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Enduring food security in the era of climate change- A review

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Abstract
Indian agriculture remains vulnerable to the vagaries of weather, and the looming threat of climate change may expose this vulnerability further. Climate change will have far-reaching impacts on crop, livestock and fisheries production, and will change the prevalence of crop pests. Given the serious threats to food security, attention should shift to an action-oriented research agenda. Changing the culture of research to focus on an action agenda, deriving stake holder-driven portfolios of options for farmers, communities and countries, ensuring that adaptation actions are relevant to those most vulnerable to climate change, combining adaptation and mitigation, while ensuring food security, spread of irrigation needs to take place against the backdrop of diminishing ground water reserves, promoting the diversification of agroeco systems to improve their adaptability to changing climate patterns and help endure food security.

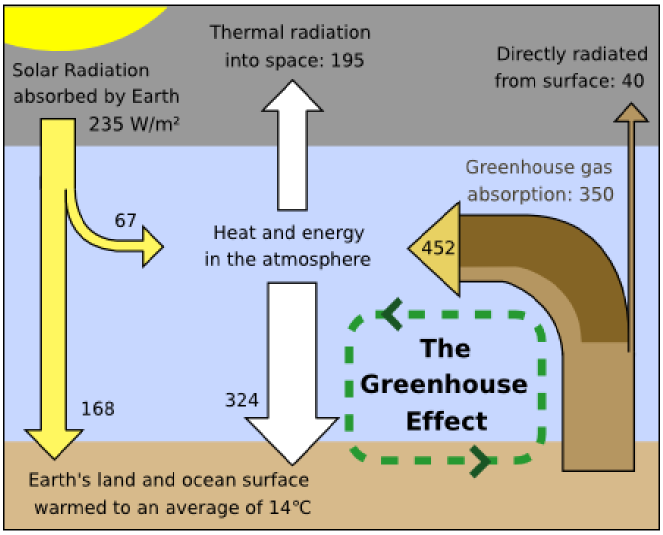
Keywords: Enduring food, era of climate, agriculture

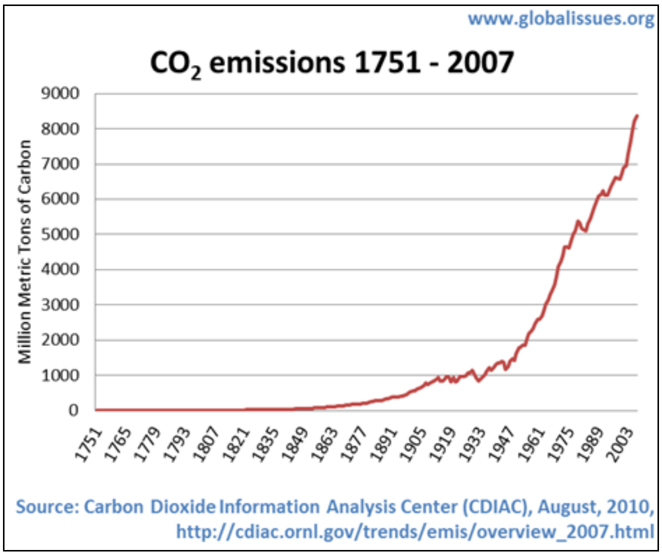
Introduction
Climate change and its causes
Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions or the distribution of events around that average (e.g., more or fewer extreme weather events). Climate change may be limited to a specific region or may occur across the whole Earth. Climate changes in response to changes in the global energy balance. On the broadest scale, the rate at which energy is received from the sun and the rate at which it is lost to space determine the equilibrium temperature and climate of Earth. This energy is then distributed around the globe by winds, ocean currents, and other mechanisms to affect the climates of different regions.
Factors that can shape climate are called climate forcings or "forcing mechanisms". These include such processes as variations in solar radiation, deviations in the Earth's orbit, mountain-building and continental drift, and changes in greenhouse gas concentrations. There are a variety of climate change feedbacks that can either amplify or diminish the initial forcing. Some parts of the climate system, such as the oceans and ice caps, respond slowly in reaction to climate forcings, while others respond more quickly.
Forcing mechanisms can be either "internal" or "external". Internal forcing mechanisms are natural processes within the climate system itself (e.g., the meridional overturning circulation). External forcing mechanisms can be either natural (e.g., changes in solar output) or anthropogenic (e.g., increased emissions of greenhouse gases). Whether the initial forcing mechanism is internal or external, the response of the climate system might be fast (e.g., a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g. thermal expansion of warming ocean water), or a combination (e.g., sudden loss of albedo in the arctic ocean as sea ice melts, followed by more gradual thermal expansion of the water). (Shah Anup, 2011) [17].

