Climate Change

PERSPECTIVE

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Climate change - Research, Mitigation and Adaptive Opportunities for Indian Agriculture

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Climate change is looming large on the globe. Food security is one of the key issues that inevitably needs to be resolved under the specters of climate change, particularly in the fragile ecosystems. Never before in the history has Indian agriculture been as vulnerable and uncertainty ridden as it is today. A glimpse of the dynamics of Indian agriculture reveals that it has systematically deviated away from its base, that is, the environment—the prop that nourishes all biological resources. Today's agriculture is valued against the prices it fetches from the market, especially the global market. Its contribution to human health and welfare, ecological integrity, resilience of nature, etc. are grossly neglected.

The agriculture had begun going anti-nature since the inception of the green revolution, which was implemented on high yielding varieties, monocultures, indiscriminate applications of chemical fertilizers and pesticides and over-exploitation of water resources for irrigation. The Green Revolution turned ghastly for small and marginal farmers as well as for the agroecosystems it operated.

"Climate change refers to general shifts in climate, including temperature, precipitation, winds, and other factors in". The two main causes for climate change are natural and anthropogenic. In the natural causes it includes natural fluctuations in the intensity of solar radiation, volcanic eruptions and short term cycles viz., ENSO whereas under anthropogenic it has burning of fossil fuel emitting CO_2, methane emission from agriculture, land fills and industry, nitrous oxide emission from agriculture and industrial sector and release of CO_2 due change in land use and land cover. The major contributors in climate change are the increase in temperature, CO_2 in atmosphere, variation in rainfall pattern, solar radiation – day length, drought and floods.

In India, global warming is likely to hurt agricultural production, fishing and tourism, and deflate asset prices in low-lying coastal regions. For every two-degree rise in temperature would knock five per cent off India's GDP (Lehman *et* al., 2007). In turn agriculture also contributes to the climate change through various process which accounts to twenty eight per cent among them emission by animals itself accounts to large quantity.

Impact of climate change on food production

The variations in the contributors to climate change mentioned play a key role in agriculture and food production. Trying to understand the overall effect of climate change on our food supply can be difficult. Increase in temperature and carbon dioxide (CO_2) can be beneficial for some crops in some places and can be explored as an opportunity in scaling the agricultural production. But to realize these benefits, nutrient levels, soil moisture, water availability and other conditions must also be met. Changes in the frequency and severity of droughts and floods could pose challenges for farmers and ranchers. Meanwhile, warmer water temperatures are likely to cause the habitat ranges of many water bodies to shift, which could disrupt ecosystems. Overall, climate change could make it more difficult to grow crops, raise animals, catch fish in the same ways and same places as we have done in the past.

Some effects are biophysical, some are ecological, and some are economic, includes - A shift in climate and agricultural zones; Changes in production patterns due to higher temperatures; A boost in agricultural productivity due to increased carbon dioxide in the atmosphere and increased vulnerability of the landless and the poor (Chakraborty and Newton, 2011; Garrett *et al*., 2011).

Biophysical variants of climate

Temperature: Warmer temperatures may make many crops grow more quickly, but could also reduce yields from a given amount of land. The increased temperature leads to increase in potential evapotranspiration, quick loss of soil moisture and reduces the length of growing period. This also increases the drought duration causing low productivity. Winter and pre-monsoon months are indicating higher raise in mean temperature than SW-monsoon months. This leads to increased local conventional rains and thunder storm causing natural disasters.

Carbon dioxide: Higher CO_2 levels can increase yields for some crops, like wheat and soybeans, by 30% or more on doubling of CO_2 concentrations. The yield for other crops, such as corn, exhibits a much smaller response (less than 10% increase). However, some factors specially rise in temperature will counteract such yield increases.

Flood/drought: More extreme temperature and precipitation can prevent crops from growing. Extreme events, especially floods and droughts harm crops and reduce yields. Heat stress also affects animals both directly and indirectly. Drought reduces the amount of quality forage to be made available to grazing livestock.

Many weeds, pests and fungi thrive under warmer temperatures, wetter climates and increased CO_2 levels which poses threat to agriculture. Climate change may increase the prevalence of parasites and diseases that affect livestock (Hatfield *et al*., 2011). It is also predicted that with respect to south-east Asia (IPCC, 2007).

