *et al*. 2003) [13]. The impact of global warming on regional precipitation is difficult to predict owing to strong dependencies on changes in atmospheric circulation, although there is increasing confidence in projections of a general increase in high-latitude precipitation, especially in winter, and an overall decrease in many parts of the tropics and sub-tropics (IPCC, 2007) [9].

The differences in precipitation projections arise for a number of reasons. A key factor is the strong dependence on changes in atmospheric circulation which itself depends on the relative rates of warming in different regions, but there are often a number of factors influencing precipitation change projections in a given location. For example, the uncertainty in precipitation change over India arises partly from the expected weakening of the dynamical monsoon circulation (decreasing the Indian monsoon precipitation) versus the increase in atmospheric water content associated with warming (increasing the Indian monsoon precipitation), (Meehl *et al*. 2007) [11]. However, changes in seasonal precipitation may be more relevant to agriculture than annual mean changes. In India, climate models generally project a decrease in dry season precipitation and an increase during the rest of the year including the monsoon season, but still with a large inter-model spread (Christensen *et al*. 2007) [4]. Precipitation is not the only influence on water availability. Increasing evaporative demand owing to rising temperatures and longer growing seasons could increase crop irrigation requirements globally by between 5 and 20 per cent, or possibly more, by the 2070s or 2080s (Döll 2002; Fisher *et al*. 2006) [5].

Historically, many of the largest falls in crop productivity have been attributed to anomalously low precipitation events (Kumar *et al*. 2004; Sivakumar *et al*. 2005) [14]. However, even small changes in mean annual rainfall can impact on productivity. For example, Indian agriculture is highly dependent on the spatial and temporal distribution of monsoon rainfall (Kumar *et al*. 2004). Changes in short-term temperature extremes can be critical, especially if they coincide with key stages of development. Only a few days of extreme temperature (greater that 32°C) at the flowering stage of many crops can drastically reduce yield (Wheeler *et al*. 2000) [18]. Crop responses to changes in growing conditions can be nonlinear, exhibit threshold responses and are subject to combinations of stress factors that affect their growth, development and eventual yield. Crop physiological processes related to growth such as photosynthesis and respiration show continuous and nonlinear responses to temperature, while rates of crop development often show a linear response to temperature to a certain level. Both growth and developmental processes, however, exhibit temperature optima. In the short-term high temperatures can affect enzyme reactions and gene expression. In the longer term these will impact on carbon assimilation and thus growth rates and eventual yield. The impact of high temperatures on final yield can depend on the stage of crop development.

The impacts of drought may offset benefits of increased temperature and season length observed at mid to high latitudes. Using models of global climate, crop production and water resources, Alcamo *et al*. (2007) [1] suggested that decreased crop production in some Russian regions could be compensated by increased production in others, resulting in relatively small average changes. However, their results indicate that the frequency of food production shortfalls could double in many of the main crop growing areas in the 2020s, and triple in the 2070s (Alcamo *et al*. 2007) [1]. Although water availability in Russia is increasing on average, the water resources model predicted more frequent low run-off events in the already dry crop growing regions in the south, and a significantly increased frequency of high run-off events in much of central Russia (Alcamo *et al*., 2007) [1].

Food production can also be impacted by too much water. Heavy rainfall events leading to flooding can wipe out entire crops over wide areas, and excess water can also lead to other impacts including soil water logging, non-aerobic condition and reduced plant growth.

4. Mitigation Strategies

Improved agricultural practices can help farmers in coping with current climatic risks by providing value-added weather services to farmers. Farmers can adapt to climate changes to some degree by shifting planting dates, choosing varieties with different growth duration, or changing crop rotations. An Early warning system should be put in place to monitor changes in pest and disease outbreaks. The overall pest control strategy should be based on integrated pest management because it takes care of multiple pests in a given climatic scenario. According to IPCC [IPCC, 2014] [10], mitigation is an intervention to reduce the emissions sources or enhance the GHG sinks, whereas adaptation is the adjustment in natural or human systems in response to actual or expected climatic change or their effects, to reduce harm or exploit beneficial opportunities. There is several adaptation methods that the agricultural sector can undertake to cope with future climate change. These include (1) changing planting dates, (2) planting different varieties or crop species, (3) promotion of alternative crops, (4) developing new drought and heat resistant varieties, (5) improved crop residue and weed management, (6) more use of water harvesting technique, (7) better pest and disease control, (8) improving the irrigation system, (9) reducing water depletion, and (10) conservation of soil moisture. With the help of the right agricultural practices and the consideration of suitable policy measures would be necessary to changing agricultural patterns in the climate change scenario.

Participatory and formal plant breeding to develop climate-resilient crop varieties that can tolerate higher temperatures, drought and salinity like varieties performing well in dry situation, short-duration crop varieties that can evade the peak heat phase, genotype that have a higher per day yield potential to counter yield loss from heat stress in growing periods. The adoption of preventive measures for drought including on-farm reservoirs in medium lands, growing of pulses and oilseeds instead of rice in uplands, ridges and furrow system in cotton crops, growing of intercrops in place of pure crops in uplands, land grading and leveling, stabilization of field bunds by stone and grasses, contour trenching, conservation furrows, mulching and use of farm yard manure. Furthermore, the efficient water use, drip and sprinkler irrigation for high value crops or irrigation at critical phases of crops would be more effective. Similarly, the efficient fertilizer use such as optimum fertilizer dose, split application of nitrogenous and potassium fertilizers, deep placement, use of *neem, karanja* coating and other such nitrification inhibitors, liming of acid soils, use of micronutrients such as zinc and boron, use of sulphur in oilseed crops, integrated nutrient management.

Remote sensing and weather forecasts could be used as a supportive measure to optimize planting and irrigation patterns. Likewise, intensification of the food production system by improving the technology and input delivery system would be helpful. Adoption of resource conservation technologies such as no-tillage, laser land leveling, and direct seeding of rice and crop diversification may help in reducing in the global warming to some extent.

5. Conclusion

Climate change relationship with agriculture is quite obvious as much of livelihood depends on agricultural activities, which mostly reliant on climatic condition. By the help of the precise farming practice agriculture could be the main solution for mitigation and adaptation response of climate change.

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