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IMPACT OF CLIMATE CHANGE ON INDIAN AGRICULTURE AND ALLIED SECTORS- SOME STRATEGY

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Climate change and variability are matter of concerns of human beings throughout the world. The recurring droughts and floods are seriously threatening the livelihood of billions of people who depend on agriculture for most of their needs. The global economy is being adversely affected due to extreme events such as droughts, floods, cold and heat waves, forest fires, landslides etc. The natural calamities like earthquakes, tsunamis, volcanic eruptions etc. though not directly related to weather disaster but may change chemical composition of the atmosphere which, in turn, lead to weather-related disasters. Among the greenhouse gases, carbon dioxide is the pre-dominant gas leading to global warming as it traps long wave radiation and emits the same back to the earth surface. The global warming is nothing but heating of surface atmosphere due to emission of greenhouse gases, thus, 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. It has been observed from various research studies that the impact of climate change on agriculture is one of the main deciding factors influencing the future's 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. Therefore, understanding the weather changes over a period of time and adjusting the management practices towards achieving better harvest are challenges to the growth of agriculture 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 are 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 crop responds differently as the global warming will have a complex impact. 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 livelihoods. Rice, wheat, maize, sorghum, soybean and barley are the major crops in the world grown in 40 percent cropped area contribute to 55 percent of non-meat calories and over 70 percent of animal feed. Consequently, any effect on these crops would adversely affect the food security. The Inter-governmental Panel on Climate Change (IPCC) has estimated that by the end of the century the global average surface warming i.e. surface air temperature will increase by 1.1- 6.4^{0}C, the level of sea will rise between 18-59cm, the oceans will become more acidic and it is very likely that hot extremes/heat waves and heavy precipitation will continue to become more frequent, there will be more precipitation at higher latitudes and less precipitation in most sub-tropical land areas. The tropical cyclones (typhoons and hurricanes) may become more intense with large peak wind speeds and heavier precipitation associated with ongoing increase in tropical sea surface temperature.

EFFECT OF CLIMATE CHANGE ON KEY SECTORS AT GLOBAL LEVEL

According to the 4th assessment report of IPCC working group, the effects of climate change on the following key sectors has been briefly discussed as under:-

- **Water:** The drought affected areas are likely to be more widely distributed. Heavier precipitation events may likely to increase in frequency leading to higher flood risks. By the year 2050, water availability is likely to decrease in mid-latitudes, in the dry tropics and in other reasons which are supplied by melted water from mountain ranges. More than 1/6th of the world's population is currently dependent on melted water from mountain ranges/glaciers.
- **Food:** While some mid and high latitude areas may initially benefit from higher agricultural production but for many others at lower latitudes particularly in seasonally dry and tropical regions, the increase in temperature, drought frequency and floods are likely to affect crop production negatively which could further increase the number of people at risk from hunger and increased level of displacement/migration.

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- **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 part to the locations already pronged to extreme weather conditions particularly to the areas undergoing rapid organisation. Where extreme weather events become more intense or more frequent, the economic and social cost of those events would certainly increase.
- **Health:** The projected changes in climate are likely to alter the health status of millions of people including increased death, disease, injury due to heat waves, floods, storms, fire and droughts. Increased malnutrition, diarrhoea and malaria disease in some areas will increase vulnerability to public health and thus, the development goals may be threatened due to long term damage to health system from disasters.

OBSERVED CHANGES IN CLIMATE AND WEATHER EVENTS IN INDIA

At the national level, an increase of 0.4 ^{0}C has been observed in surface air temperature over the past century. Similarly, a warming trend has been experienced along the west coast in central India, the interior peninsula and northeastern parts of our country. However, cooling trends have been observed in northwest and parts of south India. Although monsoon rainfall at all India level has not shown any significant trend yet regional monsoon variations has been reported. A trend of increasing monsoon seasonal rainfall has been found along the west coast, northern Andhra Pradesh and northwestern India (10-12% of the normal over the last 100 years) while a trend of decreasing monsoon seasonal rainfall has been observed over eastern Madhya Pradesh, northeastern India and some parts of Gujarat and Kerala i.e. -6 percent to -8 percent of the normal during the last century. There has been an overall increase in severe storm incidence along the coast at the rate of 0.011 events per year while the states of West Bengal and Gujarat had reported increasing trend, a decline has been observed in Odisha. The scientists have observed a rising trend in the frequency of heavy rain events and a significant decrease in the frequency of moderate events over central India from the year 1951 to 2000. After examining the reports of coastal tide gauges in the north India ocean for more than 40 years, our scientists have estimated that the rise of sea level was between 1.06 to 1.75mm per year. These rates were found in consistent with global sea level rise of 1-2mm per year estimated by the IPCC. The intensity of Indian summer monsoon is projected to increase in the beginning of 2040 and by 10 percent till the year 2100.

