SUSTAINABLE AGRICULTURE AND CLIMATE CHANGE

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Abstract

There is growing recognition in the human dimensions research community that climate change impact must take into account the reflects of other ongoing global changes. Climate change is no more an environmental concern it has emerged as biggest developmental challenge for the planet. The human society with present day weather conditions is seized with the problems of possible climatic changes in near future. The whole international community is scared of catastrophic adverse effects of future climatic changes on different spheres of man and nature, e.g. deglaciation and sea level changes, submergence of islands, nations and major coastal lowlands, atmospheric dynamics including evaporation and precipitation, global radiation balance, photosynthesis and ecological productivity, plant and animal community and many more. This paper tries to examine the adverse impacts of climatic changes on the agricultural system. As agriculture represents the core part of the Indian economy and provides food and livelihood activities to a bulk of the population. The agriculture sector represents 35% of India's National Gross Product GNP) and as such plays a crucial role in the country's development. The impact of climate on agriculture could result in problems with food security and may threaten the livelihood activities upon which much of the population depends and thrives. In a country like India where more than 70% of population is dependent on agriculture, it is imperative that the effect of such drastic changes in environment is studied. Also it is equally important that we rely more on scientifically proven facts about global climate changes rather mere conjectures and exaggerations. This paper also endeavours to find out the ongoing and emerging threats on agriculture posed by supposedly so called Climate change. Agricultural system must be sufficiently sustainable to provide for the needs of inexorably expanding populations with greatest growth in urban communities while rural producers proportionately decline. However sustainable agriculture wholly dependent on fertile arable land safe water disastrously degraded, wasted and misused. Arable land and unpolluted water are fast becoming the main determinants of future sustainable agriculture. Climate change is supposed to exert a crucial and negative effect on the mechanism of monsoon, which is the crux of Indian rainfall and precipitation.

Key Words: *Climate Change, Impacts, Vulnerability and Agriculture,*

1. Introduction

Climate is changing naturally at its own pace, since the inception of the evolution of earth, four – five billion years ago, presently but it has gained currency and momentum on account of inadvertent anthropogenic disturbances. This rapidly changing phenomenon may culminate in adverse impact on human health and biosphere on which we depend. The multi-faceted interactions among humans, microbes and the rest of the biospheres have started reflecting quantum increase in the concentration of the green house gases

i.e. Carbon dioxides, Methane and Nitrous Oxides, causing warming across the globe along with other cascading consequences in the form of glacier melting, sea level rise, submergence of coastal regions, islands, shift in the rainfall pattern and other catastrophic events. The above multifarious interactions among atmospheric compositions, climate change and human, plant and animal health need to be scrutinized and probable solutions to the undesirable changes may be sought.

Agricultural sector is one of the sensitive areas which would be influenced by the projected global warming and associated climate change. In spite of the uncertainties about the precise magnitude of climate change on regional scales, an assessment of the possible impacts of climate changes in key climate elements on our agricultural resources is important for formulating response strategies. In this paper vulnerability of agricultural sector by ongoing climate change is examined. Climate change and agriculture are interrelated processes both of which take place on a global scale. The atmospheric conditions determine the carrying capacities of the biosphere to produce enough food for the human population and domesticated animals. Despite technological advances, such as improved varieties, genetically modified organisms and irrigation systems, weather is still a key factor in agricultural productivity, as well as soil properties and natural communities. For example, weak monsoon rains in the year 1987 caused large shortfalls in crop production in India, Bangladesh and Pakistan, contributing to a reversion to wheat importation by India and Pakistan (World food Institute, 1988). The last two decades have also witnessed a continuing deterioration of food production in Africa, caused in part by persistent drought and low production potential, and international relief efforts to prevent widespread famine. At the same time agricultural trade has also grown dramatically and now provides significant food supplies for major importing nations and substantial income for exporting nations (Adams and McCarl, 2001). These examples emphasize the close links between agriculture and climate, the international nature of food trade and food security, and the need to consider the impacts of climate change in a global context. The effects of climate on agriculture are related to variability in local climates rather than global climate patterns. The earth average temperature has increased by one degree F in just over the last century (Christensen, 2007).