The Greenhouse Effect
- Energy from the sun drives the earth's weather & climate, and heats the earth's surface.
- In turn, the earth radiates energy back into space.
- Some atmospheric gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse.
- These gases are therefore known as greenhouse gases.
- The greenhouse effect is the rise in temperature on Earth as certain gases in the atmosphere trap energy.

Six main greenhouse gases are carbon dioxide, methane (CH_4) (which is 20 times as potent a greenhouse gas as carbon dioxide) and nitrous oxide, and fluorinated industrial gases: hydro fluorocarbons (HFCs), perfluoro carbons (PFC) and sulphur hexafluoride (SF_6). Water vapor is also considered a greenhouse gas. The Greenhouse effect is natural. Many of these greenhouse gases are actually life-enabling, for without them, heat would escape back into space and the Earth's average temperature would be a lot colder. However, if the greenhouse effect becomes stronger, then more heat gets trapped than needed, and the Earth might become less habitable for humans, plants and animals.

Carbon dioxide, though not the most potent of greenhouse gases, is the most significant one. Human activity has caused an imbalance in the natural cycle of the greenhouse effect and related processes. NASA's Earth Observatory is worth quoting the effect human activity is having on the natural carbon cycle.





Source: Greenhouse Effect, Wikipedia.
Image above expresses energy exchanges in (W/m^2)

India's concerns about Climate Change

Agriculture is important in India for the obvious reason of its centrality, given that it accounts for a large share in GDP (gross domestic product) (16%), and an even larger share in employment (49%). Perhaps it is even more important because, as the experience of the last few years illustrates, it has the potential to hold back Indian development: poor agricultural performance can lead to high inflation, rural distress, and political restiveness.

Agriculture in India continues to be vulnerable to the vagaries of weather, and the looming threat of climate change has the potential to expose this vulnerability further. Guiteras (2009) [7] finds that crop yields will decline by 4.5-9% in the short-run (2010-2039) and by a whopping 25% in the long-run (2070-2099) in the absence of adaptation by farmers. Further, Burgess *et al.* (2014) [3] find that a one standard deviation[1] increase in high temperature days in a year decreases agricultural yields and real wages by 12.6% and 9.8%, respectively, and increases annual mortality among rural populations by 7.3% in India.

Trends in rainfall and temperature over the past four and a half decades

Average annual temperatures have risen by around 0.48 degrees (1970 to 2016), and average monsoon rainfall has declined by 26 mm (1970 to 2016) (Siddharth Hari *et al.*, 2018) [18]. The number of 'very hot' days as well as the number of dry days has increased, consistent with models of climate change which predict increased variability in weather.

- There is large variation (heterogeneity) between irrigated and unirrigated areas-irrigated areas are far less susceptible to weather shocks especially at the extremes of the temperature and rainfall distribution.

Beyond level of temperature and rainfall

The relationship between weather and agricultural production is governed by factors other than just the level of temperature and rainfall. For example, the timing of rainfall can have significant effects on productivity. Even after controlling for the levels of temperature and rainfall, each additional 'dry day' during the monsoon (that is, days with less than 0.1 mm rainfall) reduces yields by 0.2% on average, and by 0.3% in unirrigated areas.

Long-run impact

There are three central channels through which climate change will affect agricultural productivity in the long run:

- A change in average temperature levels,
- A change in average rainfall levels, and
- A change in the number of dry days.

The Inter-Governmental Panel on Climate Change (IPCC) predicts that temperatures in India are likely to rise by 3-4 degrees Celsius by the end of the 21st century (Pathak *et al.* 2012) [14]. Thus the absence of any adaptation by farmers, such as change in cropping techniques or expansion in irrigation, agricultural incomes will fall by 12% on average, and by as much as 18% in unirrigated areas by the end of the century (Siddharth Hari *et al.*, 2018) [18]. He also observed decline in rainfall over the past three decades, could decline farm incomes by as much as 12% for *kharif* crops and 5.4% for *rabi* crops in unirrigated areas.

