Climate change and its Impact on Agriculture

Introduction: Climate change and variability are concerns of human being. The recurrent droughts and floods threaten seriously the livelihood of billions of people who depend on land for most of their needs. The global economy is adversely being influenced very frequently due to extreme events such as droughts and floods, cold and heat waves, forest fires, landslips etc. The natural calamities like earthquakes, tsunamis and volcanic eruptions, though not related to weather disasters, may change chemical composition of the atmosphere. It will, in turn, lead to weather related disasters. Increase in aerosols (atmospheric pollutants) due to emission of greenhouse gases such as Carbon Dioxide due to burning of fossil fuels, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) etc., Ozone depletion and UV-B filtered radiation, eruption of volcanoes, the "human hand" in deforestation in the form of forest fires and loss of wet lands are causal factors for weather extremes. The loss of forest cover, which normally intercepts rainfall and allows it to be absorbed by the soil, causes precipitation to reach across the land eroding top soil and causes floods and droughts. Paradoxically, lack of trees also exacerbates drought in dry years by making the soil dry more quickly. Among the greenhouse gases, CO_2 is the predominant gas leading to global warming as it traps long wave radiation and emits it back to the earth surface. The global warming is nothing but heating of surface atmosphere due to emission of greenhouse gases, thereby increasing global atmospheric temperature over a long period of time. Such changes in surface air temperature and consequent adverse impact on rainfall over a long period of time are known as climate change. If these parameters show year-to-year variations or cyclic trends, it is known as climate variability.

However, the official definition by the United Nations Framework Convention on Climate Change (UNFCCC) is that climate change is the change that can be attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. However, scientists often use the term for any change in the climate, whether arising naturally or from human causes. In particular, the Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified by changes in the mean and

/ or the variability of its properties, and that persists for an extended period, typically decades or longer.

Weather and climate: Weather is the set of meteorological conditions such as wind, rain, snow, sunshine, temperature, etc. at a particular time and place. By contrast, the term climate describes the overall long-term characteristics of the weather experienced at a place. The ecosystems, agriculture, livelihoods and settlements of a region are very dependent on its climate. The climate, therefore, can be thought of as a long-term summary of weather conditions, taking account of the average conditions as well as the variability of these conditions. The fluctuations that occur from year to year, and the statistics of extreme conditions such as severe storms or unusually hot seasons are part of the climatic variability.

The Earth‵s climate has varied considerably in the past, as shown by the geological evidence of ice ages and sea level changes, and by the records of human history over many hundreds of years. The causes of past changes are not always clear but are generally known to be related to changes in ocean currents, solar activity, volcanic eruptions and other natural factors. The difference now is that global temperatures have risen unusually rapidly over the last few decades. There is strong evidence of increase in average global air and ocean temperatures, widespread melting of snow and ice, and rising of average global sea levels. The IPCC Fourth Assessment Report concludes that the global warming is unequivocal. Atmosphere and ocean temperatures are higher than they have been at any other time during at least the past five centuries, and probably for more than a millennium. Scientists have long known that the atmosphere‵s greenhouse gases act as a blanket, which traps incoming solar energy and keeps the Earth‵s surface warmer than it otherwise would be, and that an increase in atmospheric greenhouse gases would lead to additional warming.

Important Weather Extremes and their Impact at Global Level

The year 1998 was the warmest and declared as the weather-related disaster year. It caused hurricane havoc in Central America and floods in China, India and Bangladesh. Canada and New England suffered heavily due to ice storm in January while Turkey, Argentina and Paraguay suffered with floods in June 1998. In contrast, huge crop losses were noticed in Maharashtra (India) due to un-seasonal and poor distribution of rainfall during 1997-98. The 1997/1998 El Nino event (The El Nino is nothing but warming of Pacific), the strongest of the last century, affected 110 million people and costed the global economy nearly US$ 100 billion.

The year 2003 was the year of heat and cold waves across the world. The European Union (EU) suffered to a large extent due to heat wave that occurred in summer 2003. In India Uttar Pradesh, Bihar, West Bengal, Orissa and Andhra Pradesh are the States that experienced summer heat waves. When the EU suffered heat wave during the summer in 2003, India experienced severe cold wave from December 2002 to January 2003. Some parts of Jammu, Punjab, Haryana, Himachal Pradesh, Bihar, Uttar Pradesh and the North Eastern States experienced unprecedented cold wave. The crop yield loss varied between 10 and 100% in the case of horticultural crops and seasonal crops. The fruit size and quality were also adversely affected in horticultural crops. However, temperate fruits like apple, perch, plum and cherry gave higher yield due to extreme chilling. The damage was more in low-lying areas where cold air settled and remained for a longer time on the ground (Samra *et al.,* 2004).

High temperature in March 2004 adversely affected crops like wheat, apple, mustard, rapeseed, linseed, potato, vegetables, pea and tea across the State of Himachal Pradesh in India. The yield loss was estimated between 20% and 60% depending upon the crop. Wheat and potato harvest was advanced by 15-20 days and the flowering of apple was early by 15 days. The optimum temperature for fruit blossom and fruit set is 24^0C in the case of apple while it experienced above 26^0C for 17 days. The entire region recorded between 2.1 and 7.9^0C higher maximum temperature against the normal across the State of Himachal Pradesh in March 2004 (Prasad and Rana, 2006). A decline of 39% in annual cocoa yield was noticed in 2004 when compared to that of 2003 due to rise in maximum temperature of the order of 1 to 3^0C from 14^{th} January to 16^{th} March in Central part of Kerala, India. Such trend was noticed whenever summer temperature shot up by 2 to 3^0C when compared to that of normal maximum temperature of 33 to 36.5^0C.

Untimely rains and hailstorms destroyed wheat crop of 15,000 hectares (Ha.) over UP, Haryana and Punjab in Rabi season 2007 in India. In contrast, heavy snowfall over Kashmir valley was recorded in 2007 due to western disturbances. Similar was the case during monsoon 2007, causing floods across several continents (Hurricane Dean in August in Mexico) including India and Bangladesh. Heavy rains again in September in Andhra Pradesh, Karnataka and Kerala led to floods and thus the year 2007 was declared as the flood year in India. A huge crop loss was noticed in several states of the Country due to floods in *kharif*, 2007. Similar was the case in Algeria, Uganda, Sudan, Ethiopia and Kenya. Bangladesh suffered heavily due to super cyclone ‘ Sidr’ that hit in November 2007.