Research on the impacts of climate change and vulnerability on agriculture is a high priority in India as the impact, if it follows the predictions, is expected to be widespread and severe. Developing the ability to confidently estimate the impacts of climate change on agriculture is critically important. If ever achieved, it could provide the global information needed to help farmers develop their own long- range response to climate change. Fortunately, we are very near to have such a capability, and it may take 5-7 years to substantially improve the revolution and accuracy of the climate model and evaluate the implications for agriculture (UNFCC, 2007).

I focus on India's agricultural vulnerability to two stressors: climate change and economic globalization. Among India's population of more than one billion people, about 68% are directly or indirectly involved in the agricultural sector (Tiwari, 2003). This sector is particularly vulnerable to present -day climate variability, including multiple years of low and erratic rainfall. Scenarios generated by global circulation models show that India could experience warmer and wetter conditions as a result of climate change, particularly if the summer monsoon becomes more intense and stronger (Mitra 2002) . However increased rate of evapotranspiration due to the higher temperatures may offset the

increased precipitation, leading to negative impact on soil moisture. There are also considerable uncertainties associated with climate model projections of tropical monsoon behaviour, and simulations that include sulphate aerosol forcing indicate decreasing summer monsoon rainfall (Bagla, 2002) Although the direct temperature and Carbon Dioxide effects of climate change may lead to productivity increases for some irrigated crops, there is a general consensus that major agricultural production areas are likely to be adversely affected by climate change, particularly in areas that become increasingly water- stressed (Kumar and Parikh, 2001).

The agricultural sector in India is influenced by more than changing climatic conditions. Widespread promotion of Green Revolution technologies during the 1960s increased agricultural yields in India for some crops and farmers by introducing high yielding varieties that depend on inputs, including irrigation, chemical fertilizers and pesticides. In recent years national and state agricultural policies have emphasized decentralized and participatory natural resources management, particularly for practices such as watershed development and agro forestry (Sanyal, 1993). At the same time rapid liberalization in the Indian economy has had significant structural effects on Indian agriculture. Since 1991, economic reforms have included reductions and changes in import and export restrictions and tariffs, changes in access to agricultural credit and reductions of production subsidies. Although liberalization of agricultural trade has been limited relative to other sectors of the Indian economy, India's potential participation in the WTO Agreement on Agriculture suggests that greater changes are forthcoming (Rajan and Sen, 2002). The effects of these economic changes are expected to be uneven, with some regions and farmers benefitting from market liberalization and from new inflows of investments and technology, while others may have difficulty adjusting to a more open economy, particularly to the effects of increasing competition from agricultural imports (Gulati and Kelly, 1999).

2. Scenerio of Indian Agriculture

Agriculture sector alone represents 16.6 percent of India's Gross Domestic Product (GDP), plays a crucial role in the country's development and shall continue to occupy an important place in the national economy. It sustains the livelihoods of nearly 52 percent of the population (Singh, 2008). So it seems obvious that any abrupt or significant change in climate on a global scale will exert considerable impact on local agriculture and ultimately affect the world food supply. Scores of the studies have been carried out to investigate how farming might be affected in the different regions. Several uncertainties limit the accuracy of current projections. One relates to the degree of temperature increase and its geographic distribution. Another pertains to the concomitant changes likely to occur in the precipitation patterns that determine the water supply to the crops, and the evaporative demand imposed on the crops in carbon dioxide enriched atmosphere.

The problems of predicting the future course of agriculture in the changing world are compounded by the fundamental complexities of natural agricultural systems, and socio-economic systems governing the world food supply and demand. For most people the face of the Carbon Dioxide concern is global warming leading to climate change. It is quite unfortunate that one aspect of the problem always dominates, particularly this one. Each one of us has a lifetime of experience, and opinion about temperature. Atmospheric temperature varies with latitude, longitude, altitude and time. One number, global mean temperature, is usually quoted as a proxy

for this highly variable quantity. Even if global mean temperature for a given year is the highest of on record, we know a significant portion of the globe at the ground level could be cooler than usual. This is due to the definition of the "mean" which is a kind of average. People in those colder regions (who are not climatic scientists) will tend to disbelieve global warming since they experience cooler than normal temperatures that year. If mean temperature goes up year after year, this will happen every time. Before long, almost everyone disbelieves these global warming pronouncements. It is our human nature we are up against here.

