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IMPACT OF CLIMATE CHANGE ON CROP PRODUCTION

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Abstract: *Climate change and global warming is the greatest concern of mankind in 21st century. Climate change and agriculture are inter-related process. Due to increasing population many of the resources are required sustainable food security because the food security challenges are at large scale. At the same time climate change is also effecting adversely the agriculture production at both global and local levels. Production and productivity of existing crops and cropping system are adversely effected due to aberration of climate. The regions differ significantly, both in the biophysical characteristics of their climate and soil and in the vulnerability of their agricultural systems and people to climate change. An analysis of the biophysical impact of climate changes associated with global warming shows that higher temperatures generally hasten plant maturity in annual species, thus shortening the growth stages of crop plants. Global estimates of agricultural impacts have been fairly rough to date, because of lack of consistent methodology and uncertainty about the physiological effects of* CO_2*. He argues that the effects of carbon dioxide (*CO_2*) enrichment, without associated changes in climate, would probably be beneficial for agriculture. Higher temperatures, however, could increase the rate of microbial decomposition of organic matter, adversely affecting soil fertility in the long run.*
Keywords: *Population, sustainable approach, food security, climate change, Soil, Temperature and Global Warming.*

Introduction: Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events and long term, caused by changing temperatures and precipitation patterns, People who are already vulnerable and facing food insecurity are likely to be the first affected. Access to sufficient food, clean water, stable health condition, ecosystem resources and security of settlements are intricately intermingled with agriculture. No doubt, climate change will have profound impact on agriculture on both of its crucial components, the production and protection sector.

Agriculture-based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loss of livestock. Peoples living on the coastal areas, floodplains as well as on mountains, dry lands and the Arctic zones are mostly at risk. As an indirect effect, low-income people are everywhere, but particularly in urban areas, will be at risk of food insecurity owing to loss of assets and lack of adequate insurance coverage.

Nevertheless, this may also lead to shifting vulnerabilities in both developing and developed countries. Food systems will also be affected through possible internal and international migration, resource- based conflicts and civil unrest triggered by climate change and its impacts. Agriculture, forestry and fisheries would not only be affected by climate change, but also contribute to it through emitting greenhouse gases. They also hold part of the remedy, though they can contribute to climate change mitigation through reducing greenhouse gas emissions by changing agricultural practices.

At the same time, it is necessary to strengthen the resilience of rural people and to help them cope with this additional threat to food security. Particularly in the agriculture sector, climate change adaptation can go hand-in-hand with mitigation. Climate change adaptation and mitigation measures need to be integrated into the overall development approaches and agenda.

Mean global temperatures have been increasing since about 1850, mainly owing to the accumulation of greenhouse gases in the atmosphere. The main causes are the burning of fossil fuels (coal, oil and gas) to meet increasing energy demand, and the spread of intensive agriculture to meet increasing food demand, which is often accompanied by deforestation. The process of global warming shows no signs of abating and is expected to bring about long-term changes in weather conditions.

These changes will have serious impacts on the four dimensions of food security: food availability, food accessibility, food utilization and food system stability. Effects are already being felt in global food markets, and are likely to be particularly significant in specific rural locations where crops fail and yields decline. Impacts will be felt in both rural and urban locations where supply chains are disrupted, market prices increase, assets and livelihood opportunities are lost, purchasing power falls, human health is endangered, and affected people are unable to cope.

Until about 200 years ago, climate was a critical determinant for food security. Since the advent of the industrial revolution, however, humanity's ability to control the forces of nature and manage its own environment has grown enormously. As long as the economic returns justify the costs, people can now create artificial microclimates, breed plants and animals with desired characteristics, enhance soil quality, and control the flow of water. Advances in storage, preservation and transport technologies have made food processing and packaging a new area of economic activity. This has allowed food distributors and retailers to develop long-distance marketing chains that move produce and packaged foods throughout the world at high speed and relatively low cost. Where supermarkets with a large variety of standard-quality produce, available year-round, compete with small shops selling high-quality but only seasonally available local produce, the supermarkets generally win out.

The consumer demand that has driven the commercialization and integration of the global food chain derives from the mass conversion of farmers into wage-earning workers and middle-level managers, which is another consequence of the industrial revolution. Today, food insecurity persists primarily in those parts of the world where industrial agriculture, long-distance marketing chains and diversified non-agricultural livelihood opportunities are not economically significant.

At the global level, therefore, food system performance today depends more on climate than it did 200 years ago; the possible impacts of climate change on food security have tended to be viewed with most concern in locations where rainfed agriculture is still the primary source of food and income.

Rising sea levels and increasing incidence of extreme events pose new risks for the assets of people living in affected zones, threatening livelihoods and increasing vulnerability to future food insecurity in all parts of the globe. Such changes could result in a geographic redistribution of vulnerability and a re-localization of responsibility for food security–prospects that need to be considered in the formulation of adaptation strategies for people who are currently vulnerable or could become so within the foreseeable future.

The potential impacts of climate change on food security must therefore be viewed within the larger framework of changing earth system dynamics and observable changes in multiple socio-economic and environmental variables.

A food system comprises multiple food chains operating at the global, national and local levels. Some of these chains are very short and not very complex, while others circle the globe in an intricate web of interconnecting processes and links. One simple chain, which is important for food security in many households practicing rainfed agriculture, begins with a staple cereal crop produced in a farmer's field, moves with the harvested grain through a local mill and back to the farmer's home as bags of flour, and finishes in the cooking pot and on the house hold members' plates.

Evidence indicates that more frequent and more intense extreme weather events (drought, heat and cold waves, heavy storms, floods etc.), rising sea levels and increasing irregularities in seasonal rainfall patterns (including flooding) are already having immediate impacts on not only food production, but also food distribution infrastructure, incidence of food emergencies, livelihood assets and human health in both rural and urban areas.

The physiological utilization of foods consumed also affects nutritional status, and this–in turn–is affected by illness. Climate change will cause new patterns of pests and diseases to emerge, affecting plants, animals and humans, and posing new risks for food security, food safety and human health. Increased incidence of water-borne diseases in flood-prone areas, changes in vectors for climate-responsive pests and diseases, and emergence of new diseases could affect both the food chain and people's physiological capacity to obtain necessary nutrients from the foods consumed. Vector changes are a virtual certainty for pests and diseases that flourish only at specific temperatures and under specific humidity and irrigation management regimes. These will expose crops, livestock, fish and humans to new risks to which they have not yet adapted. They will also place new pressures on care givers within the home who are often women, and will challenge health care institutions to respond to new parameters.

After about three decades of low and relatively stable level, international agricultural commodity prices experienced a dramatic rise from late 2006 until they surge as large as the all-time high in June 2008. The World Bank Food Price Index rose by about 50 percent from June 2010 to February 2011 and attained its 2008 hike. Several studies addressed the potential causes and consequences of high level and volatile food prices. Climate change (extreme weather events) is one of the root causes for the recent high and volatile food prices. An increase in price volatility has implications for resource allocation, investment decisions of farmers and thus on their welfare and future livelihoods. Although food prices have increased in almost all countries and for many agricultural commodities, the impact of the rise in prices differs across countries for many reasons.

Climate change threatens to modify both the envelopes that characterize different crop production systems, and the associated yield variability and production and financial risk [1]. Adaptation strategies are discussed that will assist crop producers to cope with rising global temperatures and carbon dioxide levels, along with of ten reduced rainfall, soil moisture and water availability. The need to improve productivity or efficiency is driven not only by economic pressures, but also by the need to mitigate greenhouse gas emissions (per kg of product), to conserve biodiversity and address rising global demand for food, particularly if the area under crop cannot be increased [2]. However, there can be a risk of substantial losses if inappropriate adaptation strategies are selected. Finally, we focus on the implications of climate change for global food supply, food security and grain exports.

Climate is fundamental to crop growth. Moisture stimulates seeds to germinate, the time to emergence being temperature-dependent. The rate of growth of roots, stem and leaves depends on the rate of photosynthesis, which in turn depends on light, temperature, moisture and carbon dioxide (CO_2). Temperature and day length also determine when plants produce leaves, stems and flowers, and consequently the filling of grain or the expansion of fruit. The yield of grain crops depends on grain number and grain weight at harvest, which in turn depends on biomass at anthesis and the availability of moisture post-anthesis. In this section we explore how light, temperature and moisture and other climatic factors determine land use, crop emergence and growth and saleable product.