Beijing in China had temperature as high as 16^0C in February 2007, the highest since the meteorological record began in 1840, followed by one of its coldest and snowiest winter in 2008. As a result of heavy snow for a period of three weeks since 10^{th} of January 2008, 104 million ha. of farm land was damaged in addition to destruction of 22,000 houses and the economic loss was estimated at $ 7.5 billion. The La Nina phenomena may be another reason for severe snow storms. The La Nina is a large pool of unusually cold water in the equatorial Pacific that develops over a few years and influences global weather, which is opposite to El Nino. The El Nino is nothing but warming of Pacific. The mercury dipped to a new low of 9.4^0C over Mumbai on 6.2.2008. The frequency of such unusual weather phenomena is likely to increase across the world and huge economic loss is expected.

The Mean Sea Level (MSL) rise is likely to be slightly less than one mm/year along the Indian coast. Sea level rise may lead to disappearance of low-lying areas of coastal belt in addition to changes in ocean biodiversity. It threatens health of corals and polar bear population. Greater number of high surges and increased occurrences of cyclones in post-monsoon period, along with increased maximum wind speed, are also expected. This phenomenon of sea level rise threatens the area of land available for farming.

As per the United Nations Report of FAO, India stands to lose 125 million tonnes equivalent to 18% of its rainfed cereal production from climate change by 2015. China’s rainfed cereal production potential of 360 million tonnes is expected to increase by 15% during the same period**.** It would also cause a worldwide drop in cereal crops, leaving 400 million more people at risk of hunger, and leaving three billion people at risk of flooding and without access to fresh water supplies. The crop production losses due to climate change may also drastically increase the number of undernourished people, severely hindering progress in combating poverty and food security. The severest impact is likely to be in sub-Saharan African countries, which are least able to adapt to climate change or to compensate for it through increase in food imports. In 2004 and 2005, twenty four (24) sub- Saharan African countries faced food emergencies, caused by a lethal combination of locusts and drought. In addition, adverse hot and dry weather in United States and drought conditions in parts of the EU lowered cereal output during 2005 when compared to that of 2004. The simulation models indicate that the global warming leads to reduction in rice and wheat production in northern India.

The Indian economy is mostly agrarian based and depends on onset of monsoon and its further behaviour. The year 2002 was a classical example to show how Indian food grains' production depends on rainfall of July and it was declared as the all-India drought, as the rainfall deficiency was 19% against the long period average of the country and 29% of the area was affected due to drought. The "All-India drought" is declared when the rainfall deficiency for the Country as a whole is more than 10% of normal, and when more than 20% of the Country's area is affected by drought conditions. The kharif season food grain production was adversely affected by a whopping fall of 19.1% due to "All–India drought" during monsoon 2002.

Climate change and agriculture

Based on some of the past experiences indicated above, impact of climate change on agriculture will be one of the major deciding factors influencing the future food security of mankind on the earth. Agriculture is not only sensitive to climate change but also one of the major drivers for climate change. Understanding the weather changes over a period of time and adjusting the management practices towards achieving better harvest are challenges to the growth of agricultural sector as a whole. The climate sensitivity of agriculture is uncertain, as there is regional variation in rainfall, temperature, crops and cropping systems, soils and management practices. The inter-annual variations in temperature and precipitation were much higher than the predicted changes in temperature and precipitation. The crop losses may increase if the predicted climate change increases the climate variability.

Different crops respond differently as the global warming will have a complex impact. The tropics are more dependent on agriculture as 75% of world population lives in tropics and two thirds of these people's main occupation is agriculture. With low levels of technology, wide range of pests, diseases and weeds, land degradation, unequal land distribution and rapid population growth, any impact on tropical agriculture will affect their livelihood. Rice, wheat, maize, sorghum, soybean and barley are the six major crops in the world grown in 40% cropped area, and contribute to 55% of non-meat calories and over 70% of animal feed (FAO, 2006). Consequently, any effect on these crops would adversely affect the food security.

Main projections for climate change at Global Level: The projections of future climate patterns are largely based on computer-based models of the climate system that incorporate the important factors and processes of the atmosphere and the oceans, including the expected growth in greenhouse gases from socio-economic scenarios for the coming decades. The IPCC has examined the published results from many different models and on the basis of the evidence has estimated that by 2100-

- The global average surface warming (surface air temperature change) will increase by 1.1 - 6.4 °C.
- The sea level will rise between 18 and 59 cm.
- The oceans will become more acidic.
- It is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent.
- It is very likely that there will be more precipitation at higher latitudes and it is likely that there will be less precipitation in most subtropical land areas.
- It is likely that tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and heavier precipitation associated with ongoing increases of tropical sea surface temperatures.

Likely Effects of climate change on key sectors at Global Level: The IPCC Fourth Assessment Report of the Working Group II: Impacts, Adaptation and Vulnerability describe the likely effects of climate change, including from increases in extreme events. The effects on key sectors, in the absence of countermeasures, are summarized as follows.

Water: Drought affected areas are likely to be more widely distributed. Heavier precipitation events are very likely to increase in frequency leading to higher flood risks. By mid-century, water availability is likely to decrease in mid-latitudes, in the dry tropics and in other regions supplied by melted water from mountain ranges. More than one sixth of the world's population is currently dependent on melt water from mountain ranges.

Food: While some mid latitude and high latitude areas will initially benefit from higher agricultural production, for many others at lower latitudes, especially in seasonally dry and tropical regions, the increases in temperature and the frequency of droughts and floods are likely to affect crop production negatively, which could increase the number of people at risk from hunger and increased levels of displacement and migration.

Industry, settlement and society: The most vulnerable industries, settlements and societies are generally those located in coastal areas and river flood plains, and those whose economies are closely linked with climate sensitive resources. This applies particularly to locations already prone to extreme weather events and especially to areas undergoing rapid urbanization. Where extreme weather events become more intense or more frequent, the economic and social costs of those events will increase.

Health: The projected changes in climate are likely to alter the health status of millions of people, including increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts. Increased malnutrition, diarrhea disease and malaria in some areas will increase vulnerability to extreme public health, and development goals will be threatened by long term damage to health systems from disasters.

Projected Impact on Asia

- Asia-Pacific region may experience the worst effect on rice and wheat yields worldwide, and decreased yields could threaten the food security of 1.6 billion people in South Asia.