- By the 2050s freshwater availability will decrease, particularly in large river basins;
- Coastal areas, especially heavily populated mega delta regions will be at greatest risk due to increased flooding from the sea and in some cases, flooding from rivers;
- Endemic morbidity and mortality due to diarrhoeal diseases associated with floods and droughts are expected to rise due to projected changes in the hydrological cycle.

Effect of climate variant on food crops

Rise in CO_2 level from 280-660 ppm has increased the grain yield (50-70 g m^{-2}) of rice and seed weight (17.85 g $plant^{-1}$) of soybean and pod yield in groundnut (46.7%). Increase in temperature by 2.0^0C over normal also decreases the Crop duration (3 & 7.7 days), Grain yield (8.5 & 12.2 q ha^{-1}) in case of rice and wheat, respectively and also increase in solar radiation from 1-3 MJ m^{-2} day^{-1} resulted in increased yield of wheat from 18-40%. Both maximum and minimum temperature has negative impact on yield of rice declined by 10% for every 1ºC increase in minimum temperature. The quality of grains or food produce are also affected by the change. Simulated studies predicted for crop production also reveals decline in yield over years with increase in temperature, CO_2 & solar radiation (Srivastava *et al*., 2009; Ahmad Wani *et al*., 2010).

In addition to the direct effect of these climatic factors, the other biotic factors which cross the way in the crop production also are affected by the change in climate which in turn affects the crop productivity directly.

Indian agriculture, basically characterized as a means of subsistence, is changing fast market demand driven leading to indiscriminate application of inputs and exploitation of nature. Also the climate change affects the factors influencing crop production. These invaders include pests, diseases and weeds. The analysis of the potential impacts of climate change on these is therefore essential for the adoption of adaptation measures, as well as for the development of resistant cultivars, new control methods or adapted techniques, in order to avoid more serious losses. Accelerated climate change affects components of complex biological interactions differentially, often causing changes that are difficult to predict. Climate change also poses a threat to the control of these invaders. As climate variables continue to change new races/species of invaders may become able to invade previously uninhabitable areas.

Depending on the specific interaction between invaders, crops and climate there may be an increase, a decrease or no change in their effects on agricultural crops. Also, all in all, a net decline of 2.5% in agricultural production has been projected by a recent study over the next two to five decades with a major reduction in coastal regions.

Impact of changes on plant pest

- Change in temperature will directly influence infection, reproduction, dispersal, survival between seasons and other critical stages in the life cycle of a pest population.
- At higher temperature, lignification of cell walls increased in forage species and enhanced resistance to fungal pathogens.
- Increase in temperature with sufficient soil moisture may increase evapo-transpiration resulting in humid microclimate and may lead to increased pest incidence.

- Higher temperature may be more favourable for the proliferation of insect pests (longer growing seasons, higher possibility to survive during winter time). At high temperature *R* genes against pathogens may not work wherein only few can withstand, shall be selected for the changing temperature regime E.g., Bacterial blight resistant genes are susceptible (Xa1 –Xa10) the exception is Xa7 (Webb *et al*., 2010).
- Under elevated CO_2 barley plants were able to mobilize assimilates into defense structures including the formation of papillae and accumulation of silicon at sites of appressorial penetration of *Erysiphe graminis* (Chakrabortya and Newton, 2011).
- Enhanced CO_2 may affect insect pests through amount and quality of the host biomass (higher consumption rate of insect herbivores due to reduced leaf N). Changes will occur at all stages in the pathogen life cycle under elevated CO_2. Despite initial delays and reduction in host penetration, established colonies grow faster inside host tissues at elevated CO2 (Hibberd *et al*., 1996a).
- Studies indicate that the UV-B component of solar radiation plays a natural regulation on plant diseases. Stimulatory effect of near-UV light on reproduction of many fungi, and spore production in *Leptosphaerulina trifoli* peaks at 287 nm are reported (Mina and Sinha, 2008).
- Pest modifies host resistance and result in changes in the physiology of host-pest interactions. The most likely consequences are shifts in the geographical distribution of host and pathogen and altered crop losses, caused in part by changes in the efficacy of control strategies (Coakley et al., 1999). While physiological changes in host plants may result in higher disease resistance under climate change scenarios, host resistance to disease may be overcome more quickly by more rapid disease cycles, resulting in a greater chance of pathogens evolving to overcome host plant resistance. Pesticide efficacy may change with increased CO_2, moisture, and temperature. The more frequent rainfall events predicted by climate change models could result in farmers finding it difficult to keep residues of contact pesticides on plants, triggering more frequent applications. Systemic pesticides could be affected negatively by physiological changes that slow uptake rates, such as smaller stomatal opening or thicker epicuticular waxes in crop plants grown under higher temperatures.