Temperature has major effects on photosynthesis and respiration, plant growth and phenological development [3]. Phenology is particularly important in cooler regions and at higher altitudes. As a rough guide, atmospheric temperatures experienced by crops decrease by about 1°C for each 2° increase in latitude, or for each 100 m increase in altitude. Temperature is important in controlling phenological changes in development from germination and seedling emergence, through vegetative growth to floral initiation and reproductive growth. Of course variation in temperature tolerance is evident both within populations of single plants and between genotypes. Temperature within a plant, particularly at the growing points, may differ from prevailing air temperatures for a number of reasons, including plant structure and density, distance from the soil surface, and shade.

Agriculture production is directly dependent on climate change and weather. Possible changes in temperature, precipitation and CO_2 concentration are expected to significantly impact crop growth. The overall impact of climate change on worldwide food production is considered to be low to moderate with successful adaptation and adequate irrigation [4] Global agricultural production could be increased due to the doubling of CO_2 fertilization effect. Agriculture will also be impacted due to climate changes imposed on water resources [5] India will also begin to experience more seasonal variation in temperature with more warming in the winters than summers [6]. India has experienced 23 large scale droughts starting from 1891 to 2009 and the frequency of droughts is increasing. Climate change is posing a great threat to agriculture and food security. Water is the most critical agricultural input in India, as 55% of the total cultivated areas do not have irrigation facilities. India is home to 16% of the world population, but only 4% of the world water resources. Agriculture is directly dependent on climate, since temperature, sunlight and water are the main drivers of crop growth Indian agriculture consumes about 80-85% of the nation's available water [7].

Effect of Climate Change

1. Increase in temperature increases transpiration and in drier regions leads to water stress causing yield reduction. In India, only about 41% area is irrigated and remaining 59% is rainfed. Even if we realize full irrigation potential in the country, nearly 50% area will still remain rainfed. Under such circumstances, increase in temperatures and changes in rainfall patterns.
2. The changed climate will probably lead to a decrease in crop productivity, but with important regional difference.
3. High temperature increases the rate of development in plants. A short life cycle, though less productive, can be beneficial for escaping drought and frost and late maturing cultivars could benefit from faster development rate. In colder regions, global warming could lead to longer of growth period and optimal assimilation at elevated temperatures
4. Droughts, floods, tropical cyclones, heavy precipitation, and heat waves will negatively impact agricultural production.
5. Rapid melting of glaciers in Himalayas could affect availability of water for irrigation especially in the Indo-Gangetic plains as well as neighboring countries.
6. The current fertilizer-use efficiency that ranges between 2% and 50% in India is likely to be reduced further with increasing temperature.
7. Small changes in temperature and rainfall will have significant impact on quality of fruits and vegetables with resultant implications in domestic and external trade.
8. Changes in temperature and humidity will also change insect pest and disease population.
9. Floral abortions, flower and fruit drop taking place rapidly.
10. Higher temperature increases irrigation requirement in higher amount.
11. Suitability and adaptability of current cultivars would change.
12. Changes in the distribution of existing pests, diseases and weeds, and an increased threat of new incursions and also increased incidence of physiological disorders such as tip burn
13. Increase in pollination failures if heat stress days occur during flowering
14. Increased risk of spread and proliferation of soil borne diseases as a result of more intense rainfall events (coupled with warmer temperatures)

Elevated atmospheric: CO_2 concentrations increase plant growth and yield and may improve plant water use efficiency. However, a number of factors such as pests, soil and water quality, adequate water supply, and crop-weed competition may severely limit the realization of any potential benefits [8].

Changes in precipitation patterns: Especially in the frequency of extreme events such as droughts and floods, are likely to severely affect agricultural production. These impacts will tend to affect poor developing countries disproportionately; especially those currently exposed to major climate risks [9]. However, increased frequency of extremes may also increase damage in well-established food production regions of the developed world. For instance, the European heat wave of 2003, with temperatures up to 6°C above long-term means and precipitation deficits up to 300 millimeters, resulted in crop yields falling 30 percent below long-term averages, as well as severe ecosystem, economic, and human losses.

Weeds, pests and diseases: Under climate change have the potential to severely limit crop production. Whereas quantitative knowledge is lacking compared to other controllable climate and management variables, some anecdotal data show the proliferation of weed and pest species in response to recent warming trends. For example, the activity of mountain pine beetle and other insects in the United States and Canada is taking place notably earlier in the season and resulting in major damage to forest resources. Similarly, in 2006, Northern Europe experienced the first ever incidence of bluetongue, a disease generally affecting sheep, goat and deer, in the tropics. More frequent climate extremes may also promote plant and animal disease and pest outbreaks. In Africa, droughts between the years 1981–1999 have been shown to increase the mortality rates of national livestock herds by between 20 percent and 60 percent.

Vulnerability of organic carbon pools to climate change has important repercussions for land sustainability and climate mitigation. In addition to plant species responses to elevated CO_2, future changes in carbon stocks and net fluxes will critically depend on land use actions such as afforestation/ reforestation, and management practices such as Nitrogen (N) fertilization, irrigation, and tillage, in addition to plant species responses to elevated CO_2 [10].

Biotechnological Methods Used to Address the Problems of Climate Change: Different conventional and modern biotechnological methods that can be employed for adaptation and mitigation of problems arising due to climate change are discussed below (Table 1, 2):

Reduction of Green House Gases: Agricultural practices such as deforestation, inorganic fertilizer use and overgrazing by cattle are responsible for emission of about 25% of green house gases (CO_2, CH_4 and N_2O) [11]. Use of biofuels, carbon sequestration and reduction in use of artificial fertilizers are some of conventional measures that can help in decreasing green house gases and thus reducing adverse effects of global warming and climate change [11].

Use of Biofuels: Automobile emission and agricultural practices are two main reasons for adverse effects on climate including global warming. Production of biofuels, both from traditional and genetically modified (GMO) crops such as sugarcane, oilseed, rapeseed, and jatropha can reduce the CO_2 emission by the transport sector and thus its negative effects on climate [12, 11, 13]. Adoption of energy efficient farming will employ machines that use bioethanol and biodiesel instead of the conventional fossil fuels or mix biofuels with fossil fuels thereby decreasing use of fossil fuels to some extent [14, 15]. Therefore use of bio-fuels can help in solving problem of climate change due to use of fossil fuels leading to emission of gases especially CO_2.

While ethanol production from crops such as corn may be a substitute for fossil fuels, they also compete with corn grown as a food crop and thus lead to increase in their prices. The solution of this problem may be use of non-food plants for biofuel production. Switchgrass a non food crop and algae are examples of plant sources which can produces fuel less expensively than either petroleum or food crop corn [16,17].

Less Fuel Consumption: Organic farming methods like compost and mulching techniques use less fuel and additionally due to reduced ploughing result in less use of weeds and herbicides [18]. Irrigation is a fuel consuming process therefore by employing efficient irrigation practices, fuel consumption can be reduced, which will subsequently reduce the amount of CO_2 released into the atmosphere [13].

Using modern biotechnological methods, GMO crops are produced which result in less fuel usage by reducing frequency of spraying and reducing tillage or excluding the tillage practice. For example, insect-resistant GM crops reduce fuel usage and CO_2 production by reducing insecticides application. Reduction of fuel usage employing biotechnology resulted in savings of about 962 million kg of CO_2 emitted in 2005, while the adoption of reduced tillage or no tillage practices led to a reduction of 40.43 kg/ha or 89.44 kg/ha CO_2 emissions due to less fuel usage respectively [19-20].

Table 1. Adaptation and mitigation of climate changes employing conventional agricultural biotechnology approaches

Measure	Biotechnological Approach	Application
Climate change mitigation	No-till practices	Coffee and banana and horticultural farming
Reduced use of artificial fertilizers	Biofertilizers	Employing animal manure and composting
Carbon sequestration	Agroforestry	Mycorestoration; symbiotic association of mycorrhizal and actinorrhizal species
		Afforestation
	Biofuels	Bioethanol from sugarcane

		Biodiesel from jatropha, palm oil
Climate change adaptation	Mulching	Horticlutural practices
Adaptation to biotic and abiotic stresses	Tissue culture	Drought tolerant sorghum, millet, sunflower
	Cross breeding	Drought resistant pearl millet
	Agroforestry	Shading management in coffee and banana crops
Improved agricultural productivity	Increased crop yield per unit area of land	Crop rotation, traditional pesticides.