Impacts of climate change on food security

Crops, livestock and fisheries-quantity and quality

Despite inherent limitations in crop-climate modelling model-based projections of climate change impacts indicate near certainty that global crop production will decrease as a result of climate change (Porter *et al.*, 2014) [15]. Based on a meta-analysis of 1700 model simulations, the most recent IPCC assessment de-monstrated that, despite uncertainties, on average, global mean crop yields of rice, maize and wheat are projected to decrease between 3% and 10% per degree of warming above historical levels (Challinor *et al.*, 2014b) [4]. Additionally, most evidence suggests reduced quality due to decreases in leaf and grain N, protein and macro- and micronutrient (Fe, Zn, Mn, Cu) concentrations associated with increased CO_2 concentrations and more variable and warmer climates (Da Matta *et al.*, 2010) [5]. Impacts on livestock systems will be mediated through reduced feed quantity and quality, changes in pest and disease prevalence, and direct impairment of production due to physiological stress. Growth and meat, egg and milk yield and quality decrease as temperatures go beyond 30 °C due to reduced feed intake (Thornton and Gerber, 2010) [19]. Barange *et al*. (2014) [2] project 5-10% decreases in potential fish catch in tropical marine ecosystems by 2050.

In the long run, the climatic change could affect agriculture in several ways:

- *Productivity*, in terms of quantity and quality of crops.
- *Agricultural practices*, through changes of water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers.
- *Environmental effects*, in particular in relation of frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion, reduction of crop diversity
- *Rural space*, through the loss and gain of cultivated lands, land speculation, land renunciation, and hydraulic amenities.
- *Adaptation*, organisms may become more or less competitive, as well as humans may develop urgency to develop more competitive organisms, such as flood resistant or salt resistant varieties of rice.

Immediate concern-use of coal

The overriding immediate concern for India should be the fast pace at which negotiations are taking place on the climate front. India's main energy resource is coal. With the threat of climate change, India is called upon to change its energy strategy based on coal, its most abundant resource, and to use other energy sources (e.g. oil, gas, renewables and nuclear energy) instead, which may turn out to be expensive. Thus, an immediate issue is to come up with a better negotiation strategy such that we have more freedom to decide which type of energy we use, how we generate power, how to reduce methane emissions by agricultural practices or forestry and so on. Negotiations are important for us as a means to reduce or postpone future vulnerability by getting the developed countries to reduce their emissions.

Temperature potential effect on growing period

Duration of crop growth cycles are above all, related to temperature. An increase in temperature will speed up development. In the case of an annual crop, the duration between sowing and harvesting will shorten (for example, the duration in order to harvest corn could shorten between one and four weeks). The shortening of such a cycle could have an adverse effect on productivity because senescence would occur sooner.

Effect of elevated carbon dioxide on crops

Carbon dioxide is essential to plant growth. Rising CO_2 concentration in the atmosphere can have both positive and negative consequences. Increased CO_2 is expected to have positive physiological effects by increasing the rate of photosynthesis. Currently, the amount of carbon dioxide in the atmosphere is 380 parts per million. In comparison, the amount of oxygen is 210,000 ppm. This means that often plants may be starved of carbon dioxide, due to the enzyme that fixes CO_2, rubisco also fixes oxygen in the process of photorespiration. The effects of an increase in carbon dioxide would be higher on C3 crops (such as wheat) than on C4 crops (such as maize), because the former is more susceptible to carbon dioxide shortage. Studies have shown that increased CO_2 leads to fewer stomata developing on plants (Woodward and Kelly, 1995) [20] which leads to reduced water usage.

Agricultural surfaces and climate changes

Sea levels are expected to get up to one meter higher by 2100, though this projection is disputed. A rise in the sea level would result in an agricultural land loss, in particular in areas such as South East Asia. Erosion, submergence of shorelines, salinity of the water table due to the increased sea levels, could mainly affect agriculture through inundation of low-lying lands (Nicholls, 2000) [13].

Low lying areas such as Bangladesh, India and Vietnam will experience major loss of rice crop if sea levels are expected to rise by the end of the century. Vietnam for example relies heavily on its southern tip, where the Mekong Delta lies, for rice planting. Any rise in sea level of no more than a meter will drown several km^2. of rice paddies, rendering Vietnam incapable of producing its main staple and export of rice.