Climate change and agriculture are inter related. Agriculture contributes, of course partly to the global warming by spewing green house gas and in turn gets affected by its consequences. However, green house emissions from different farm sectors and the effect of global warming on these sectors have not been quantified The Indian Council of Agricultural Research (ICAR) has estimated that annual wheat output may decline by four to five million tons with everyone degree Celsius rise in temperature.

Many climatologists predict a significant global warming in the coming decades due to rising carbon dioxide and other green house gases. As a consequence, major change in the hydrological regimes has been also forecast to occur. Changes in the precipitation, temperature, solar radiation will have an effect on crop productivity and livestock agriculture, including changes in farm profitability, prices, supply, demand, trade and regional comparative advantages. The magnitude and geographical distribution of such climate induced changes may affect our ability to expand the food production area as required to feed the burgeoning population of more than 10,000 million people projected for the middle of the next century.

Agriculture is sensitive to shot-term changes in weather and seasonal, annual and longer term variations in climate. For the long-term changes, agriculture is able to tolerate moderate variations and changes in the climatic mean. Changes beyond these bands of tolerance may require shifts in crops, new technologies, and infrastructure or ultimately conversion to different land uses. Crop yield is the culmination of a diversified range of factors. The variations in the meteorological parameters are more of transitory in nature and have paramount influence on the agricultural systems, although other parameters like soil characteristics and seed genetics, pest and diseases cause a significant loss to world food production under different climatic conditions (FAO, 2006).

The increase in the amount of the green houses gases was caused primarily by anthropogenic sources (Savindra, 2006) .The increased agricultural activities and organic waste management are presumed to be contributing to the building up of both methane and nitrous oxide in the atmosphere. However Indian agriculture is not contributing significantly to the global climatic change, as green house emissions from agriculture is comparatively low. India's total contribution to global methane emission from all sources is only 18.5 Tg per year (UNFCC, 2007). Agriculture (Mainly rice paddies and ruminant animal production) is a major source of Methane emission and contributes 68% to it. The continuously flooded rice fields emit methane because anoxic conditions favour methanogenesis. Since India and China are major rice producing countries, US-EPA attributed 37.8Tg Methane/year to the Indian rice paddies. Increase in atmospheric carbon dioxide has a fertilization effect on crops with photosynthetic pathway and thus, promotes their growth and productivity.