The climate changes impacts in agricultural sector needs to be addressed through mitigation and adaptive strategies. The mitigation strategies include the selection of technologies that can help mitigate greenhouse gas (GHG) emissions from the agriculture sector and promote a sustainable agriculture sector (Smith *et al.,* 2008). The adaptive strategies includes the location and crop specific contingencies.

Mitigation Strategies:

1. Agricultural biotechnology: Agricultural biotechnology stands out as a promising tool for the development of traits and varieties that help to mitigate and adapt to climate change. GM crops with pest resistance (Bt) and herbicide tolerance and conventionally bred varieties using marker selection in tissue culture have benefited agriculture by improving productivity and disease resistance. Biotechnological approach for reducing GHC through

- Efficient 'C' sequestering through higher biomass (Ainsworth *et al*., 2008)
- Resistance to pest and diseases reduced the pest and pesticide load. Herbicide-resistance crops can be successfully cultivated under reduced tillage and save energy.
- Less photosynthetic migration to roots over shoots

2. Cover crops and Intercrops: These can protect soil from erosion, Fix atm. N besides adding huge biomass. Cover cropping is an effective method of reducing emissions of CO_2. These crops grow over entire land areas or in localized spots such as grassed waterways, field margins, and shelterbelts. Compared to leaving fields fallow, they reduce emissions and can sequester carbon during periods when primary crops are not in the field (Lal, 1998). Cover crops are usually an option on surplus agricultural land or on cropland of marginal productivity.

3. Nutrient Management: Efficient use of nitrogenous fertilizers can reduce N_2O emissions from agricultural fields. In addition, by reducing the quantity of synthetic fertilizers required, improved management can also reduce CO_2 emissions associated with their manufacture.

- Management of nitrogenous fertilizers: Fertilizer nitrogen management practices significantly influence the emissions of nitrous oxide in agriculture (Petersen *et al*., 2006). These practices are fertilizer type, timing, placement, and rate of fertilizer application, as well as coordinating the time of application with irrigation and rainfall events.
- Use of Nitrification inhibitors: Emission of N_2O can be reduced by using nitrification inhibitors (Bhatia *et al*., 2010), which slow the microbial processes that lead to N_2O formation. Ex: AM, N serve
- Slow release fertilizers: The use of slow release fertilizers offers a cost effective mitigation option. Slow release of urea and NH_4 based fertilizers can be achieved by using various coatings, chemical modifications, and changing the size of fertilizer granules. Ex: Urea super granules, Pellets (Travis Lybbert and Daniel Sumner, 2010).
- Synchronized nutrient application: Fertigation – Synchronous timing of N fertilizer application with N demand from plants is an important factor in determining the emissions of N_2O from row crop cultivation. Crop nitrogen intake capacity is generally low at the beginning of the growing season, increasing rapidly during vegetative growth and dropping sharply as the crop nears maturity.

4. Mitigation of C, N & P by mycorrhiza: One of the prime factors associated with enhancing soil carbon sequestration is the release of glomalin in mycorrhizal systems. Specific mycorrhizae: *Glomus intraradices, Glomus mosseae, Glomus fascicullatum, Glomus margarita* and *Glomus pellucida* have been reported to enhance soil carbon due to the release of glomalin. Glomalin is a glycoprotein that serves as gluing agent that facilitates soil aggregate formation and improves soil physical properties (Subramanian *et al.,* 2009).