- The crop model indicates that in South Asia, average yields in 2050 for crops will decline from 2000 levels by about 50 percent for wheat, 17 percent for rice, and about 6 percent for maize because of climate change.
- In East Asia and the Pacific, yields in 2050 for crops will decline from 2000 levels by 20 percent for rice, 13 percent for soybean, 16 percent for wheat and 4 percent for maize because of climate change.
- With climate change, average calorie availability in Asia in 2050 is expected to be about 15 percent lower and cereal consumption is projected to decline by as much as 24 percent compared to a no-climate change scenario.
- In a no-climate change scenario, the number of malnourished children in South Asia would fall from 76 to 52 million between 2000 and 2050, and from 24 to 10 million in East Asia and the Pacific.
- Climate change will erase some of this progress, causing the number of malnourished children in 2050 to rise to 59 million in South Asia and to 14 million in East Asia and the Pacific, increasing the total number of malnourished children in Asia by about 11 million.
- To counteract the effects of climate change on nutrition, South Asia requires additional annual investments of 1.5 billion USD in rural development, and East Asia and the Pacific require almost 1 million USD more. Over half of these investments in both regions must be for irrigation expansion.
- The Asian countries most vulnerable to climate change are Afghanistan, Bangladesh, Cambodia, India, Lao PDR, Myanmar, and Nepal.
- Afghanistan, Bangladesh, India, and Nepal are particularly vulnerable to declining crop yields due to glacial melting, floods, droughts, and erratic rainfall, among other factors.
- Asia is the most disaster-afflicted region in the world, accounting for about 89 percent of people affected by disasters worldwide.

Observed Changes in Climate and Weather Events in India

Surface Temperature

At the national level, increase of 0.4° C has been observed in surface air temperatures over the past century. A warming trend has been observed along the west coast, in central India, the interior peninsula, and northeastern India.

However, cooling trends have been observed in northwest India and parts of south India.

Rainfall

While the observed monsoon rainfall at the All India level does not show any significant trend, regional monsoon variations have been recorded. A trend of increasing monsoon seasonal rainfall has been found along the west coast, northern Andhra Pradesh, and north-western India (+10% to +12% of the normal over the last 100 years) while a trend of decreasing monsoon seasonal rainfall has been observed over eastern Madhya Pradesh, north-eastern India, and some parts of Gujarat and Kerala (-6% to - 8% of the normal over the last 100 years)

Extreme Weather Events

Trends of Extreme Weather Events observed in multi-decadal periods of more frequent droughts followed by less severe droughts. There has been an overall increasing trend in severe storm incidence along the coast at the rate of 0.011 events per year. While the states of West Bengal and Gujarat have reported increasing trends, a decline has been observed in Orissa. Scientists, while analysing a daily rainfall data set, have shown (i) a rising trend in the frequency of heavy rain events, and (ii) a significant decrease in the frequency of moderate events over central India from 1951 to 2000.

Rise in Sea Level

Using the records of coastal tide gauges in the north Indian Ocean for more than 40 years, Scientists have estimated that sea level rise was between 1.06-1.75 mm per year. These rates are consistent with 1-2 mm per year global sea level rise estimates of the IPCC.

Indian Summer Monsoon (ISM) intensity is projected to increase in the beginning of 2040 and by 10% by 2100.

Impacts on Himalayan Glaciers

The Himalayas possess one of the largest resources of snow and ice and its glaciers form a source of water for the perennial rivers such as the Indus, the Ganga, and the Brahmaputra. Glacial melt may impact their long-term lean-season flows, with adverse impacts on the economy in terms of water availability and hydropower generation.

The available monitoring data on Himalayan glaciers indicates that while recession of some glaciers has occurred in some Himalayan regions in recent years, the trend is not consistent across the entire mountain chain.

Some Projections of Climate Change over India for the 21st Century

Some modelling and other studies have projected the following changes due to increase in atmospheric GHG concentrations arising from increased global anthropogenic emissions:

Annual mean surface temperature

The simulation studies by Indian Institute of Tropical Meteorology (IITM), Pune, estimated that annual mean surface temperature is expected to raise by the end of century, ranges from 3 to 5° C with warming more pronounced in the northern parts of India.

Impacts on Water Resources

Changes in key climate variables, namely temperature, precipitation and humidity, may have significant long-term implications for the quality and quantity of water. River systems of the Brahmaputra, the Ganga, and the Indus, which benefit from melting snow in the lean season, are likely to be particularly affected by the decrease in snow cover. A decline in total run-off for all river basins, except Narmada and Tapti, is projected in India's NATCOM I. A decline in run-off by more than two-thirds is also anticipated for Sabarmati and Luni basins. Due to sea level rise, the fresh water sources near the coastal regions will suffer salt intrusion.

Impacts on Agriculture and Food Production

Food production in India is sensitive to climate changes such as variability in monsoon rainfall and temperature changes within a season. Studies by Indian Agricultural Research Institute (IARI) and others indicate greater expected loss in the Rabi crop. Every 1°C rise in temperature reduces wheat production by 4-5 Million

Tonnes. Small changes in temperature and rainfall have significant effects on the quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants, and basmati rice. Pathogens and insect populations are strongly dependent upon temperature and humidity, and changes in these parameters may change their population dynamics. Other impacts on agricultural and related sectors include lower yields from dairy cattle and decline in fish breeding, migration, and harvests. Global reports indicate a loss of 10-40% in crop production by 2100.

Indian climate is dominated by the southwest monsoon, which brings most of the region's precipitation. It is critical for the availability of drinking water and irrigation for agriculture. Agricultural productivity is sensitive to two broad classes of climate-induced effects (1) direct effects from changes in temperature, precipitation or carbon dioxide concentrations, and (2) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases. Rice and wheat yields could decline considerably with climatic changes (IPCC 1996; 2001). However, the vulnerability of agricultural production to climate change depends not only on the physiological response of the affected plant, but also on the ability of the affected socio-economic systems of production to cope with changes in yield, as well as with changes in the frequency of droughts or floods. The adaptability of farmers in India is severely restricted by the heavy reliance on natural factors and the lack of complementary inputs and institutional support systems. The loss in net revenue at the farm level is estimated to range between 9% and 25% for a temperature rise of 2 °C to 3.5 °C. Scientists also estimated that a 2°C rise in mean temperature and a 7% increase in mean precipitation would reduce net revenues by 12.3% for the country as a whole. Agriculture in the coastal regions of Gujarat, Maharashtra, and Karnataka is found to be the most negatively affected. Small losses are also indicated for the major food-grain producing regions of Punjab, Haryana, and western Uttar Pradesh. On the other hand, West Bengal, Orissa, and Andhra Pradesh are predicted to benefit to a small extent from warming.