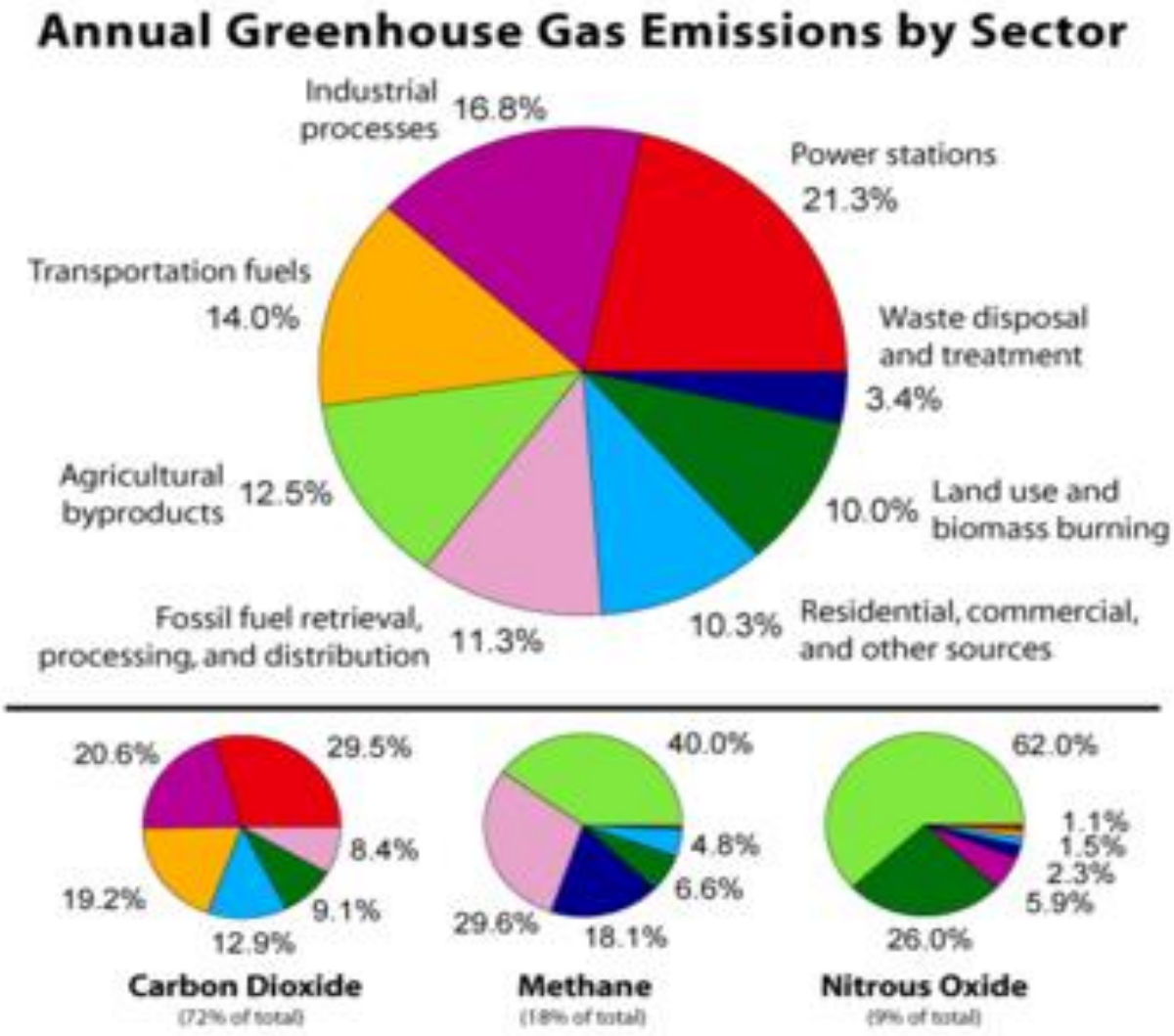

Fig. 1.1 Annual Green House Gas Emissions by Various Sectors. Source- wikipaedia

The mean temperature in India is projected to increase by 0.1 -0.3 degree Celsius in kharif and 0.3 -0.7 degree during Rabi by 2010 and 0.4-2.0 degree Celsius during kharif and to 1.1 – 4.5 degree Celsius in Rabi by 2070 (IPCC, 1996). Similarly, mean rainfall is projected not to change by 2010, but to increase by up to 10% during Rabi and kharif by 2070. At the same time there is an increased possibility of climate extremes, such as the timing of onset of monsoon, intensities and frequencies of drought and floods. The way climate change is occurring several sectors of the agriculture are susceptible severely.

A study published in "Science "suggests that due to climate change southern Africa could lose more than 30% of its main crop, maize by 2030. The 2001 IPCC Third Assessment Report concluded that the poorest countries would be hardest hit, with reductions in crop yields in most tropical and sub- tropical regions due to decreased water availability, and new or changed insect pest incidence. In Latin America and Africa many rain fed crops are near their maximum temperature tolerance, so that agricultural productivity is likely to fall sharply for even small climate changes; falls in agricultural productivity of up to 30% over the 21st

century are projected. As climate change poses threats differently to different regions and latitudes. Average crop yield is expected to drop down to 50% in Pakistan according to the UKMO scenario whereas corn production in Europe is expected to grow up to 25% in hydrologic conditions. Most favorable effects on yield tend to a large extent on realization of the potentially beneficial effects of carbon dioxide on crop growth and increase of efficiency in water use. Decrease in potential yield is likely to be caused by shortening of the growing period, decrease in water availability and poor vernalization.