5. Tillage: Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue on fields before and after planting the next crop to reduce soil erosion and runoff, as well as other benefits such as carbon sequestration. Zero tillage and minimum tillage reduce the energy requirement and burning of petroleum products (Dinnes, 2004).

6. Bio-char: Biochar can be used to improve agriculture and the environment in several ways and its stability in soil and superior nutrient retention properties make it an ideal soil amendment to increase crop yield. Biochar applications to soil sequester carbon and reduce emissions of non-CO_2 greenhouse gases. It also provides habitat for micro-organisms, which can increase soil microbial diversity. Biochar also acts as a soil conditioner that enhances plant growth, retains nutrients, and improves soil properties (Lehman *et al.,* 2006).

7. Irrigation: Irrigation is sufficiently common that little description is required. Suffice as to say that all types of irrigation, such as flood, sprinkler, surface and sub-surface drip, can all enhance crop yields with subsequent increases in crop residues and enhanced carbon sequestration (Smith *et al*., 2008).

8. Manure and Bio-solid management

- ❖ Improved production, storage and Handling: Scientific production, covering and incorporation
- ❖ Off-field crop residue management: Vermi-composting
- ❖ Organic agriculture: Green manures & Bio-fertilizers
- ❖ Anaerobic decay of agricultural wastes: Household biogas digesters
- ❖ Bio-energy: Biofuels – trees, corn, sugarcane

9. Agro-Forestry including Horticulture: Agro-forestry is one of the important terrestrial carbon sequestration systems. It involves a mixture of trees, agricultural crops, and pastures to exploit the ecological and economic interaction of an agro-ecosystem. Agro-ecosystems play a central role in the global carbon cycle and contain approximately 12% of world terrestrial carbon (Youkhana and Idol, 2009).

10. Livestock management - Ammoniated straw and silage: The cellulose part of the straw can be digested and utilized by ruminant animals, while the lignin part cannot be digested. The main function of ammonization is to generate ammonolysis reaction using ammonia and straw, by damaging the ester bonds between lignin and polysaccharide, so that it can contact with digestive enzymes more easily, with an improvement in digestibility of straw. The digestibility and feed intake of ammoniated straw can be increased by approximately 20%, and the content of crude protein in ammoniated straw can be increased by two to three times (Guo, 1996).

Management of rice production systems

A. Fertilizer, manure, and straw management mitigation technology

- ❖ Fertilizer types, amount, timing, proportion., Slow releasing fertilizers, Biofertilizers, Green manures
- ❖ Potassium fertilizer application technology (Babu *et al.,* 2006)
- ❖ MOP application drop the redox potential, Inhibit methanogenic bacteria, Stimulate methanotropic bacterial population – Microbial biomass

B. Water management

- ❖ Mid-season drainage technology (Wassman *et al*., 2000)
- ❖ Alternate wetting and drying (IRRI, 2009)

C. Reduced tillage: Conservation Agriculture, Zero tillage / minimum tillage

D. Direct seeding / Aerobic rice

E. SRI – Alternate wetting and drying

F. Aerobic transplanting and inter-cultivation

G. Change methanogenic activity using electron acceptor viz., Ferrihydrate (Lueders and Friedrich 2002).

Adoptive Strategies: These are aiming at implementing mechanisms to the already changed and expected climate change. The important adoptive strategies are

- ❖ Soil and water conservation
- ❖ Rainwater management: *in-situ* and *Ex-situ*
- ❖ Precision management practices
- ❖ Contingent Crops and Production practices
- ❖ Emphasis for organic farming, Bio-fertilizers, Bio-pesticides (Bio control agents)
- ❖ Mechanization for timely operation

The agriculture sector is a significant contributor to GHG emissions and requires major consideration in global mitigation efforts. A lack of awareness and guidance as well as a lack of economic strength of farmers have led to continuation of older and higher GHG-emitting agricultural practices. Land management practices, bio-energy plantation and utilisation, reduced tillage farming and other soil organic carbon

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management should be adopted to promote mitigation besides, appropriate location specific adoptive measures. Climate change is inevitable and likely to impact but, need is for the seeds of mindset to manage key agricultural activities to make climate smart farm and nation.

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