Impacts on health

Changes in climate may alter the distribution of important vector species (for example, malarial mosquitoes) and may increase the spread of such diseases to new areas. If there is an increase of 3.8 °C in temperature and a 7% increase in relative humidity, the transmission windows i.e., months during which mosquitoes are active, will be open for all 12 months in 9 states in India. The transmission windows in Jammu and Kashmir and in Rajasthan may increase by 3-5 months. However, in Orissa and some southern states, a further increase in temperature is likely to shorten the transmission window by 2-3 months.

Impacts on Forests

Climate projections indicate that the country is likely to experience shift in forest types, with consequent changes in forests produce, and, in turn, livelihoods based on those products. Correspondingly, the associated biodiversity is likely to be adversely impacted.

Vulnerability to Extreme Events

Heavily populated regions such as coastal areas are exposed to climatic events such as cyclones, floods, drought, and large declines in sown areas in arid and semi-arid zones occur during climate extremes. Large areas in Rajasthan, Andhra Pradesh, Gujarat, and Maharashtra and comparatively small areas in Karnataka, Orissa, Madhya Pradesh, Tamil Nadu, Bihar, West Bengal, and Uttar Pradesh are frequented by drought. About 40 million hectares of land is flood-prone, including most of the river basins in the north and the northeastern belt, affecting about 30 million people on an average each year. Such vulnerable regions may be particularly impacted by climate change.

Impacts on Coastal Areas

A mean Sea Level Rise (SLR) of 15-38 cm is projected along India's coast by the mid 21st century and of 46-59 cm by 2100. In addition, a projected increase in the intensity of tropical cyclones poses a threat to the heavily populated coastal zones in the country (NATCOM, 2004).

Impacts on Biodiversity

The Intergovernmental Panel on Climate Change has projected that global average temperature increase during 21st century will range from 1.4^{o} to 4^{o} Celsius. Research by the Consultative Group on International Agricultural Research based on distribution models of wild relatives of three staple crops of the poor i.e. Peanuts, cowpea and potato suggests that 16-22 per cent of wild species will be threatened by extinction by 2055. Loss of genetic diversity can have serious long-term consequences globally.

Impacts on Pest

Some of the most dramatic effects of climate change on pests and diseases are likely to be seen among arthropod insects like mosquitoes, midges, ticks, fleas and sand flies, and the viruses they carry. With changes in temperature and humidity levels, the populations of these insects may expand their geographic range, and expose animals and humans to diseases to which they have no natural immunity. Plant pests, which include insects, pathogens and weeds, continue to be one of the biggest constraints to food and agricultural production. Fruit flies, for instance, cause extensive damage to fruits and vegetables production. Controlling such pests often requires the use of pesticides, which can have serious side effects on human health and the environment. Climate change may also play a role in food safety. A growing number of pests and diseases could lead to higher and even unsafe levels of pesticide residue and veterinary drugs in local food supplies. And changes in rainfall, temperature and relative humidity can readily contaminate foods like groundnuts, wheat, maize, rice and coffee with fungi that produce potentially fatal mycotoxins.

I) ***Effect of rising temperature*:** In temperate climate, increased temperature could increase insect population. Rising temperature may affect insect survival, development, geographic range and population size. It may affect insect physiology. Under such situation some insects take several years to complete life cycle (Cicadas, Arctic moths) and some insects develop quickly at certain temperature range based on degree days (cabbage maggot, onion maggot, European corn borer, Colorado potato beetle, aphids, diamond back moth). Therefore, crop damage increase. Migratory pests may migrate earlier. Natural enemy-host relationship may affect resulting into reduced parasitism. Rising temperature may change gender ratios of insects such as thrips. The population of insects will increase due to lower winter mortality of insects as a result of warmer winter. Higher temperature may tend to shift crops geographically and hence its pests to higher altitudes. From fossil records it is understood that diversity of insect species and intensity of feeding increase with increase in temperature. Increased temperature could decrease insect population (aphids) in some crops, which cannot be grown in higher temperature. The same condition may be conducive for increased activity of natural enemies of that pest further reducing its population.

II) ***Effect of Precipitation*:** Rain drops physically dislodge the insects from their hosts such as leafhoppers, plant hoppers, thrips, cut worms etc. while others drown to death e.g. mealy bugs, pupae of fruit fly, *Helicoverpa, Spodoptera, Etiella* , rice stem borers etc. Flooding is used as a control measure for termites and stem borers too. Heavy rainfall causes pest epizootics by fungal pathogens (sugarcane pyrilla). It is anticipated that cutworm infestation will be more in future because they are sensitive to flooding and summer rainfall, which will increase in future.

III) ***Effect of rising CO_2 level:*** Carbon dioxide is a perfect example of a change that could have both positive and negative effects. Carbon dioxide is expected to have positive physiological effects through increased photosynthesis. The impact is higher on C_3 crops such as wheat and rice than on C_4 plants like maize and grasses. The direct effects of changes in CO_2 concentration will be through changes in temperature, precipitation and radiation. However, indirect effects will bring changes in soil moisture and infestation by pests and diseases because of rising temperature and relative humidity. Such indirect effects through the increase in temperature will reduce crop duration, increase crop respiration rates, evapo-transpiration, decrease fertilizer use efficiency and enhance pest infestation. There is general consensus that the yield of main season (*Kharif*) crop will increase due to the effect of higher CO_2 levels. However, large yield decreases are predicted for the rabi crops because of increased temperatures. The rising CO_2 level in atmosphere has indirect impact on insect population. Soybean crop in higher CO_2 concentration had 57% more insect damage (Japanese beetle, Leafhopper, Root worm, Mexican bean beetle) than earlier. It causes increase in level of simple sugars in the leaves that stimulates more feeding by insects. Increased C/N ratio in plant tissue due to increased CO_2 level may slow insect development and increase life stages of insect pests vulnerable to attack by parasitoids. At our current rate of green house emissions, several of the main pests that target corn will increase in number and expand their range by the end of 21^{st} century.