The Himalayas possess one of the largest resources of snow and ice. Its glaciers form a source of water for the perennial rivers like The Ganga, The Indus and The Brahamputra. The available monitoring data on Himalayan glacier indicates that while recession of some glacier has occurred in some Himalayan regions in recent years, the trend is not consistent across the entire mountain range.

SOME PROJECTIONS OF CLIMATE CHANGE IN INDIA FOR THE 21ST CENTURY

The simulation studies conducted by Indian Institute of Tropical Meteorology (IITM), Pune estimated that annual mean surface temperature is expected to rise 3-5^{0}C by the end of century, thus, warming more in the northern parts of India. The river systems of The Brahamputra, The Ganga and The Indus which benefit from the melting snow in the lean season are likely to be affected by the decrease in snow cover. A decline in total run-off for all river basins expect The Narmada and The Tapti is projected in India's Initial National Communication (NATCOM 1). A decline in run-off by more than 2/3rd is also anticipated for The Sabarmati and The Luni basin. Moreover, due to rise in sea level, the freshwater resources near the coastal region will suffer salt intrusion.

IMPACT 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. The study is conducted by Indian Agricultural Research institute (IARI), New Delhi and other institutes indicated greater expected loss in the production of rabi crops. Every one-degree sea rise in temperature reduces wheat production by 4-5million tonnes. Small changes in temperature and rainfall have significant effect on quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants and basmati rice. We all know that pathogen and insect population are strongly dependent upon temperature and humidity and hence, changes in these parameters may change their population dynamics. Lower yield from dairy cattle, decline in fish breeding, migration and harvest etc. are other impacts of climate change on agriculture and related sectors. As per global reports, there may be a loss of 10-14 percent in crop production by the year 2100. The yield of rice and wheat may also decline considerably with climate changes.

Change in climate may alter the distribution of important vector species, for e.g., malarial mosquitoes and may increase the spread of such diseases to new areas. If there is an increase of 3.8^{0}C temperature and a 7 percent increase in relative humidity, the transmission windows i.e. the months during which mosquitoes are active will open for all the 12 months in 9 states of our country. The transmission windows in Jammu & Kashmir and Rajasthan may increase by 3-5 months, however, in Odisha and some southern states, further increase in

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temperature may shorten the transmission window by 2-3 months. The climate projection indicate that the country may experience shift in forest types with consequent changes in forest produce and consequently livelihoods based on those products. Further, the associated diversity may likely to be adversely affected. Heavily populated regions such as coastal areas are exposed to climatic events like cyclones, floods, drought and large decline in sown areas in arid and semi-arid zones may occur due to climate change. About 40 million hectares of land is flood prone including most of the river basin in north and north-eastern belt affecting about 30 million people each year. Such vulnerable regions particularly impacted by climate change. According to research conducted by the Consultative Group on International Agricultural Research (CGIAR), 16-22 percent of wild species of three staple crops of the poor namely Peanuts, Cowpea and Potato will be threatened by extinction by the year 2055 and the loss of genetic diversity can have serious long-term consequences globally. Climate change may also play a role in food safety. An increasing number of pests and diseases may lead to higher and even unsafe level of pesticide residue and veterinary drugs in local food supplies. Change sin rainfall, temperature and relative humidity can readily contaminate food like groundnut, wheat, maize, rice and coffee with fungi that produce potentially fatal mico-toxins. Climate change has the potential to modify host physiology and resistance along with rate of development of pathogen. New disease complexes may arise and the plants growing in marginal climate could experience chronic stress which could pre-dispose them to disease and pest outbreak. At increased level of carbon dioxide, there will be increased partitioning of assimilates to roots in crops such as sugar beet, radish and carrot. Though more carbon stored in roots, losses from soil born diseases of root crops may be reduced under climate change, however, for foliar diseases favoured by high temperature and humidity, increase in temperature and precipitation under climate change may result in increased crop loss.