Table 2. Climate change mitigation through modern plant biotechnology approaches

Measure	**Biotechnological Approach**	**Application**
Mitigation of climate change Consumption of less fuel	Development of herbicide resistant transgenic plants to reduce herbicide spraying	GM soy beans GM canola
	Development of insect resistant transgenic plants to reduce insecticide spraying	*Bt* maize, cotton and eggplant
Reduction in use of artificial fertilizers	Genetic Engineering of nitrogen fixation	Genetic improvement of *Rhizobium*; inducing N-fixation in non-leguminous plants
Carbon sequestration	Biotechnological approaches to help No-till farming	Herbicide resistant GM soy beans, canola
	Green energy	GM energy crops
	GM crops having nitrogen efficiency	N-efficient GM canola
Climate change adaptation	Molecular marker assisted breeding for stress resistance	Drought resistant maize, wheat hybrids
Adaptation to biotic and abiotic stresses	Genetically engineered drought tolerant plants	GM *Arabidopsis*, tobacco, maize, wheat, cotton, soybean
	Engineering salt tolerance	GM tomato, rice
	Genetically engineered heat tolerant plants	GM *Arabidopsis*, GM *Brassica* sp.
Enhanced agricultural productivity per unit area of land	Increased crop yield per unit area of land	GM cassava, potatoes, bananas, maize and canola crops resistant to fungal, bacterial and viral diseases

Reduced Use of Artificial Fertilizers: The environment has been contaminated with toxic agricultural chemicals especially inorganic fertilizers used to increase agricultural productivity, which subsequently affect the biogeochemical cycle and climate [21]. Formation and release of greenhouse gases (particularly N_2O) from the soil to the atmosphere chiefly occurs due to the use of inorganic nitrogenous fertilizers especially ammonium sulphate, ammonium chloride, ammonium phosphates [22]. The artificial fertilizers are produced from fossil fuels, therefore they add towards further reduction of an already dwindling fuel resource. One way to cope with the adverse effects of artificial fertilizers on climate is to reduce the use of artificial fertilizers on the other hand we can use some alternative source such as biofertlizers. Minimizing artificial fertilizers use can also help in reduced nitrogen pollution of ground and surface waters. Besides biofertilizers, other organic farming technologies employing crop rotation and intercropping with leguminous plants with nitrogen-fixing abilities are some of the conventional biotechnological methods for reducing artificial fertilizer use.

Biofertilizers can be produced through conventional biotechnological methods employing composted humus and animal manure. On the hand, employing modern genetic engineering techniques, nitrogen-fixing characteristics of *Rhizobium* inoculants were improved [23]. Besides leguminous plants, attempts were also made for inducing nodular structures on the roots of non-leguminous cereal crops such as rice and wheat for enabling them also to fix nitrogen in the soil and increase soil fertility [24-25]. Cultivation of nitrogen-efficient genetically modified canola has prevented to significant extent the loss of nitrogen fertilizer into the atmosphere or leaching into soil.

Biotechnology for Biotic and Abiotic Stress Tolerance

Biotic Stress: Development of genetically engineered plant strains that are resistant to biotic stresses such as insects, fungi, bacteria and viruses could reduce crop loss. *Bacillus thuringiensis* (*Bt*) gene which gives resistance to insects, pests such as the European corn borer, but has apparently no harmful effect on humans and environment has been introduced into corn, cotton, and soybeans, thus reducing damage to these crops. Therefore, GM crops can play important role in integrated pest management (IPM). Herbicide tolerance trait has also been introduced into corn, soybeans, and canola. Genetically modified potatoes, cassava and other crops that are resistant to biotic stresses are in development and some of these are already been commercialized [26].

Abiotic Stress: Salinity, drought, extreme temperatures, oxidative stress are some of the abiotic stresses which affect agricultural productivity and climate. Plant biotechnological methods in combination with conventional breeding techniques is an important approach for imparting abiotic stress tolerance in crops. These approaches include selection and growing of drought tolerant crops thus allowing their growth in harsh environmental conditions on otherwise non-agriculture lands [27]. By employing modern biotechnological approaches such as genetic engineering, useful genes or alleles imparting resistance to various stresses can be transferred across different species from the animal or plant kingdoms. In this way, crops tolerant to various abiotic stresses have been developed in response to climatic changes [28].

In Australia, field trials of 1,161 lines of genetically modified (GM) wheat and 1,179 lines of GM barley modified to contain one of 35 genes to enhance tolerance to a range of abiotic stresses including drought, cold, salt and low phosphorous obtained from wheat, barley, maize, moss or yeasts were done. Field trials of Sugarcane that contains transcription factor (*OsDREB1A*) were also done [29]. More than a dozen of other genes influencing salt tolerance have been reported in various plants, some of which can be employed in developing salt tolerance in sugarcane, rice, barley, wheat [30], tomato [31] and soybean. Structural genes (key enzymes for osmolyte biosynthesis, such as proline, glycine/ betaine, mannitol and trehalose, redox proteins and detoxifying enzymes, stress-induced LEA proteins) and regulatory genes, including dehydration–responsive, element-binding.

Phytoremediation to Increase Fertile Agriculture Land Area: Pollutants such as heavy metals, released into the soil and water due to industrial and other activities have reduced the fertile agriculture land. Some plant species have the capacity to uptake heavy metals through their root systems and accumulate them in their foliage or other tissues. These plants can then be harvested to rid the land of pollutants (phytoremediation), thus providing an increase in valuable, fertile agriculture land area [32, 33].

Mycorestoration and other Agroecological Methods for Mitigating Effects of Climate Change: In many tropical regions, modified temperature and precipitation patterns due to global climate change are having adverse effects on agriculture [13]. Practices like shade management in crop systems, can potentially help in coping the effects of high temperature and precipitation due to extreme climatic conditions [34]. Mycobiotechnology, a branch of biotechnology involving fungi is being used to solve environmental problems and restore degraded ecosystems [35]. Mycorestoration employs some saprophytic and mycorrhizal fungi for repairing or restoring ecologically degraded habitats. Many non-legume woody plants such as casuarinas (*Casuartna* sp.) and alders (*Alnus* sp.) can fix nitrogen in symbiotic association with actinomycete bacteria (*Frankia* sp.), thus helping forestry and agroforesty [36]. Both endo and ectomycorrhizal symbiotic fungi together with actinomycetes have been used in recovery of degraded forests [24] and increasing soil fertility and water uptake by plants [37]. Afforestation would indirectly contribute to improved agricultural productivity and food security because forests create microclimates that improve rainfall availability. Forests act as carbon sinks therefore adding towards carbon sequestration and thus reducing greenhouse effect.

Alternative Approaches to Farming for Addressing Effects of Climate Change: Some alternative methods are also being applied to cope with adverse effects of climate change one such approach is precision agriculture, in which resources and inputs e.g. water and fertilizers are optimized. In precision agriculture, complex devices such as global positioning system (GPS) are employed to identify factors ranging from moisture and nutrient content of soils to pest infestation of a given crop. Based upon the exact information provided by this system, optimal inputs can be applied to a specific region of a given crop only at the time of their requirement thus reducing unnecessary and untimely use of water, ferlitilizers, pesticides, herbicides etc (earthobservatory.nasa.gov, www.ghcc.msfc.nasa.gov). In a much simple practice, called drip irrigation, small amounts of water are applied to plant root systems by a network of irrigation pipes. This technique has been very helpful for crops growing in drought-infested areas. In another technique, small amounts of fertilizers are applied to the roots of crops at specific times in the growing season. These simple agricultural practices have enabled farmers who have poor access to water or artificial fertilizers to optimize their crop yield with minimum inputs [38].