IV) ***Effect on insecticide Use Efficiency*:** Warmer temperature requires more number of insecticide applications (i.e., three, more than normal) for controlling corn pests. Entomologists predict more generation of insects in warm climate that necessitates more number of insecticide applications. It will increase cost of protection and environmental pollution. Synthetic pyrethroids and naturalite spinosad will be less effective in higher temperature. Therefore, it is advisable for the farmers not to use insecticides with similar mode of action frequently to avoid development of resistance in case of more number of applications. Cultural management practices e.g. early planting may not be helpful because of early emergence of pests due to warmness.

V) ***Effect on natural pest control***: Global warming is expected to make regional climates more varied and unpredictable which could affect relationship between insects and their natural enemies. In years of most variable rainfall, the caterpillars have significantly less number of parasitoids. This could be because the parasitoids use cues e.g. change in local climate to determine the best time for laying eggs. Unpredictable rains might disrupt the parasitoids ability to track their caterpillar hosts. The wasps use start of the rain as cues to hatch out of their cocoons and look for a caterpillar to lay their eggs. If the rains are late, they emerge late and may not find larval stage of host resulting in reduced natural pest control. Due to changes in climate, the frequency of occurrence of droughts, heat waves, windstorms and floods etc. will increase disrupting the natural ecosystems.

VI) ***Effect on Forest insect pests:*** It is difficult to predict impacts of climate change on forest insect pests because of complexity of interactions between insects and trees. Population of green spruce aphid (*Elatobium abietinum*) will increase due to global warming. The spruce bark beetle (*Dendroctonus micans*) will increase due to warming because its predator *Rhizophagus grandis* is benefited by temperature rise. The Asian long horn beetle (*Anoplophora glabripennis*) population will increase in warmer coastal areas that attack street plantations. In general, it is assumed that many forest insect pests will increase as a result of climate change. At the same time, it is likely that pests' natural enemies will benefit. So it is unclear to some extent as to what the overall effect of global climate change will be on forest insect pests.

Impact of Climate Change on Disease

Any direct yield gains caused by increased CO_2 or climate change could be offset partly or entirely by losses caused by phytophagous insects, plant pathogens and weeds. It is, therefore, important to consider these biotic constraints on crop yields under climate change.

I) **Impacts on Plant Pathosystems:** Climate change has the potential to modify host physiology and resistance and to alter stages and rates of development of the pathogen. The most likely impacts would be shifts in the geographical distribution of host and pathogen, changes in the physiology of host-pathogen interactions and changes in crop loss. Another important impact may be through changes in the efficacy of control strategies.

II) **Geographical Distribution of Host and Pathogen:** New disease complexes may arise and some diseases may cease to be economically important if warming causes a pole ward shift of agro climatic zones and host plants migrate into new regions. Pathogens would follow the migrating hosts and may infect remnant vegetation of natural plant communities not previously exposed to the often more aggressive strains from agricultural crops. The mechanism of pathogen dispersal, suitability of the environment for dispersal, survival between seasons, and any change in host physiology and ecology in the new environment will largely determine how quickly pathogens become established in a new region. Changes may occur in the type, amount and relative importance of pathogens and affect the spectrum of diseases affecting a particular crop. This would be more pronounced for pathogens with alternate hosts. Plants growing in marginal climate could experience chronic stress that would predispose them to insect and disease outbreaks. Warming and other changes could also make plants more vulnerable to damage from pathogens that are currently not important because of unfavorable climate

III) **Physiology of Host-Pathogen Interactions – Elevated CO_2**: Increases in leaf area and duration, leaf thickness, branching, tillering, stem and root length and dry weight are well known effects of increased CO_2 on many plants. Scientists have suggested that elevated CO_2 would increase canopy size and density, resulting in a greater biomass of high nutritional quality. When combined with increased canopy humidity, this is likely to promote foliar diseases such as rusts, powdery mildews, leaf spots and blights. The decomposition of plant litter is an important factor in nutrient cycling and in the saprophytic survival of many pathogens. Increased C:N ratio of litter is a consequence of plant growth under elevated CO_2. Scientists have indicated that decomposition of high-CO_2 litter occurs at a slower rate. Increased plant biomass, slower decomposition of litter and higher winter temperature could increase pathogen survival on over wintering crop residues and increase the amount of initial inoculum available to infect subsequent crops. Host-pathogen interactions in selected fungal pathosystems, two important trends have emerged on the effects of elevated CO2. First, the initial establishment of the pathogen may be delayed because of modifications in pathogen aggressiveness and/or host susceptibility. The second important finding has been an increase in the fecundity of pathogens under elevated CO_2.

IV) **Elevated Temperature:** Increases in temperature can modify host physiology and resistance. Considerable information is available on heat-induced susceptibility and temperature-sensitive genes. In contrast, lignification of cell walls increased in forage species at higher temperatures to enhance resistance to fungal pathogens. Impacts would, therefore, depend on the nature of the host-pathogen interactions and the mechanism of resistance. Agricultural crops and plants in natural communities may harbor pathogens as symptomless carriers, and disease may develop if plants are stressed in a warmer climate. Host stress is an especially important factor in decline of various forest species.

Crop Loss: At elevated CO_2, increased partitioning of assimilates to roots occurs consistently in crops such as carrot, sugar beet and radish. If more carbon is stored in roots, losses from soil borne diseases of root crops may be reduced under climate change. In contrast, for foliar diseases favored by high temperature and humidity, increases in temperature and precipitation under climate change may result in increased crop loss. The effects of enlarged plant canopies from elevated CO_2 could further increase crop losses from foliar pathogens.

Research Finding of ICAR on Climate Change: To meet the challenges as posed by climate change on the agricultural system, ICAR has accorded high priority in understanding the impacts of climate change and developing adaptation and mitigation strategies through its network research programs. Some of the research findings are as follows:

- Significant negative rainfall trends were observed in the Eastern parts of Madhya Pradesh, Chhattisgarh and parts of Bihar, Uttar Pradesh, parts of northwest and NE India and also a small pocket in Tamil Nadu. Significant increase in rainfall has also been noticed in Jammu and Kashmir and in some parts of southern peninsular.

- The maximum and minimum temperature (1960-2003) analysis for northwest region of India showed that the minimum temperature is increasing at annual, kharif and rabi season time scales. The rate of increase of minimum temperature during rabi is much higher than during kharif. The maximum temperature showed increasing trend in annual, kharif and rabi time scales but very sharp rise was observed from the year 2000 onwards.