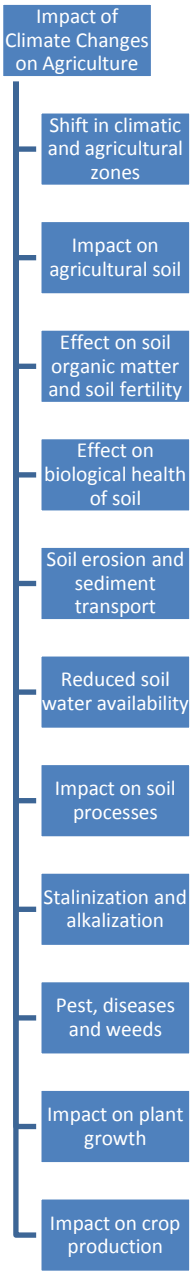

Fig. 1.2.Sectors that must be taken into account while conducting the study of the impacts of climate change on agriculture.

3. Global Temperature, Monsoon and Agriculture

Climate change is perhaps the biggest challenge facing the world today, and the very existence of man depends on how effectively this challenge is tackled. All governments have come together on a common forum to devise means to cope with this phenomenon, which threatens to play havoc and catastrophe to the lives of people across the globe. Global temperatures are rising, glaciers are melting away, sea levels are rising, and established climatic patterns are dramatically changing posing serious threats to many species of both flora and fauna. As these changes take place agriculture is getting affected adversely and the threat of sudden and phenomenal decrease is turning into reality. Developing countries like ours would be the worse hit. The pattern of monsoon has been unpredictable, uncertain and erratic for last one decade in India. And scientists attribute these changes to the climate change.

Agriculture is highly sensitive to climate variability and weather extremes such as droughts, floods and severe storms. Agriculture production in many countries including India will be impacted by climate variability (Tiwari, 2003). It is estimated that greater loss is expected in Rabi as compared to kharif crops. By 2020 in some African and Asian countries, yield from rain fed agriculture could be reduced by up to 50%. Climate change affects everyone but the worst affected would be millions of small and marginal farmers and people who are already the most vulnerable. The second aspect of climate change is that in temperate latitudes a rise in temperature would help countries increase food productivity.

The monsoon is the governing force for the way of life in the Asian sub- continent as agriculture depends on the rains. Overall half of the tropics (One quarter of the surface area of the entire globe) can be defined as a monsoon climate (Savindra, 2006). The intensity of the weather means these monsoon climates are a natural laboratory for scientists to observe the way the land, sea and atmosphere regimes interact with each other and influence weather through the exchange of moisture and energy. The large area involved and the grand scale of weather within monsoon climates suggests that monsoons play a significant role in the management of the global climate. One of the most important variables is the timing of the beginning of wet season. The fate of the Indian agriculture is bound head and tail to the course of the monsoon. When the monsoon deviates from its normal patterns, agricultural operations may be disrupted, and since India's economy is based largely upon agriculture, the result of such deviations can be disastrous. If the rain comes too late, farmers will sow few or no seeds, fearing a drought. If there is a lack of continued showers or breaks in the rain, plant seedlings may not survive. As the crops grow, later breaks or meagre rainfall may limit the number and size of maturing plants. If the rains are too hard, young plants and seedlings can be washed away. All these factors can greatly increase the price, or decrease the availability of publicly available food in India.

Our agriculture is not only driven by irrigation facilities, soil fertilities and fertilizers but mostly on the erratic behaviour of the monsoon. Global warming is intensifying the monsoon in Central India, according to a study that warns of increasing risk from heavier rains during the season (Sreelata, 2006). The research published in "Science Today" reinforces claims that global warming is boosting the power and number of storms and other extreme events across the globe. Heavy monsoon rains in Central India between 1981 and 2000 were most severe, intense and frequent than in 1950s and 1960s, and increased by 10 percent since the early

1950s (Sreelata, 2006).Severe rains doubled over the same period. At the same time, there were fewer moderate rains; say the team lead by Prof. B.N. Goswami from the Indian Institute of Tropical Meteorology, Pune, India. These trends are likely linked to rising global temperature. Scientists had already observed that the Asian monsoon gained in strength over the past few centuries. More than half the world population depends on the annual Asian monsoon to bring much- needed water for agriculture and basic human needs (Bhatwal, 2006). The South Asian summer monsoon –critical to agriculture in Bangladesh, India, Nepal and Pakistan could be weakened and delayed due to rising temperatures in the future, according to a recent climatic modelling study.