Indian Scenario of Climate Change: The warming may be more pronounced in the northern parts of India. The extremes in maximum and minimum temperatures are expected to increase under changing climate, few places are expected to get more rain while some may remain dry. Leaving Punjab and Rajasthan in the North West and Tamil Nadu in the South, which show a slight decrease on an average a 20 per cent rise in all India summer monsoon rainfall over all states are expected. Number of rainy days may come down (*e.g*. MP) but the intensity is expected to rise at most of the parts of India (*e.g.* North East). Gross per capita water availability in India will decline from 1820 m3/ yr in 2001 to as low as 1140 m3/yr in 2050. Corals in Indian Ocean will be soon exposed to summer temperatures that will exceed the thermal thresholds observed over the last 20 years. Annual bleaching of corals will become almost a certainty from 2050. Currently the districts of Jagatsinghpur and Kendrapara in Odisha, Nellore and Nagapattinam in Tamilnadu, and Junagadh and Porabandar districts in Gujarat are the most vulnerable to impacts of increased intensity and frequency of cyclones in India (NATCOM, 2004). The past observations on the mean sea level along the Indian coast show a long-term (100 year) rising trend of about 1.0 mm/year. However, the recent data suggests a rising trend of 2.5 mm/year in sea level along Indian coastline. The sea surface temperature adjoining India is likely to warm up by about 1.5–2.0^{o}C by the middle of this century and by about 2.5–3.5^{o}C by the end of the century. A 1 meter sea-level rise is projected to displace approximately 7.1 million people in India and about 5764 sq km of land area will be lost, along with 4200 km of roads (NATCOM, 2004).

Impact of Climate Change on Indian Agriculture: Rainfall in India has a direct relationship with the monsoons which originate from the Indian and Arabian Seas. A warmer climate will accelerate the hydrologic cycle, altering rainfall, magnitude and timing of run-off. In arid regions of Rajasthan state an increase of 14.8 per cent in total ET demand has been projected with increase in temperature [39]. Therefore, change in climate will affect the soil moisture, groundwater recharge, and frequency of flood or drought, and finally groundwater level in different areas [40, 41]. India's agriculture is more dependent on monsoon from the ancient periods. Any change in monsoon trend drastically affects agriculture. Even the increasing temperature is affecting the Indian agriculture. In the Indo-Gangetic Plain, these pre-monsoon changes will primarily affect the wheat crop (>0.5^{o}C increase in time slice 2010-2039 [42]). In the states of Jharkhand, Odisha and Chhattisgarh alone, rice production losses during severe droughts (about one year in five) average about 40% of total production, with an estimated value of $800 million. Increase in CO_2 to 550 ppm increases yields of rice, wheat, legumes and oilseeds by 10-20%. A 1oC increase in temperature may reduce yields of wheat, soybean, mustard, groundnut, and potato by 3-7%. Productivity of most crops to decrease only marginally by 2020 but by 10-40% by 2100 due to increases in temperature, rainfall variability, and decreases in irrigation water. The major impacts of climate change will be on rain fed or un-irrigated crops, which is cultivated in nearly 60% of cropland. A temperature rise by 0.5^{o}C in winter temperature is projected to reduce rain fed wheat yield by 0.45 tonnes per hectare in India [43].

Indian agriculture, and thereby India's food production, is highly vulnerable to climate change largely because the sector continues to be highly sensitive to monsoon variability. After all, about 65 percent of India's cropped area is rain-fed. From ancient times India's agriculture has been dependent on monsoons. Any change in monsoon trends drastically affects agriculture. Even the increasing temperature is affecting Indian agriculture.

Acute water shortage conditions, together with thermal stress, will affect rice productivity even more severely. Recent studies done at the Indian Agricultural Research Institute indicate the possibility of a loss of between 4 and 5 million tonnes in wheat production in the future with every rise of 1^{o}C temperature throughout the growing period. Rice production is slated to decrease by almost a tonnes/hectare if the temperature rises by 2 degree celsius. In Rajasthan, a 2 degree rise in temperature was estimated to reduce production of pearl millet by 10 to 15 percent. If maximum and minimum temperatures rise by 3 and 3.5 degrees respectively, then soya bean yields in M.P will decline by 5 percent compared to 1998.

Agriculture will be affected in the coastal regions of Gujarat and Maharashtra, as fertile areas are vulnerable to inundation and salinization.

According to the 2006 Human Development Report of the UNDP, 2.5 billion people in South Asia will be affected by water scarcity by the year 2050 [44]. Rising temperature, changing precipitation patterns, and an increasing frequency of extreme weather events are expected to be the main reasons for reducing regional water availability and impacting hydrological cycles of evaporation and precipitation. This will drastically affect agriculture production in a region where over 60 percent of the agriculture is rained, such as in India.

The impact of climate change on water availability will be particularly severe for India because large parts of the country already suffer from water scarcity, to begin with, and largely depend on groundwater for irrigation. According to the decline in precipitation and droughts in India has led to the drying up of wetlands and severe degradation of ecosystems. About 54 percent of India faces high to extremely high water stress [45].

Predicted effects of climate change on agriculture over the next 50 years

Climatic element	Expected changes by 2050's	Confidence in prediction	Effects on agriculture
CO_2	Increase from 360 ppm to 450 - 600 ppm (2005 levels now at 379 ppm)	Very high	Good for crops: increased photosynthesis; reduced water use
Mean Sea level rise	Rise by 10 -15 cm Increased in south and offset in north by natural subsistence/rebound	Very high	Loss of land, coastal erosion, flooding, salinization of groundwater
Temperature	Rise by 1-2^{o}C. Winters warming more than summers. Increased frequency of heat waves	High	Faster, shorter, earlier growing seasons, range moving north and to higher altitudes, heat stress risk, increased evapotranspiration
Precipitation	Seasonal changes by ± 10%	Low	Impacts on drought risk' soil workability, water logging irrigation supply, transpiration
Storminess	Increased wind speeds, especially in north. More intense rainfall events.	Very low	Lodging, soil erosion, reduced infiltration of rainfall
Variability	Increases across most climatic variables. Predictions uncertain	Very low	Changing risk of damaging events (heat waves, frost, droughts floods) which effect crops and timing of farm operations

Source: Climate change and Agriculture, MAFF (2000)

Measure to overcome these Consequences of Climate Change on Horticultural Crops: Under the basic research some of the researchable issues under basic sciences include i.e. quantification of impacts of elevated temperature and CO_2 on growth, development and yield of horticultural crops. Biotechnological approaches for multiple stress tolerance with monitoring the penology of perennial crops under changing climates etc.

Under the applied research focus should be given on the development of suitable agronomic adaptation measures for reducing the adverse-climate related production losses. Development of crop simulation models for horticultural crops for enabling regional impact, adaptation and vulnerability analysis along with identification and refinement of indigenous technological knowledge to meet the challenges of weather related aberrations. Quantification of carbon sequestration potential of perennial horticultural systems. To develop eco-friendly, water use efficient irrigation system and fertilizer application systems. Development of pre and post harvest produce storage systems which can meet the challenges of climate related risks and recycling/usage of horticultural biomass should be emphasized.

Under the capacity building there is need to train the researchers, horticultural extension personnel and farmers on climate change issues. Infrastructural development also needs to be taken up to make the Indian Horticulture resilient to climate change. More storage structure and training on making of value added products can augment the farm income to make farmer more resilient to adverse situations.

Climate Change and Biological Responses: Northern latitude ecosystems are subjected to regularly occurring seasonal changes. But prolonged extremes and wide fluctuations in weather may overwhelm ecological resilience, just as they may undermine human defences. Repeated winter thawing and refreezing depresses forest defences, increasing vulnerability to pest infestations [46]. And sequential extremes and shifting seasonal rhythms can alter synchronies among predators, competitors and prey releasing opportunists from natural biological controls. Several aspects of climate change are particularly important to the responses of biological systems. First, global warming is not uniform. Warming is occurring disproportionately at high latitudes, just above Earth's surface and during winter and night-time. The Antarctic Peninsula has warmed about 2°C over the last century, while temperatures within the Arctic Circle increased 5°C [47]. Since 1950, northern hemispheric springs have been surfacing earlier, and fall appears later. While inadequately studied in the US, warm winters have been demonstrated to facilitate over wintering, thus northern migration of the ticks that carry tick-borne encephalitis and Lyme disease. Agricultural zones are shifting northward, but not as swiftly as are key pests, pathogens and weeds that, in today's climate, consume 52% of the growing and stored crops worldwide .An accelerated hydrological (water) cycle is demanding significant adjustments from biological systems along with ocean warming . Communities of marine species have shifted. A warmer atmosphere also holds more water vapour (6% for each 1°C warming) and insulates escaping heat and enhances greenhouse warming. More evaporation also fuels more intense, tropical-like downpours, while warming and parching of Earth's surface intensifies the pressure gradients that draw in winds (e.g., winter tornadoes) and large weather systems. Elevated humidity and lack of night-time relief during heat waves directly challenge human (and livestock) health. These conditions also favour mosquitoes.