- It was observed from the experiments on impact of high temperature on pollen sterility and germination in rice that maximum temperature above 35°C and minimum temperature 23°C at flowering stage increased the pollen sterility in two normal and three basmati varieties of rice and the effect is more profound in basmati cultivars.

- Biological yields were reduced drastically with elevated ambient temperature in tunnel experiments. The degrees of reduction in grain yield enhanced with rise in ambient temperature at 1, 2 and 3°C. The reduction of grain yield by 60, 64 and 70 percent in Pusa Sugandh-2 and 45, 52, 54 percent in Pusa 44 variety which was mainly attributed to maximum reduction in number of panicles/m^2 followed by the number of panicles/m^2 and 1000 grain weight.

- High thermal stress during post-flowering duration manifested 18, 60 and 12 percent reduction in economic yield of wheat, mustard and potato, respectively.

- Coconut yields were not affected with the increase of maximum temperature up to 44°C but above that reduced the yield.

- The growth and yield response of castor crop at first and second germination levels showed positive response to enhanced CO_2.

- The reproductive phase (days to flowering) and maturity phase shortened by 5 and 15 days in early and late sown varieties of wheat at Palm Valley of Himachal Pradesh.

- One to ten days shortening of reproductive phase in rice was observed in Palampur region.

- Increasing temperature above 1°C in the Himalayan region is adversely affecting the yield of apple.

- In Himachal Pradesh, rainfall at low (1100 m) and mid (1800-2000 m) elevation has declined and erratic. At higher ranges (2600-2700 m) snowfall has declined from 10 feet (40 years back) to 1-2 feet in the recent years.

- Deodar, Kail and Kharsu are drying and dying (yellowing) at (1700-2300 m) elevation, whereas at higher elevation (2500 m) Insect attack in oak was observed in Shimla region.

- A rise in 2-6°C temperature impacts the growth, puberty and maturity of cross breeds and buffaloes. The time to attain puberty prolongs from 1 to 2 weeks because of the slow growth rates at higher temperature.

- Milk production in Holstein Friesian cross breed cows was affected due to rise in maximum and minimum temperatures above 22°C. Decrease of milk production in Murra buffaloes was also observed with increase in temperature above 2°C. The extreme events like heat wave (> 4°C) and cold wave (< 3°C) reduced the milk yield by 10-30 percent in first lactation and 5-20 percent in second and third lactations in cattle and buffaloes.

- Total methane emission due to enteric fermentation and manure management of 485 million heads of livestock was worked out at 9.36 Tg/annum for the year 2006. It was 9.32 Tg/annum in the year 2003.

- Reduction of methane emission in cattle (cross breed steers) was achieved by modifying the diet by supplementing fenugreek seeds (Trigonella foerum).
- Trends in Surface Sea Temperature (SST) showed significant increase at the rate of 0.045°C per decade along the southwest, northwest and northeast coasts whereas the rate of increase of 0.095°C per decade was observed along the southeast coast.
- The oil sardine fish once restricted to southwest coast along 8°N to 12°N was extended along the other coastal areas and also extended into Bay of Bengal up to Orissa and West Bengal coast due to congenial environment prevailed with the increasing SSTs.
- A shift in lower stretch fish species like Puntim ticto, Xenentodon cancila, Mystus vittatus and Glossogobius giuris, etc. to the cold water rithron zone of the river Ganga at Haridwar due to rise in average temperature condition of the river from 17.5°C to 25.5°C.

Some Current Actions for Adaptation and Mitigation in India

Adaptation, in the context of climate change, comprises the measures taken to minimize the adverse impacts of climate change, e.g. relocating the communities living close to the sea shore, for instance, to cope with the rising sea level or switching to crops that can withstand higher temperatures. Mitigation comprises measures to reduce the emissions of greenhouse gases that cause climate change in the first place, e.g. by switching to renewable sources of energy such as solar energy or wind energy or nuclear energy instead of burning fossil fuel in thermal power stations.

Current government expenditure in India on adaptation to climate variability exceeds 2.6% of the GDP, with agriculture, water resources, health and sanitation, forests, coastal-zone infrastructure and extreme weather events, being specific areas of concern.

Programmes

Crop Improvement: Programmes address measures such as development of arid-land crops and pest management as well as capacity building of extension workers and NGOs to support better vulnerability-reducing practices.

Drought Proofing: The current programmes seek to minimize the adverse effects of drought on production of crops and livestock, and on productivity of land, water and human resources, so as to ultimately lead to drought proofing of the affected areas. They also aim to promote overall economic development and improve the socio-economic conditions of the resource poor and disadvantaged.

Forestry: India has a strong and rapidly growing afforestation programme. The afforestation process was accelerated by the enactment of the Forest Conservation Act of 1980, which aimed at stopping the clearing and degradation of forests through a strict, centralized control of the rights to use forestland and mandatory requirements of compensatory afforestation in case of any diversion of forestland for any non-forestry purpose. In addition, an aggressive afforestation and sustainable forest management programme resulted in annual reforestation of 1.78 mha during 1985-1997, and is currently 1.1 mha annually. Due to this, the carbon stocks in Indian forests have increased over the last 20 years to 9 -10 gigatons of carbon (GtC) during 1986 to 2005.

Water: The National Water Policy (2002) stresses that non-conventional methods for utilization of water, including inter-basin transfers, artificial recharge of groundwater, and desalination of brackish or sea water, as well as traditional water conservation practices like rainwater harvesting, including roof-top rainwater harvesting, should be practiced to increase the utilizable water resources. Many states now have mandatory water harvesting programmes in several cities.

Coastal Regions: In coastal regions, restrictions have been imposed in the area between 200 m and 500 m of the HTL (High Tide Line) while special restrictions have been imposed in the area up to 200 m to protect the sensitive coastal ecosystems and prevent their exploitation. This, simultaneously, addresses the concerns of the coastal population and their livelihood. Some specific measures taken in this regard include construction of coastal protection infrastructure and cyclone shelters, as well as plantation of coastal forests and mangroves.

Risk Financing: Two risk-financing programmes support adaptation to climate impacts. The Crop Insurance Scheme supports the insurance of farmers against climate risks, and the Credit Support Mechanism facilitates the extension of credit to farmers, especially for crop failure due to climate variability.