A Perdue University research group found that climate change could influence monsoon dynamics and cause less summer precipitation, a delay in the start of monsoon season and longer breaks between the rainy periods. Almost half of the world's population live sin areas affected by these monsoons, and even slight deviations from the normal monsoon pattern can have great impact. The summer monsoons are responsible for approximately 75% of the total annual rainfall in major parts of the region and produce almost 90% of India's water supply that ultimately leads to the fate of agriculture (Savindra, 2006).

Developing world already contends with chronic food problems. Climate change presents yet another significant challenge to be met. While overall food production may not be threatened, those least able to cope will likely bear additional adverse impacts (WRI, 2005). The estimate of Africa is that 25-42% of species habitats could be lost, affecting both food and non-food crops. Habitat change is already underway in some areas, leading to species range shifts. In developing countries, 11% of arable land could be affected by climate change, including a reduction of cereal production up to 65 countries (FAO, 2005).

4. Projected Effects of Climate Change on Indian Agriculture

To find out and evaluate the varying impacts of climate change on our agriculture the Indian Council of Agriculture Research has conducted these following studies-

1- Increase in Carbon dioxide to 550 ppm increases yields of rice, wheat, legumes and oil seeds by 10-20%.
2- A 1 degree C increase in temperature may reduce yields of wheat, soybean, mustard, groundnut and potato by 3-4%. Much higher losses at higher temperatures.
3- Productivity of most crops to decrease only marginally by 2020 but by 10-40% by 2100.
4- Less loss in potato, mustard and vegetables in north-western India due to reduced frost damage.
5- Animal distress due to heat, effects on reproduction.
6- Loss of 1.5 million tons of milk by 2020.
7- Imbalance in food trade due to positive impacts on Europe and N.America and negative impacts on us.

5. Soil Productivity

The most important process is the accelerated decomposition of organic matter which releases the nutrients in short run, but may reduce the fertility in the long run. Soil temperature influences the rates at which organic matter decomposes; nutrients are released and taken up and plant metabolic processes proceed. Chemical reactions that affect soil minerals and organic matter are strongly influenced by higher soil and water temperature. Soil productivity and nutrient cycling are therefore influenced by the mount and activity of soil micro-organisms. Soil microorganisms fulfill two

major functions, i.e. they act as agents of nutrient element transportation as well as store carbon and mineral nutrients in their living biomass, acting as a liable reservoir for plant available nutrients with a fast turnover.

Findings of the All India Co- ordinated Long Term Fertility Trials indicate that regions having higher organic carbon content (>0.6%) in the beginning, showed a declining trend, whereas the regions with lower organic carbon content remained more or less static or slight increase in the organic carbon content was noticed in around 25 years .In general, Indian agricultural soils are low in carbon contents, and for attaining higher agricultural production, we have to depend upon the chemical fertilizers and manures. The hypothesis of increased organic carbon degradation with the temperature increase has to be linked with the crop intensity factor, which is considerably higher for India, where proportion of the small and marginal land holdings is increasing due to rapid growth in population with time.

Further changes in rainfall due to global climatic change may affect the surface moisture and availability, which becomes important for germination and crop stand establishment in the rain fed areas. It has also been suggested that climate change could increase rates of soil erosion, further hampering food production. Increases in rainfall will accelerate the rates of soil loss, reducing farm productivity even more. A further negative consequence of accelerated erosion will be increased sedimentation in streams and reservoirs. This will shorten the life span of dams. If erosion goes unchecked, continued soil impoverishment would eventually force farmers to abandon their lands. Thus erosion is among the major threats to food production in a warmer climate.

6. Insects and Diseases

Incidence of pest and diseases is most severe and critical in the tropical regions due to favourable climatic/weather conditions, multiple cropping and availability of alternate pests throughout the year. Therefore in South Asia, pests and diseases deleteriously affecting the crop yields are common and prevalent. Climatetors are the causative agents in determining the population fluctuations of pests. They influence plant diseases establishment, progression and severity. Clear and accurate understanding of population dynamics, as influenced by biotic and abiotic parameters of environment is of much help in pest forecasting and to formulate control measures.