Erosion and fertility

The warmer atmospheric temperatures observed over the past decades are expected to lead to a more vigorous hydrological cycle, including more extreme rainfall events. Erosion and soil degradation is more likely to occur. Soil fertility would also be affected by global warming. However, because the ratio of carbon to nitrogen is a constant, a doubling of carbon is likely to imply a higher storage of nitrogen in soils as nitrates, thus providing higher fertilizing elements for plants, providing better yields. The average needs for nitrogen could decrease, and give the opportunity of changing often costly fertilisation strategies.

Due to the extremes of climate that would result, the increase in precipitations would probably result in greater risks of erosion, whilst at the same time providing soil with better hydration, according to the intensity of the rain. The possible evolution of the organic matter in the soil is a highly contested issue: while the increase in the temperature would induce a greater rate in the production of minerals, lessening the soil organic matter content, the atmospheric CO_2 concentration would tend to increase it.

Reducing risks to food security from climate change

i) Changing the culture of research to focus on an action agenda

Incentives in most research systems reward publication of papers over solving problems and achieving outcomes. (Knight *et al*., 2008) [9]. Climate change and food security research is bedevilled by uncertainty and needs to focus on delivering multiple and often conflicting objectives involving a range of stakeholders (e.g. different kinds of farmers, local service agencies, development agencies) where there are often winners and losers (Naess *et al*., 2015) [11]. The research implementation gap has to be narrowed if progress on the urgent challenge of climate change (including variability) is to be achieved. By focussing on current climate variability, there is less excuse for inaction due to uncertainty.

ii) Deriving stake holder-driven portfolios of options for farmers, communities and countries

The second challenge relates to what action should look like in different contexts, from farm to national levels. Resources are scarce and should be directed to those actions with greatest benefits. Action is needed in the short-term and must be driven by careful prioritization. Addressing food security in the face of climate change requires multi-dimensional, cross-scale, and context- specific action. Action plans are frequently established in sectoral silos, limiting opportunities to build synergies and allocate investments in effective and efficient ways from a systems perspective

iii) Ensuring that adaptation actions are relevant to the most vulnerable

The third challenge then is to ensure that adaptation actions take into account differential vulnerability to climate change. Vulnerability to climate change is determined by geographical, social, class, economic, ecological and political factors, which determine an individual or household's resources to achieve food security in the face of climatic shocks and trends. Gender affects individuals' and families' exposure to risk, as well as their access to and control of resources, finance, land, technology and services (Quisumbing *et al*., 2015) [16].

iv) Combining adaptation and mitigation, while ensuring food security

Increasing food production by 60% by 2050 to meet future consumption trends will also increase greenhouse gas emissions from agriculture, particularly from regions with low current productivity. Yet, to limit global warming by 2 °C above pre-industrial levels by 2100, IPCC scenarios indicate that agriculture must reduce emissions. To meet future food goals while minimizing further impacts on the climate, low emissions development (LED) options for producing food are needed. The fourth immediate challenge is to identify and test options and incentive systems that secure food using low emissions pathways. In this way, society can tackle the dual challenges of adaptation and mitigation.

v) Policy implications suggested in Ideas for India (Siddharth Hari *et al*., 2018) [18]

- First, there is an urgent to need to spread irrigation. While significant progress has been made over the past few decades, the proportion of cultivated land under irrigation is less than 50% today-a lot remains to be done. The central challenge here is that this spread of irrigation needs to take place against the backdrop of diminishing ground water reserves, particularly in parts of north India.
- Second, research in agriculture technology needs to be stepped up in order to develop crop varieties and cropping techniques which are more resilient to the vagaries of weather.
- Finally, subsidies (power and fertiliser) that favour the indiscriminate use of water need to be rationalised and reduced, and support should instead be extended through non-distortionary forms such as direct transfers (as Telangana is attempting today). More generally though, the cereal- and sugarcane-centricity of agricultural policy must be reviewed and overhauled.

vi) Coping mechanisms and strategies

Coping mechanisms and strategies used by smallholder/ traditional family farming communities to enhance resiliency against climatic variability are.