Disaster Management: The National Disaster Management programme provides grants-in-aid to victims of weather related disasters and manages disaster relief operations. It also supports proactive disaster prevention programmes, including dissemination of information and training of disaster management staff.

India's Policy Structure Relevant to GHG Mitigation

India has in place a detailed policy, regulatory and legislative structure that relates strongly to GHG mitigation: The Integrated Energy Policy was adopted in 2006. Some of its key provisions are:

- Promotion of energy efficiency in all sectors
- Emphasis on mass transport
- Emphasis on renewable including biofuels plantations
- Accelerated development of nuclear and hydropower for clean energy
- Focused R & D on several clean energy related technologies

The experience gained so far enables India to embark on an even more proactive approach through National Action Plan on Climate Change (NAPCC). NAPCC identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively. It outlines a number of steps to simultaneously advance India's development and climate change related objectives of adaptation and mitigation. The following eight National Missions form the core of the National Action Plan, representing multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change:

i. National Solar Mission
ii. National Mission for Enhanced Energy Efficiency
iii. National Mission on Sustainable Habitat

iv. National Water Mission
v. National Mission for Sustaining the Himalayan Ecosystem
vi. National Mission for a "Green India"
vii. National Mission for Sustainable Agriculture
viii. National Mission on Strategic Knowledge for Climate Change

Coping options for Farmers

- Awareness on Climate Change: Farmers need to be sensitized on climate variability, climate change, its impact on crop production, and coping options.

- ***Agromet* Advisories:** The farming community is provided with Agromet advisories. Its bulletins are prepared taking into account the prevailing weather, soil and crop condition and weather prediction. Measures / practices / suggestions to be taken in view of weather forecast to minimize the losses and optimize inputs (Land preparation, selection of crop & cultivars, Date of sowing, Date of harvesting, Irrigation scheduling, Pesticides & Fertilizer application, Extreme weather events, etc.). Agro-advisory bulletin consist of three parts (i) Weather events occurred during past week and weather forecast for five days ahead. These forecast includes weather parameters like cloud amount, rainfall, average Wind Speed, Wind Direction, RH, maximum and minimum temperature. (ii) It contains actual information on state and stage of crop growth, ongoing agricultural operations, disease and insect pest occurrence. (iii) It provides value added information on various farm activities to be taken based on weather

  There are 23 State Agromet Service Centers. These prepare Agromet advisory in collaboration with State Department of Agriculture on Tuesday & Friday. The Agromet advisory is disseminated through All India Radio (AIR), Print Media, Doordarshan, Website and SMS.

- **An Insurance Product based on a Weather Index:** The basic idea of weather insurance is to estimate the percentage deviation in crop output due to adverse weather conditions. Weather insurance protects against additional expenses or loss of profit from specific bad weather events.

- **Contingency Planning:** It is a plan devised for an exceptional risk, which is impractical or impossible to avoid. Ministry of Agriculture, through Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs), is working on district-specific contingency plan for the agriculture and allied sectors. This includes fisheries and animal husbandry and started in March 2010 under Rashtriya Krishi Vikas Yojana (RKVY). Contingency plans for about 300 out of the total 600 odd districts were prepared and validated by experts and hosted in Department of Agriculture and Cooperation (DAC), ICAR, Centre for Research in Dry land Areas (CRIDA) website. The comprehensive district-specific document is having details on the crops and cultivation practices to be adopted in case of deficient or delay in monsoon, unseasonal rains, frosts or unusually high temperature, excessive rains etc. Each district is a scientific document for adaptation in case of eventualities.

- **Demonstration of Climate Resilient Technologies to the farmers may be undertaken by the Extension personnel in the areas of-**
    i) **Natural resource management: Interventions on in-situ moisture** conservation, rain water harvesting and recycling for supplemental irrigation, improved drainage in flood prone areas, conservation tillage, ground water recharge and water saving irrigation methods etc.
    ii) **Crop Production:** Introducing drought/temperature tolerant varieties, advancement of planting dates of rabi crops in areas with terminal heat stress, water saving paddy cultivation methods (SRI, aerobic, direct seeding), frost management in horticulture through fumigation, community nurseries for delayed monsoon, custom hiring centers for farm machineries for timely planting, location specific intercropping systems with high sustainable yield index etc
    iii) **Livestock and Fisheries:** Augmentation of fodder production during droughts/floods, improving productivity of Common Property Resources (CPRs), promotion of improved fodder/feed storage methods, preventive vaccination, improved shelters for reducing heat/cold stress, management of fish ponds/tanks during water scarcity and flooding etc.

    iv) **Institutional Interventions:** Institutional interventions, either by strengthening the existing ones or initiating new ones, relating to seed bank, fodder bank, custom hiring center, collective marketing, and introduction of weather index based insurance and climate literacy through a village level weather station.

- **Extension system** has to focus more on diversifying the livelihood options, changing suitable cropping patterns to adjust to the change which is occurring in the particular location, planting more drought tolerant crops, promoting increased share of non-agricultural activities and Agro-forestry practices, identifying the traditional coping strategies, improved on - farm soil & water conservation, promoting mixed cropping pattern and making provision for access to various information sources related to weather and other advisories of climate change would minimize the risks and certainty of farmers related to climate change.

Conclusions

From the above, it is clear that the occurrence of floods and droughts, heat and cold waves are common across the world due to climate change. Their adverse impact on livelihood of farmers is tremendous. It is more so in India as our economy is more dependent on Agriculture. Interestingly, weather extremes of opposite in nature like cold and heat waves and floods and droughts are noticed within the same year over the same region or in different regions and likely to increase in ensuing decades. The human and crop losses are likely to be heavy. The whole climate change is associated with increasing greenhouse gases and human induced aerosols and the imbalance between them may lead to uncertainty even in year-to-year monsoon behaviour over India. Therefore, there should be a determined effort from developed and developing countries to make industrialization environment friendly by reducing greenhouse gases pumping into the atmosphere. In the same fashion, awareness programmes on climate change and its effects on various sectors viz., agriculture, health, infrastructure, water, forestry, fisheries, land and ocean biodiversity and sea level and the role played by human interventions in climate change need to be taken up on priority basis. In the process, lifestyles of people should also be changed so as not to harm earth atmosphere continuum by pumping greenhouse gases and CFCs into the atmosphere. From the agriculture point of view, effects of extreme weather events on crops are to be documented on regional scale so that it will be handy to planners in such re-occurrence events for mitigating the ill effects. Also, there is need to guide farmers on projected impact climate change and sensitise them on probable mitigation and adaptation options to minimize the risk in Agricultural sector.