Climate and the Ecology of Animals and Plants: Temperature and rainfall determine where each species can live and reproduce. Climate change will directly affect:

- The geographic range of species
- The timing of species' life cycles
- The population dynamics of species
- The location of natural habitats (some species will have to move with their host habitats)
- The structure and composition of ecosystems (i.e. the decline and extinction of some species and the invasion of other species)

Climate and the Physiology of Animals and Plants: Higher levels of carbon dioxide could stimulate the growth of some weed species, especially summer-active weeds in higher rainfall zones. However, the decline in rainfall predicted for southern Australia may counteract this. Woody weeds will benefit from increased carbon dioxide more than grasses. Many plant species respond to accumulated day degrees—the cumulative sum of daily temperatures—to 'read' the season and trigger critical development stages such as stem elongation and flowering. Warmer temperatures will accelerate the rate at which day degrees accumulate, so the life cycles of some plant species may accelerate. Because plants are host to many pest animals, the life cycle of some pest species, such as Red Legged Earth Mite, aphids and rabbits, will respond to their plant hosts and change their feeding and reproductive patterns accordingly. Warmer temperatures will directly affect the ability of animals to maintain their body temperature and avoid heat stress. Increased levels of carbon dioxide can affect the carbon-to-nitrogen ratio of plant material, thereby reducing the nitrogen available to plant-eating animals and insects. Insects that need lower temperatures to activate dormancy may have shorter overwintering periods. Warmer temperatures may reduce the production of dew which is an important source of moisture for many insects and smaller vertebrate species.

The effects of climate change on food production are not limited to crops. It will affect food production and food security via its direct or indirect impact on other components of the agricultural production systems, especially livestock production which is closely linked with crop production. India owns 57 % of the world's buffalo population and 16 % of the cattle population. It ranks first in the world in respect of cattle and buffalo population, third in sheep and second in goat population. The sector utilizes crop residues and agricultural by-products for animal feeding that are unfit for human consumption. Livestock sector has registered a compounded growth rate of more than 4.0% during last decade, in spite of the fact that a majority of the animals are reared under sub-optimal conditions by marginal and small holders and milk productivity per animal is low. Increased heat stress associated with rising temperature may, however, cause distress to dairy animals and possibly impact milk production.

A rise of 2 to 6°C in temperature is expected to negatively impact growth, puberty and maturation of crossbred cattle and buffaloes. The low producing indigenous cattle are found to have high level of tolerance to these adverse impacts than high yielding crossbred cattle. Therefore, high producing crossbred cows and buffaloes will be affected more by climate change. Heat stress on animals will reduce rate of feed intake. The higher temperatures and changing rainfall patterns may cause increased spread of the existing vector-borne diseases and macro-parasites, alter disease pattern, give rise to new diseases and affect reproduction behaviour. All these factors will affect performance of the livestock.

Hidden Harvest: After crops are harvested, respiration is the major process to be controlled. Postharvest physiologists and food scientists do not have many options to interfere with the respiratory process of harvested commodities, since they are largely dependent on the product specific characteristics [48]. In order to minimize undesirable changes in quality parameters during the postharvest period, growers and entrepreneurs can adopt a series of techniques to extend the shelf-life of perishable plant products. Postharvest technology comprises different methods of harvesting, packaging, rapid cooling, storage and transportation, among other important technologies. This set of strategies is of paramount importance to help growers all over the world to withstand the challenges that climate changes will impose throughout the next decades.

Effects of CO_2 Exposure: The greenhouse effect is primarily a combination of the effects of water vapor, CO_2 and minute amounts of other gases (methane, nitrous oxide, and ozone) that absorb the radiation leaving the Earth´s surface [49]. The warming effect is explained by the fact that CO_2 and other gases absorb the Earth's infrared radiation, trapping heat. Since a significant part of all the energy emanated from Earth occurs in the form of infrared radiation, increased CO_2 concentrations mean that more energy will be retained in the atmosphere, contributing to global warming [50]. CO_2 concentrations in the atmosphere have increased approximately 35% from pre-industrial times to 2005 [51].

The studies concluded that increased atmospheric CO_2 alters net photosynthesis, biomass production, sugars and organic acids contents, stomatal conductance, firmness, seed yield, light, water, and nutrient use efficiency and plant water potential.

Study the effects of high CO_2 concentrations on the physical and chemical quality of potato tubers [52]. They observed that increases in atmospheric CO_2 (50% higher) increased tuber malformation in approximately 63%, resulting in poor processing quality, and a trend towards lower tuber greening (around 12%). Higher CO_2 levels (550 µmol CO_2/mol) increased the occurrence of common scab by 134% but no significant changes in dry matter content, specific gravity and underwater weight were observed. Higher (550 µmol CO_2/mol) concentrations of CO_2 increased glucose (22%), fructose (21%) and reducing sugars (23%) concentrations, reducing tubers quality due to increased browning and acryl amide formation in French fries. high CO_2 concentrations, indicating loss of nutritional and sensory quality.

Effects of Ozone Exposure: The effects of ozone on vegetation have been studied both under laboratory and field experiments. Stomatal conductance and ambient concentrations are the most important factors associated with ozone uptake by plants. Ozone enters plant tissues through the stomates, causing direct cellular damage, especially in the palisade cells [53]. The damage is probably due to changes in membrane permeability and may or may not result in visible injury, reduced growth and, ultimately, reduced yield [54].

The review of the pertinent literature related to plant responses to ozone exposure reveals that there is considerable variation in species response. Greatest impacts in fruit and vegetable crops may occur from changes in carbon transport. Underground storage organs (e.g., roots, tubers, bulbs) normally accumulate carbon in the form of starch and sugars, both of which are important quality parameters for both fresh and processed crops. If carbon transport to these structures is restricted, there is great potential to lower quality in such important crops as potatoes, sweet potatoes, carrots, onions and garlic.

Exposure of other crops to elevated concentrations of atmospheric ozone can induce external and internal disorders, which can occur simultaneously or independently. These physiological disorders can lower the postharvest quality of fruit and vegetable crops destined for both fresh market and processing by causing such symptoms as yellowing (chlorosis) in leafy vegetables, alterations in starch and sugars contents of fruits and in underground organs. Decreased biomass production directly affects the size, appearance and other important visual quality parameters. Furthermore, impaired stomatal conductance due to O_3 exposure can reduce root growth, affecting crops such as carrots, sweet potatoes and beet roots [55].

Carry out a set of experiments to determine the effectiveness of O_3 in preventing ethylene-mediated deterioration and postharvest decay in both ethylene-sensitive and ethylene-producing commodities [56], when stored at optimal and sub-optimal temperatures. On mushrooms, which have no known site of ethylene activity, effects from O_3 would be antimicrobial only. O_3 at the concentration of 0.04 μL/L appeared to have potential for extending the storage life of broccoli and seedless cucumbers, both stored at 3 °C. When mushrooms were stored at 4 °C and cucumbers at 10 °C, response to O_3 was minimal.

O_3 also showed the capability of removing ethylene from the environment, inside cold rooms. At concentrations of 0.4 μL/ L, O_3 was effective in removing ethylene (1.5 2.0 μL/L) from an apple and pear storage room. Apples and pears submitted to O_3-enriched atmospheres showed no difference on fruits quality.

Strawberries cv. Camarosa stored for three days under refrigerated storage (2 C) in a O_3-enriched atmosphere (0.35 μL/L)showed a 3-fold increase in vitamin C content when compared to berries stored at the same temperature under normal atmosphere as well as a 40% reduction in emissions of volatile esters in ozonized fruits [57]. On the other hand, reported that strawberries stored in atmospheres with O_3 ranging from 0.3 to 0.7 μL/L showed no effect on ascorbic acid levels after 7 days of storage under refrigerated conditions.

Quality attributes and sensory characteristics were evaluated on tomato fruits cv. Carousel after O_3 exposure (concentration ranging from 0.005 to 1.0 μmol/mol) at 13 C and 95% RH. Soluble sugars (glucose, fructose), fruit firmness, weight loss, antioxidant status, CO_2/H_2O exchange, ethylene production, citric acid, vitamin C (pulp and seed) and total phenolic content were not significantly affected by O_3 treatment when compared to fruits kept under O_3-free air. A transient increase in b-carotene, lutein and lycopene content was observed in O_3-treated fruit, though the effect was not consistent. Sensory evaluation revealed a significant preference for fruits subjected to low-level O_3-enrichment (0.15 μmol/mol) [58].