Global warming exerts its negative impacts on the growth and development of all organisms including pests themselves.

Increased temperature is the most prominent and considerable factor affecting the insect distribution and abundance in time and space, since these are cold- blooded organisms. These insects cannot regulate their body temperature and thereby ambient temperature influences their survival, growth, development and reproduction. Diseases are always the hurdles in the productivity. The swarms of locust produced in the Middle East usually fly eastward into Pakistan and India during summer season and they lay eggs during monsoon periods. The swarms as results of this breeding return during autumn to the area of winter rainfall spreading all quarters of India and badly influencing the standing kharif crops (Rao and Rao, 1996). Changes in the rainfall temperature and wind speed may influence the migratory behaviour of the locust. With the increase in temperature, the rate of development of insects may also increase, if temperature still lies within optimal range for the pests. As a consequence, they could complete

more number of generations for inflicting more loss to our crops. Any small change in temperature can result in changed virulence as well as appearance of new pests in a region. Crop- pest interaction needs to be examined in relation to climate change in order to assess the crop loss.

With the rise in the concentration of carbon dioxide, the nutritional status of crop will change, and the net effect on agricultural production will depend upon interaction between pests and crops.

7. Mitigation and Adaptation

Agriculture is one of the major sources of green house gas emission. Climate change has been a cause of serious concern if the agricultural sector has to grow in the context of country's overall economic growth, to respond to rural household's livelihood, country's food security and poverty alleviation. It may take some years to fully experiences the devastating effects of climate change on agriculture but the time is ripe for the government, private sector and public to have adequate concern, commitment and accountability to mitigate the impacts of climate change.

1- Improving and modifying warning systems followed by efficient monitoring and watch.
2- Developing climate impact modules that give a better understanding of how climate change may affect crop, livestock and fish farming and forestry at local level in order to be well prepared.
3- Building sufficient resilience of food systems to avoid enormous future economic losses in agriculture, livestock, fisheries and forestry.
4- Evolving comprehensive climate resilience strategies comprising risk assessment, developing of varieties that can perform well in stressful and adverse conditions, better land, water and livestock management and bringing about specific changes in agricultural practices that can respond to climate change strongly and effectively.
5- Developing a database on climate, soil and water use and crop yields to assess, map and monitor land use performance under given technology conditions. Assessment of how vulnerable our food system is and how we can adapt agriculture, livestock, fisheries and forestry to future climate related disasters. Increasing coastal inundation, salinisation and erosion as a consequence of sea level rise and human activities and contaminate and reduce the size of productive agricultural lands, thereby threatening household's livelihood and country's food security. Steps to mitigate the impacts of climate change on agriculture need top priority.
6- Assisting farmers in coping with current climatic risks. By providing weather services, agro-advisories, insurance, community banks for seed and fodder.
7- Intensifying food production systems. Technology, input delivery systems and market links should be encouraged to restructure and revitalise.
8- Improving land and water management.
9- Strengthening research for enhancing adaptive capacity.

8. Conclusion

The climate change as realized through trends of temperature increase and rise in the concentration of carbon dioxide is a major concern. Multiple environmental changes will have consequences for global vegetation. To the extent that crop yields and ecosystems are affected, there can be important economic consequences. We are now experiencing the adverse effects of climate change. Shift in the rainfall pattern, increased amount of carbon dioxide and other GHG gases, biological health of soil, pests, diseases and weeds, glacier retreat, submergence of islands

and coastal areas and erratic behaviour of migratory birds directly pose a definite threat for our forthcoming future generations and earth. We must make an all out effort to mitigate the possible effects of climate change. Intensive agriculture in our country has already started showing signs of yield stagnation in some parts of north- west India, raising the alarm of sustaining the yields by adoption of suitable and most appropriate agronomic management options. This concern has now been viewed along with the climate change and its variability. Crop simulation techniques offer an opportunity to link the climate change with the other socio-economic and bio-physical aspects. These models can effectively work out the impact an also suggest suitable mitigation options and techniques to sustain the agricultural productivity. There might be some hindrances and obstacles in the adoption of the efficient adaptation techniques. Because almost all the developing and underdeveloped countries suffer some social and technical constraints that may not necessarily result in sustainable production over long time frames. But a concerted adaptive strategy which is politically appropriate, socially viable, culturally acceptable and environmentally sustainable is need of hour for the welfare of the humanity and the planet earth.