Reference

Asian Development Bank, 2009. Addressing Climate Change in the Asia and Pacific Region.

Briefing Note (1), 2008, International Strategy for Disaster Reduction, Geneva, September, 2008 International Food Policy Research Institute, 2009. Climate Change: Impact on Agriculture and Costs of Adaptation, 2009 Jamil Ahmad, Dastgir Alam and Ms. Shaukat Haseen. 2011.

Impact of Climate Change on Agriculture and Food Security in India Int. Jr. of Agril., Env. and Biotech. Vol. 4, No. 2 : June 2011 : 129-137

Singh. H.S. Potential Impact of Climate Change on Mangroves in India (0894-B2)

Document on National Action Plan on Climate Change, India

IPCC (Intergovernmental Panel on Climatic Change) 2006. The Economics of Climate Change: Stern Review. The Summary of conclusions. Survey of the Environment 2007, The Hindu, pp141-145.

IPCC (Intergovernmental Panel on Climatic Change) 2007. Climate Change: The Physical Science Basis. Extracts from the IV Assessment Report. Survey of the Environment 2007, The Hindu, pp147-155.

Prasad, R and Rana, R. 2006. A study on maximum temperature during March 2004 and its impact on rabi crops in Himachal Pradesh. *J. of Agrometeorology*, 8(1): 91-99

Prasada Rao, G.S.L.H.V. and Alexander, D. 2007. Impact of climate change on the agricultural sector in tropical countries. Proceedings of the WTO Workshop, held at College of Fisheries, Panangad, Kochi on 14th December, 2007, Kerala Agricultural University, 80p

Prasada Rao, G.S.L.H.V. and Alexander, D. 2008. Impact of climate change on the agricultural sector in tropical countries-. Recommendations. Proceedings of the WTO Workshop, held at College of Fisheries, Panangad, Kochi on 14th December, 2008, Kerala Agricultural University, 26p

Ramakrishna, Y.S., Rao, G.G.S.N., Rao, S.G. and Vijayakumar, P. 2006. Impact of climate change in Agriculture. In: Environment and Agriculture (eds. Chadha, K.L. and Swaminathan, M.S.). Malhotra Publishing House, New Delhi, pp. 1-30

Samra, J.S., Singh, G and Ramakrishna, Y.S. 2004. Cold wave during 2002-03 over North India and its effect on crops. *The Hindu dated 10th January, 2004.* p. 6.

Shukla, P.R., Sharma, S.K and Ramana, V.P. 2002. *Climate Change and India - Issues, Concerns and Opportunities*. Tata – McGraw-Hill Publishing Company Ltd, New Delhi, 314p

Prasada Rao. G. S. L. H. V. impact of weather extremes on indian food grains Production

Misra. H.P. CHANGES IN CROP PEST SCENARIO IN CLIMATE CHANGE CONTEXT, Professor, Department of Entomology, College of Agriculture. O.U.A.T., Bhubaneswar

Annexure

Agriculture Contingency Plan: Template

1.0 Strategies for weather related contingencies

1.1 Drought

1.1.1 Rainfed situation

			Suggested Contingency Measures		
Early season drought (delayed onset)	**Major Farming situation**	**Crop/cropping system**	**Change in crop/cropping system**	**Agronomic measures**	**Remarks on Implemen-tation**
Delay by 2 weeks (Specify month)*					
Delay by 4 weeks					
Delay by 6 weeks					
Delay by 8 weeks					

Condition			**Suggested Contingency measures**		
Early season drought (Normal onset)	**Major Farming situation**	**Normal Crop/cropping system**	**Crop managements**	**Soil nutrient & moisture conservation measures**	**Remarks on Implement-ation**
Normal onset followed by 15-20 days dry spell after sowing leading to poor germination/crop stand etc.					
Mid season drought (long dry spell, consecutiv					

e 2 weeks rainless (>2.5 mm) period)					
Mid season drought (long dry spell) At flowering/ fruiting stage					
Terminal drought (Early withdrawal of monsoon)					

1.1.2 Drought - Irrigated situation

Condition			Suggested Contingency measures		
	Major Farming situation	Normal Crop/ cropping system	Change in crop/ cropping system	Agronomic measures	Remarks on Implementation
Delayed release of water in canals due to low rainfall					
Limited release of water in canals due to low rainfall					
Non release of water in canals under delayed onset of monsoon in catchment					
insufficient groundwater recharge due to low rainfall					

1.2 Unusual rains (untimely, unseasonal etc) (for both rainfed and irrigated situations)

Condition	Suggested contingency measure			
Continuous high rainfall in a short span leading to water logging	**Vegetative stage**	**Flowering stage**	**Crop maturity stage**	**Post harvest**
Crop1 (paddy) (Crop specific)				
Horticulture				
Crop1(Mango) (Crop specific)				
Heavy rainfall with high speed winds in a short span[2]				
Crop1 (paddy) (Crop specific)				

Horticulture				
Crop1(Mango) (Crop specific)				
Outbreak of pests and diseases due to unseasonal rains				
Crop1				
Horticulture				
Crop1(Mango)				

1.3 Floods

Condition	**Suggested contingency measure**			
Transient water logging/ partial inundation	**Seedling / nursery stage**	**Vegetative stage**	**Reproductive stage**	**At harvest**
Crop1 (paddy)				
Horticulture				
Crop1(Mango)				
Continuous submergence for more than 2 days				
Crop1 (paddy)				
Horticulture				
Crop1(Mango)				
Sea water intrusion				
Crop1				

1.4 Extreme events: Heat wave / Cold wave/Frost/ Hailstorm /Cyclone

Extreme event type	**Suggested contingency measure**			
	Seedling/ nursery stage	**Vegetative stage**	**Reproductive stage**	**At harvest**
Heat Wave				
Crop1 (paddy)				
Horticulture				
Crop1(Mango)				
Cold wave				
Crop1 (paddy)				
Horticulture				

Crop1(Mango)				
Frost				
Crop1 (paddy)				
Horticulture				
Crop1(Mango)				
Hailstorm				
Crop1 (paddy)				
Crop1(Mango)				
Cyclone				
Crop1 (paddy)				
Horticulture				
Crop1(Mango)				