The quality of persimmon (*Diospyros kaki* L. F.) fruits (cv. Fuyu) harvested at two different harvest dates was evaluated after O_3 exposure. Fruits were exposed to 0.15 μmol/mol (vol/vol) of O_3 for 30 days at 15 °C and 90% relative humidity (RH). Astringency removal treatment (24 h at 20 °C, 98% CO_2) was performed and fruits were then stored for 7 days at 20 °C (90% RH), imitating commercial conditions. Flesh softening was the most important disorder that appeared when fruit were transferred from 15 °C to commercial conditions. O_3 exposure was capable to maintain firmness of second harvested fruits, which were naturally softer that first harvested fruits, over commercial limits even after 30 days at 15 °C plus shelf-life. O_3-treated fruit showed the highest values of weight loss and maximum electrolyte leakage. However, O_3 exposure had no significant effect on colour, ethanol, soluble solids and pH. Furthermore, O_3-treated fruits showed no signs of phytotoxic injuries [59].

Climate Change and Food Security: Food security has been defined by World Food Summit in 1996 as Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. According to this definition, there are three main dimensions to food security: food availability, access to food, and food absorption. Thus, adequate food production alone is not a sufficient condition for a country's food security. Climate change affects food security in complex ways. It impacts crops, livestock, forestry, fisheries and aquaculture, and can cause grave social and economic consequences in the form of reduced incomes, eroded livelihoods, trade disruption and adverse health impacts. However, it is important to note that the net impact of climate change depends not only on the extent of the climatic shock but also on the underlying vulnerabilities. Much of the literature on the impact of climate change on food security, however, has focused on just one dimension of food security i.e., food production.

Food security is one of the leading concerns associated with climate because any variability in climatic factor can directly affect a country's ability to feed its people [60]. Climate change affects food security in complex ways. It impacts crops, livestock, forestry, fisheries and aquaculture, and can cause grave social and economic consequences in the form of reduced incomes, eroded livelihoods, trade disruption and adverse health impacts [61]. However, it is important to note that the net impact of climate change depends not only on the extent of the climatic shock but also on the underlying vulnerabilities. According to the Food and Agriculture Organization (2016), both biophysical and social vulnerabilities determine the net impact of climate change on food security [62]. What are the implications of climate change for the India's food security system? To answer this it is necessary to examine the effects of climate change on all dimensions of food security such as: food production, access and utilization.

Food Emergencies: Increasing instability of supply, attributable to the consequences of climate change, will most likely lead to increases in the frequency and magnitude of food emergencies with which the global food system is ill-equipped to cope. An increase in human conflict, caused in part by migration and resource competition attributable to changing climatic conditions, would also be destabilizing for food systems at all levels. Climate change might exacerbate conflict in numerous ways, although links between climate change and conflict should be presented with care. Increasing incidence of drought may force people to migrate from one area to another, giving rise to conflict over access to resources in the receiving area. Resource scarcity can also trigger conflict and could be driven by global environmental change. Grain reserves are used in emergency-prone areas to compensate for crop losses and support food relief programmes for displaced people and refugees. Higher temperatures and humidity associated with climate change may require increased expenditure to preserve stored grain, which will limit countries' ability to maintain reserves of sufficient size to respond adequately to large-scale natural or human incurred disasters.

Nutritional Value: Food insecurity is usually associated with malnutrition, because the diets of people who are unable to satisfy all of their food needs usually contain a high proportion of staple foods and lack the variety needed to satisfy nutritional requirements. Declines in the availability of wild foods, and limits on small-scale horticultural production due to scarcity of water or labour resulting from climate change could affect nutritional status adversely. In general, however, the main impact of climate change on nutrition is likely to be felt indirectly, through its effects on income and capacity to purchase a diversity of foods. The physiological utilization of foods consumed also affects nutritional status, and this–in turn–is affected by illness. Climate change will cause new patterns of pests and diseases to emerge, affecting plants, animals and humans, and posing new risks for food security, food safety and human health. Increased incidence of water-borne diseases in flood-prone areas, changes in vectors for climate-responsive pests and diseases, and emergence of new diseases could affect both the food chain and people's physiological capacity to obtain necessary nutrients from the foods consumed. Vector changes are a virtual certainty for pests and diseases that flourish only at specific temperatures and under specific humidity and irrigation management regimes. These will expose crops, livestock, fish and humans to new risks to which they have not yet adapted. They will also place new pressures on care givers within the home, who are often women, and will challenge health care institutions to respond to new parameters. Malaria in particular is expected to change its distribution as a result of climate change [63]. In coastal areas, more people may be exposed to vector- and water-borne diseases through flooding linked to sea-level rise. Health risks can also be linked to changes in diseases from either increased or decreased precipitation, lowering people's capacity to utilize food effectively and often resulting in the need for improved nutritional intake. Where vector changes for pests and diseases can be predicted, varieties and breeds that are resistant to the likely new arrivals can be introduced as an adaptive measure. A recent upsurge in the appearance of new viruses may also be climate-related, although this link is not certain. Viruses such as avian flu, ebola, HIV/AIDS and SARS have various implications for food security, including risk to the livelihoods of small-scale poultry operations in the case of avian flu, and the extra nutritional requirements of affected people in the case of HIV-AIDS.

The social and cultural values of foods consumed will also be affected by the availability and affordability of food. The social values of foods are important determinants of food preferences, with foods that are accorded high value being preferred, and those accorded low value being avoided. In many traditional cultures, feasts involving the preparation of specific foods mark important seasonal occasions, rites of passage and celebratory events. The increased cost or absolute unavailability of these foods could force cultures to abandon their traditional practices, with unforeseeable secondary impacts on the cohesiveness and sustainability of the cultures themselves. In many cultures, the reciprocal giving of gifts or sharing of food is common. It is often regarded as a social obligation to feed guests, even when they have dropped in unexpectedly. In conditions of chronic food scarcity, households' ability to honour these obligations is breaking down, and this trend is likely to be reinforced in locations where the impacts of climate change contribute to increasing incidence of food shortages. Food safety may be compromised in various ways. Increasing temperature may cause food quality to deteriorate, unless there is increased investment in cooling and refrigeration equipment or more reliance on rapid processing of perishable foods to extend their shelf-life. Decreased water availability has implications for food processing and preparation practices, particularly in the subtropics, where a switch to dry processing and cooking methods may be required. Changes in land use, driven by changes in precipitation or increased temperatures, will alter how people spend their time. In some areas, children might have to prepare food, while parents work in the field, increasing the risk that good hygiene practices may not be followed.

Role of Greenhouse Gases on Crop Production: The increasing levels of greenhouse gases (GHGs) in the atmosphere have been attributed as a major driving force for rapid climate change. The main GHGs contributing to this phenomenon are CO_2, CH_4 and N_2O. Apart from fossil fuel burning, the frequent volcanic eruptions are also contributing to this increase. Climate change will affect crop yields and cropping pattern due to the direct effects of changes in atmospheric concentrations of greenhouse gases in general and CO_2 in particular. The rate of CO_2 release into the atmosphere has increased by 30 times in the last three-four decades. It is estimated that a 0.5 degree celsius rise in winter temperature would reduce wheat yield by 0.45 tonnes per hectare. A recent World Bank report studied two drought prone regions in Andhra Pradesh and Maharashtra and one flood prone region in Orissa on climate change impacts. It has found that climate change could have the following serious impacts:

- In Andhra Pradesh, dryland farmers may see their incomes plunge by 20 percent.
- In Maharashtra, sugarcane yields may fall dramatically by 25-30 percent.
- In Orissa, flooding will rise dramatically leading to a drop in rice yields by as much as 12 percent in some districts [64].

Controlling Measures: By 2065 India' population is likely to cross 1.7 billion mark demanding more and diversified foods. Report that if farmers plant earlier than usual then climate-induced damages to wheat can be reduced by 60-75 per cent [65]. Other important adaptations include water harvesting, its conservation and efficient use through micro-irrigation techniques such as sprinkler and drip irrigation. According to an estimate, micro-irrigation, watershed management and insurance cover can avert 70 per cent of the avoidable loss due to drought [66].