9. References

1- Adams, Richard M., and McCarl, Bruce A. "Climate Change and its Impact on Agriculture", Oregon State University, USA, Feb 2001.

2- Aggarwal., P.K. "Vulnerability of Indian Agriculture to Climate Change". , Indian Agricultural Research Institute, New Delhi 2009.

3- Annual Publications of USEPA (United States Environmental Protection Agency) USA.

4- Bagla, P. "Drought exposes cracks in Indian Monsoon Models" Science 297, 2002.

5- Bitawat., Dilip. "An Answer to Climate Change" Yojana, New Delhi, 2009.

6- Chakrabarti. S., Suresh Kumar., S. "A Short appraisal of Climate Change Data".2009.

7- "Climate change Agricultural Policy and poverty reduction"-How much do we know, Overseas Development Institute., 2007?

8- Christensen, and Cruz. R. V. "Regional Climate Projections" Asia Climate Change, 2007.

9- Gray, Heather and Fransen, Taryn." Comaparative Analysis of National Climate Change in Developing Countries" Nov. 2009. World Resources Institute (WRI.)

10- Gulati, A. and T. Kelly, "Trade Liberalization and Indian Agriculture", New Delhi India, Oxford University Press.

11- IPCC (Intergovernmental Panel on Climate Change), 1996. Scientific Technical Analysis of Impacts, Adaptations and Climate Change, Cambridge University Press, Cambridge, UK. And N. Y.

12- IPCC (Inter Governmental Panel on Climate Change). Fourth Assessment Report (AR4) Geneva, Switzerland, 2007.

13- Jones., P. Clark. C. "Climate Change and Solution for Tomorrow". Oxford University Press, Oxford. London, 2008.

14- Mitra, A. K. "Skill of Medium Range Forecasts over the Indian Monsoon Region Using different Parameterizations of Deep

Convections. Weather and Forecasting. 2002.

15- Parikh, Jyoti. And Kumar, Kavi. K.S. "Indian Agriculture and Climate change semsitivity"vol (11), 2001.

16- Patel, Amrit. "Climate Change and agriculture Need for Mitigation and Adaptation" 2009.

17- Publications of FAO (Food and Agricultural Organization) Rome, Italy 2005.

18- Rajan, R.S., Sen, Rahul. "A Decade of Trade Reforms in India" World Economics 3, 2002.

19- Rao, Dayakar. And Rao, S. S. "Economics of Sweet Sorghum Cultivation", Aurangabad, Maharashtra, 2009.

20- Reports of Indian Council of Agricultural Research (ICAR), New Delhi, India, 2004.

21- Sanyal, B. "Urban Agriculture who cultivates and Why?" A Case study of Lusaka, Zambia. Food and Neutrition Bulletin, 7(3), 15-24. 1993.

22- Sathaye, J. A., and Ravindranath, N. H., 1998, "Climate Change Mitigation in the energy and forestry sectors of developing countries" Annual Review of Energy and the Environment.

23- "Science", 2005.

24- Singh, Raju." A Complete Summary of Economic Survey", Suman Publication House, Delhi, 2008.

25- Singh, Savindra. " Environmental Geography" Prayag Pustak Bhawan, Allahabad, India, 2006.

26- Singh, Savindra. "Physical Geography" Prayag Pustak Bhawan, Allahabad, India, 2006.

27- Tiwari, R. C. "Geography of India, Prayag Pustak Bhawan, Allahabad India, 2003.

28- UKMO (United Kingdom Meteorological Office) London UK.

29- UNFCC (United Nations Framework Convention on Climate Change), 2006. Reports of the conference, Marrakech Accords, Morocco.

30- World Food Institute (1988)