a) Multiple cropping or polyculture systems

By employing multiple cropping or polyculture systems, traditional farmers can adapt to local conditions, and sustainably manage harsh environments and meet their subsistence needs without depending on mechanization, chemical fertilizers, pesticides or other technologies of modern agricultural science. Indigenous farmers tend to combine various production systems as part of a typical household resource management scheme. The practice of multiple cropping systems enables smallholder farmers to achieve several production and conservation objectives simultaneously. Furthermore, polycultures exhibit greater yield stability and less productivity declines during a drought than in the case of monocultures. Natarajan and Willey (1986) [12] examined the effect of drought on enhanced yields with polycultures by manipulating water stress on intercrops of sorghum (*Sorghum bicolor*) and peanut (*Arachis* spp.), millet (*Panicum* spp.) and peanut, and sorghum and millet.

b) Wild plant gathering

In many parts of the developing world, the peasant sector still obtains a significant portion of its subsistence requirements from wild plants in and around crop fields (Altieri *et al*. 1987) [1]. In many agropastoral African societies, collection of edible leaves, berries, roots, tubers, fruits, etc. in the bushlands surrounding the villages constitutes an important strategy for diversification of the food base.

c) Agroforestry systems and mulching

Many farmers grow crops in agroforestry designs and shade tree cover to protect crop plants against extremes in the microclimate and soil moisture fluctuation. Farmers influence the microclimate by retaining and planting trees, which reduce temperature, wind velocity, evaporation and direct exposure to sunlight and intercept hail and rain. Lin (2007) [10] found that in coffee agroecosystems in Chiapas, Mexico, temperature, humidity and solar radiation fluctuations increased significantly as shade cover decreased; thus, it was concluded that shade cover was directly related to the mitigation of variability in the microclimate and soil moisture for the coffee crop.

d) Home gardening

In one of the oldest traditional forms of agriculture, humans in the humid tropics imitated nature in their agricultural practices through integrating trees (fruit-bearing trees and fodder trees) and other perennials as components of an elaborately constructed home garden, with a mixture of crops, mostly vegetables, herbs and other ornamentals. This type of home gardening is still prevalent in many areas of the humid tropics in India.

e) Use of local genetic diversity

In addition to adopting a strategy of *interspecific diversity*, many resource-poor farmers also exploit *intraspecific diversity* by growing, at the same time and in the same field, different cultivars of the same crop. In a worldwide survey of crop varietal diversity on farm involving 27 crops, Jarvis *et al*. (2007) [8] found that considerable crop genetic diversity continues to be maintained on farm in the form of traditional crop varieties, especially of major staple crops.

f) Soil organic matter enhancement

Soils hold about 75 percent of terrestrial carbon and show a greater potential to sequester much more carbon than trees. But in addition to carbon sequestration and affecting both the chemical and physical properties of the soil such as soil structure, diversity and activity of soil organisms, and nutrient availability, organic matter enhances the water holding capacity of the soil.

Urban agriculture François Mancebo

Urban agriculture appears as an effective means to address global warming-by reducing the effects of UHIs and reducing flood risks for example-while also fostering urban transitions to sustainability in many ways, such as creating new commons, amenities, ecosystem services, reinventing urbanity and encouraging community building by growing local food, etc. It makes a lot of sense to promote the development of urban agriculture in interstitial areas, wastelands, brown fields of former industrial sites, rooftops, derelict parks and squandering soils, since one among the many challenges of sustainability should be making better use of what is already there.

Conclusion

Thus endurance of food security against the threats imposed by climate change is a challenging task but has to be ensured to feed the ever increasing population. A summary of the policies to be followed is mentioned here in a nutshell. Effective mitigation techniques such as changing the culture of research to focus on an action agenda, deriving stake holder-driven portfolios of options for farmers, communities and countries, ensuring that adaptation actions are relevant to those most vulnerable to climate change, combining adaptation and mitigation, while ensuring food security, spread of irrigation against the backdrop of diminishing ground water reserves, adopting coping mechanisms and strategies used by smallholder/traditional family farming communities to enhance resiliency against climatic variability such as multiple cropping or polyculture systems, agroforestry systems and mulching, promoting agriculture practices that restore and increase natural and artificial carbon sinks, fostering urban transitions to sustainability in many ways, such urban gardening, offering solutions to minimize and compensate GHG emissions by implementing a responsible management of fertilizers and pesticides, reducing the use of fossil fuels and their by-products, and incorporating renewable energies into production systems, promoting the diversification of agroecosystems to improve their adaptability to changing climate patterns.

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