Adaptation Strategies: Adaptation' involves actions that reduce the impact of the event or process without changing the likelihood that it will occur. The process may include relocating the communities living close to the sea level or switching to crops that can withstand higher temperature etc**.** Some of the adaptation strategies to negate/moderate the impacts of climate change on agriculture are summarized below:

1. Developing new plant genotypes for drought, heat and cold tolerance adapted to climatic variability and ranges.
2. For short season crops such as wheat, rice, barley, oats and many vegetable crops, extension of the growing season may allow more crops in a year.
3. Development of integrated farming system models for integrating crops, livestock, fisheries, horticulture, etc. to reduce risk and assure a higher income.

Mitigation Strategies: Mitigation refers to measures for reduction of emissions of GHGs that cause climate change like switching from fossil fuel based power generation to alternative sources of renewable energy like solar, wind, nuclear etc.

1. Reducing greenhouse gas emissions through carbon sequestration in different land use systems, with a major emphasis on raising horticultural plantations and multi-purpose tree species on degraded soils.
2. Improved management of livestock populations including poultry through better

management of feeding and livestock housing.
3. Improving the efficiency of energy use in agriculture by using better designed efficient machinery and implements.
4. Integrating trees with crops and promotion of conservation agriculture practices.

Rising Sea Level: Sea level rise by thermal expansion of ocean water and water flowing in after melting of ice due to warmer climate. The crop production will be vulnerable where inundating sea water to coastal land and low lying coastal agriculture. The sea level rise will salinize the groundwater. It would be major threat to Bangladesh and Egypt where the large productivity depends on river deltas [67].

Priorities & Prospects: On the World Food Day-2016, FAO stated that if we want to deal with climate change, need to look at seven different areas related to food and agriculture where change should happen. These includes

1. Forestry
2. Agriculture
3. Livestock management
4. Food waste
5. Natural resources
6. Fisheries
7. Food systems

India's National Action Plan on Climate Change: On June 30, 2008, Prime Minister Manmohan Singh released India's first National Action Plan on climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation. The plan identifies eight core "National Missions" running through 2017 .The plan "identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively." Under the ambit of NAPCC, 8 Missions have been initiated to implement the programmes related to mitigation and adaptation. The missions are: National Solar Mission, National Mission for Enhanced Energy Efficiency in Industry, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a 'Green India', National Mission for Sustainable Agriculture, National Mission on Strategic Knowledge for Climate Change.

Socio Economic and Policy Issues: Apart from the use of technological advances to combat climate change, there has to be sound and supportive policy framework. The frame work should address the issues of redesigning social sector with focus on vulnerable areas/ populations, introduction of new credit instruments with deferred repayment liabilities during extreme weather events, weather insurance as a major vehicle to risk transfer. Governmental initiatives should be undertaken to identify and prioritize adaptation options in key sectors (storm warning systems, water storage and diversion, health planning and infrastructure needs). Focus on integrating national development policies into a sustainable development framework that complements adaptation should accompany technological adaptation methods.

Policy initiatives in relation to access to banking, micro-credit/insurance services before, during and after a disaster event, access to communication and information services is imperative in the envisaged climate change scenario. Some of the key policy initiatives that are to be considered are: Mainstreaming adaptations by considering impacts in all major development initiatives Facilitate greater adoption of scientific and economic pricing policies, especially for water, land, energy and other natural resources. Consider financial incentives and package for improved land management and explore CDM benefits for mitigation strategies. Establish a "Green Research Fund" for strengthening research on adaption, mitigation and impact assessment [68].

Storage, Processing and Distribution: Food production varies spatially, so food needs to be distributed between regions. The major agricultural production regions are characterized by relatively stable climatic conditions, but many food-insecure regions have highly variable climates. The main grain production regions have a largely continental climate, with dry or at least cold weather conditions during harvest time, which allows the bulk handling of harvested grain without special infrastructure for protection or immediate treatment. Depending on the prevailing temperature regime, however, a change in climatic conditions through increased temperatures or unstable, moist weather conditions could result in grain being harvested with more than the 12 to 14 percent moisture required for stable storage. Because of the amounts of grain and general lack of drying facilities in these regions, this could create hazards for food safety, or even cause complete crop losses, resulting from contamination with microorganisms and their metabolic products. It could lead to a rise in food prices if stockists have to invest in new storage technologies to avoid the problem. Distribution depends on the reliability of import capacity, the presence of food stocks and–when necessary–access to food aid [69]. These factors in turn often depend on the ability to store food. Storage is affected by strategies at the national level and by physical infrastructure at the local level. Transport infrastructure limits food distribution in many developing countries. Where infrastructure is affected by climate, through either heat stress on roads or increased frequency of flood events that destroy infrastructure, there are impacts on food distribution, influencing people's access to markets to sell or purchase food [70].

Exchange of food takes place at all levels–individual, household, community, regional, national and global. At the lowest levels, exchanges usually take the form of reciprocal hospitality, gift-giving or barter, and serve as an important mechanism for coping with supply fluctuations. If changing climatic conditions bring about trend declines in local production, the capacity of affected households to engage in these traditional forms of exchange is likely to decline. Trade remains the main mechanism for exchange in today's global economy. Although most food trade takes place within national borders, global trade is the balancing mechanism that keeps exchange flowing smoothly [71]. The relatively low cost of ocean compared with overland transport makes it economically advantageous for most countries to rely on international food trade to smooth out fluctuations in domestic food supply. Where trade is heavily regulated, as in southern Africa, farmers' behaviour illustrates this principle. After a food crisis such as that in southern Africa in 2002, even if recovery programmes lead to a bumper harvest of maize, in some countries the maize may not find its way into national grain markets, as announced or anticipated producer prices and market regulations could encourage farmers to channel their surplus outside formal markets [72]. FAO projects that the impact of climate change on global crop production will be slight up to 2030. After that year, however, widespread declines in the extent and potential productivity of cropland could occur, with some of the severest impacts likely to be felt in the currently food-insecure areas of sub-Saharan Africa, which have with the least ability to adapt to climate change or to compensate through greater food imports. Although the projections suggest that normal carryover stocks, food aid and international trade should be able to cope with the localized food shortages that are likely to result from crop losses due to severe droughts or floods, this is now being questioned in view of the price boom that the world has experienced since 2006. According to FAO, the global food price index rose by 9 percent in 2006 and by 37 percent in 2007. The price boom has been accompanied by much higher price volatility than in the past, especially in the cereals and oilseeds sectors, reflecting reduced inventories, strong relationships between agricultural commodity and other markets, and the prevalence of greater market uncertainty in general. This has triggered a widespread concern about food price inflation, which is fuelling debates about the future direction of agricultural commodity prices in importing and exporting countries, be they rich or poor, and giving rise to fears that a world food crisis similar in magnitude to those of the early 1970s and 1980s may be imminent, with little prospect for a quick rebound as the effects of climate change take their toll.

Recommendations to Overcome Climate Change

Adoption of Sustainable Agricultural Practices: The main problem of Indian agriculture is low productivity. To meet India's growing food demand, there is an acute need for increasing productivity in all segments of agriculture. But given the vulnerability of Indian agriculture to climate change, farm practices need to be reoriented to provide better climate resilience. India needs to step up public investment in development and dissemination of crop varieties which are more tolerant of temperature and precipitation fluctuations and are more water and nutrient efficient. Agricultural policy should focus on improving crop productivity and developing safety nets to cope with the risks of climate change.

1. India's disaster-management strategies are mostly inadequate, short-lived and poorly conceived. Also, much of the emphasis is laid on providing quick relief to the affected households as opposed to developing long-term adaptation strategies.
2. A four-pronged strategy is recommended for the water sector:
   (i) Increase irrigation efficiency.
   (ii) Promote micro irrigation in water-deficient areas.

(iii)Better water resource infrastructure planning
(iv)Restoration of water bodies in rural areas.

4. There is a need to intensify efforts to increase climate literacy among all stakeholders of agriculture and allied sectors: students, researchers, policy planners, science managers, industry and farmers.
5. It is equally important to improve delivery of credit and crop insurance products to farmers to strengthen their capacity to adopt adaptation and mitigation measures.
6. In addition, the role of local institutions in strengthening capacities e.g., SHGs, banks and agricultural credit societies should be promoted.
7. Agricultural policy should focus on improving crop productivity and developing safety nets to cope with the risks of climate change.
8. Achieving food security in the context of climate change calls for an improvement in the livelihoods of the poor and food-insecure to not only help them escape poverty and hunger but also withstand, recover from, and adapt to the climate risks they are exposed to.
9. Climate Monitoring Efforts and Communication of Information
10. Policies that Support Research, Systems Analysis, Extension Capacity, Industry and Regional Networks
11. Investment in New Technical or Management Strategies
12. Training for New Jobs Based on New Land Uses, Industry Relocation and Human Migration
13. New Infrastructure, Policies and Institutions
14. Climate Change Mitigation–the Concept
15. Barriers to Mitigation

Key Mitigation Technologies in Agriculture

- Improved crop and grazing land management to increase soil carbon storage;
- Restoration of cultivated peaty soils and degraded lands;
- Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions;
- Improved nitrogen fertilizer application techniques to reduce N_2O emissions;
- Dedicated energy crops to replace fossil fuel use;
- Improved energy efficiency
- A large proportion of the mitigation potential of agriculture(excluding bio-energy) arises from soil carbon sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change
- Considerable mitigation potential is also available from reductions in methane and nitrous oxide emissions in some agricultural systems
- Biomass from agricultural residues and dedicated energy crops can be an important bio-energy feedstock, but current concerns with food prices make this aquestionable alternative.

Key Mitigation Technologies–Carbon Sinks in Forests

- About 65% of the total mitigation potential (up to 100US$/tCO2-eq) is located in the tropics and about 50% of the total could be achieved by reducing emissions from deforestation.
- Forest-related mitigation options can be designed and implemented to be compatible with adaptation, and can have substantial co-benefits in terms of employment, income generation, biodiversity and water shed conservation, renewable energy supply and poverty alleviation.

Stronger Emphasis on Public Health: India has historically had a poor record in public health. With the worsening challenges of climate change, the country's policymakers have also paid little attention to its impacts on health. Despite the fact that the disease burden from vector-borne and diarrheal diseases is very high in urban slums and tribal areas of India, this area was overlooked when the original National Action Plan for Climate Change (NAPCC) was formulated. The Ministry of Health is currently formulating a National Mission for Health under the ambit of NAPCC but given the close relationship between climate change, infectious diseases and food absorption, public expenditure on health needs to be stepped up drastically.

Conclusion: Agriculture and human well-being will be negatively affected by climate change. Crop yields will decline, production will be affected, crops and other agricultural commodities prices will increase, and consumption of cereals will fall, leading to reduced calorie intake and increased child malnutrition. By adopting efficient agricultural practices effect of climate change are managed in favour of growth and development of crop as well as minimized risk on natural resources.

Our findings indicate with climate change producing more food with limited resources will be a big challenge in the absence of adaptation and mitigation strategies. It is therefore imperative to promote uptake of sustainable agricultural practices to overcome the potential threats to food security. It is estimated that India needs 320 MT of food grains by the year 2025. For a country like India, sustainable agricultural development is essential not only to meet the food demands, but also for poverty reduction through economic growth by creating employment opportunities in non-agricultural rural sectors.

Thus Climate change is an important obstacle in the sustainable development of agriculture and food security of India. Along with the measures and policies being implemented by the government the education, knowledge and awareness among the people about the adverse impact of climate change the active and whole hearted participation of the people and society as whole is very much necessary.

Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns, People who are already vulnerable and food insecure are likely to be the first affected. Agriculture-based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loss of livestock. People living on the coasts and flood plains and in mountains, drylands and the Arctic are most at risk. As an indirect effect, low-income people everywhere, but particularly in urban areas, will be at risk of food insecurity owing to loss of assets and lack of adequate insurance coverage. This may also lead to shifting vulnerabilities in both developing and developed countries. Food systems will also be affected through possible internal and international migration, resource- based conflicts and civil unrest triggered by climate change and its impacts.

The policies of developing countries shall give special emphasis on the most vulnerable people by putting poor communities at the heart of planning, addressing women's needs and interests, and providing social protection schemes. On the other hand, rich countries must cut down their global emissions and shall provide the finance and technology needed to poor countries to help them in reducing emissions. Although States and United Nations are taking important steps towards mitigating the risk of climate change but still much needs to be done. Negligence on the part of those governments and corporations towards peoples who have been displaced or further impoverished by climate change is a form of violence. State shall focus on focus on placing those who have been displaced because of drought, flood, etc. due to climate change. Its time to show strong solidarity with countries most vulnerable to the impacts of climate change, and underscore the need to support efforts aimed to enhance their adaptive capacity, strengthen resilience and reduce vulnerability. Parties shall strengthen and support efforts to eradicate poverty, ensure food security and to take stringent action to deal with climate change challenges in agriculture.

The role of plant biotechnology in adaptation to climatic changes has been discussed in this review. Various conventional and modern biotechnological methods as measures for climate change adaptation and mitigation have been taken into account. These include reduction of CO_2 emissions, carbon sequestration, reduced consumption of conventional fossil fuels, use of biofuels, less use of artificial fertilizers, precision farming, phytoremediation, nutritionally enhanced foods and adaptation for biotic and abiotic stress tolerance in plants through genetic engineering to cope with various insects, pests, drought, heat and salinity stresses encountered due to climate change. These approaches integrating both conventional and modern biotechnological methods may solve food security problems of evergrowing human population by increasing agricultural productivity and may also be helpful in adapting our environment to various adverse effects of climate change.

Today, India is at the cross road in the context of global climate change. Adequate attention has been offered worldwide in order to create greater awareness amongst the public, policy makers and of course the scientific community. The existing studies present that climate change models with higher spatial resolution can be a way forward for future climate projections. Meanwhile, scholastic projections of more than one climate model are necessary for providing insights into model uncertainties as well as to develop risk management strategies. It is projected that water availability will increase in some parts of the world, which will have its own effect on water use efficiency and water allocation. Crop production can increase if irrigated areas are expanded or irrigation is intensified, but these may increase the rate of environmental degradation. Since climate change impacts on soil water balance will lead to changes of soil evaporation and plant transpiration, consequently, the crop growth period may shorten in the future impacting on water productivity. Crop yields affected by climate change are projected to be different in various areas, in some areas crop yields will increase, and for other areas it will decrease depending on the latitude of the area and irrigation application.

Increased atmospheric concentrations of CO_2 enhance photosynthetic efficiency and reduce rates of respiration, offsetting the loss of production potential due to temperature rise. However, early evidence was obtained from plant level and growth chamber experiments and has not been corroborated by field-scale experiments; it has become clear that all factors of production need to be optimal to realize the benefits of CO_2 fertilization. Early hopes for substantial CO_2 mitigation of production losses due to global warming have been restrained. A second line of reasoning is that by the time CO_2 levels have doubled, temperatures will also have risen by 4 C, negating any benefit.

'Climate' development will need to incorporate as much adaptive innovation as possible, and prioritize activities that have benefit whether or not climate change manifests itself as anticipated. A good example is the improvement of nitrogen fertilizer efficiency and the consequent reduction of the amount applied.

Improved data gathering would support better forecasting of both droughts and floods. Technologies for forecasting, even to the optimization of rainfall use, already exist and are commercially available in some (developed) countries. The quality of forecasting needs to improve, and much needs to be done to improve the communication and understanding of forecasts.

Crop patterns can be adjusted to allow earlier or later planting, to reduce water use, and to minimize or optimize irrigation or supplementary irrigation supplies. Yield and water productivity can be enhanced by adopting better soil moisture conservation practices and better management, as well as by increasing provision of other factor inputs (NPK fertilizer, weed and pest control). The options for different mixes of rainfed and irrigated land, for expansion and intensification, will vary for each situation according to the relative priorities accorded to equity in benefits to users, impacts on ecosystems and costs. Sometimes national perspectives in urban food security will dominate, but in others, a rural focus will prevail.

In the future, particularly in the changing climate conditions, to ensure food security will require a greater emphasis than now on land and water management, crop management and post-harvest management. The availability of energy will be a significant factor affecting production. Developments in the use of non-polluting, renewable resources of energy will play a significant role in conserving the resource base of agricultural production. Any major breakthrough in this sector, should be globally shared without reservations about political, social or economic considerations. Such a breakthrough, in addition to supporting agricultural production, would help control the "greenhouse effect" itself and will be to the benefit of mankind. Often developing countries are blamed by the affluent developed nations that the developing nations are more prone and vulnerable to the impacts of climate change. Hence in this conference, an initiative on this burning topic, which is need of the hour will be deliberated with possible causes and management due to climate change.

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