Various studies conducted by Indian Council of Agriculture Research (ICAR) have revealed that the maximum temperature above 35^0C and minimum temperature 23^0C at flowering stage increased the pollen sterility in two normal and three basmati varieties of rice, the effect was more profound in basmati cultivars. The degree of reduction in grain yield enhanced with rise in ambient temperature at 1, 2 and 3^0C. similarly, high thermal stress during post flowering duration had manifested 18, 60 and 12 percent reduction in economic yield of wheat, mustard and potato respectively. The reproductive phase (i.e. days to flowering) and maturity phase shortened by 5 and 15 days in early and late sown variety of wheat at Palm valley of Himachal Pradesh. Similarly , shortening of reproductive phase in rice was observed in Palampur region. It was further revealed from study that increase in temperature above 1^0C in the Himalayan region adversely affected yield of the apple. In Himachal Pradesh, rainfall at low elevation (1100m) and mid elevation (1800-2000m) has declined and erratic. At higher ranges (2600-2700m), the snowfall has declined from 10feet (40years back) to 1-2feet in the recent years. Deodar, Kail and Kharsu are drying and dying (yellowing) at 1700-2300m elevation whereas at higher elevation i.e. 2500m and above insect attack in oak was observed in Shimla regions. A rise in 2-6^0C temperature has impacted the growth, puberty and maturity of crossbreeds and buffaloes. Milk production in Holstein Frisian crossbreed cows was affected due to rise in maximum and minimum temperature above 22^0C. Similarly, decrease of milk production in Murrah buffaloes was also observed with increase in temperature above 2^0C.

STRATEGIES FOR ADAPTATION AND MITIGATION IN INDIA

In the context of climate change, adaptation comprises of the majors taken to minimise the adverse impact of climate change. For e.g. relocating the communities living close to the seashore so that they may cope with the rising sea level or switch to those crops which can withstand higher temperature. Mitigation comprises of major to reduce the emissions of greenhouse gases that cause climate change in the first place. For e.g. by switching to renewable sources of energy such as solar energy or wind energy or nuclear energy instead of burning fossil fuels in thermal power stations. Our government is also taking appropriate steps in this regard. The current government expenditure on adaptation to climate variability exceeds 2.6 percent of the GDP with agriculture, water resources, health and sanitation, forest, coastal zone infrastructure etc. being specific areas of concern besides certain programmes have also been undertaken which are being discussed as under:-

- **Crop Improvement:** This programme addresses majors such as development of arid land crops and pest management as well as capacity development of extension workers and NGOs to support better vulnerability-reducing practices.
- **Drought Proofing:** The current programmes seek to minimise the adverse effect of drought on production of crop and livestock besides productivity of land, water and human resources ultimately leading to drought proofing to the affected areas.
- **Afforestation programme:** The country has a strong and rapidly growing afforestation programme which has resulted in annual re-forestation of 1.78 million hectares during the year 1985-1997 and presently 1.1 million hectares annually.
- **Programme pertaining to water utilisation:** The National Water Policy 2002 stresses that non-conventional methods for utilization of water like rainwater harvesting, rooftop rainwater harvesting,

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artificial recharge of groundwater, desalination of brackish or sea water etc. should be practiced to increase the utilizable water resources. Many states now have mandatory water harvesting programme in their several cities/urban areas.

- **Programme pertaining to coastal regions:** In coastal regions, restriction has been imposed in the area between 200m to 500m High Tide Line (HTL) with special restrictions in the area up to 200m to protect the sensitive coastal ecosystem and prevent their exploitation. These simultaneous addresses the concern of coastal population and their livelihood. Certain measures have been taken in this regard like construction of coastal protection infrastructure, cyclone shelters, plantation of coastal forest and mangroves.
- **Programme related to risk financing:** Two risk financing programmes namely Crop Insurance Scheme (supporting the farmers against climate risk) and Credit Support Mechanism which facilitates the extension of credit to farmers particularly for crop failure due to climate variability.
- **Disaster management programme:** The National Disaster Management Programme provides grants-in-aid to the victims of weather-related disasters and properly manages disaster relief operations. The programme also supports proactive disaster prevention programmes including dissemination of information and training of disaster management staff.

India has also a detail policy, regulatory and legislative structure that strongly relates to greenhouse gas mitigation. The integrated energy policy adopted in the year 2006 contains certain key provisions like promotion of energy efficiency in all sectors, emphasis on mass transport, on renewable energy including bio-fuel plants, accelerated development of nuclear and hydro power for clean energy and focus on research and development in several clean energy related projects. National Action Plan on Climate Change (NAPCC) identifies majors that promote our development objectives besides outlining a number of steps to promote India's development and climate change related objectives of adaptation and mitigation. The eight national missions viz; National Solar Mission, National Mission for Enhances Energy efficiency, 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 and National Mission on Strategic Knowledge on Climate Change form the core of the National action Plan representing multi-pronged, long-term and integrated strategies for achieving key goals in context of climate change. There are certain strategics for farmers to cope up climate change:-

- **Creating awareness on climate change:** The farmers need to be sanitised on climate variability, climate change, its impact on crop production and various coping options. This could be done through agromet advisories. Its bulletins are prepared taking into account the prevailing weather, soil and crop condition as well as weather prediction. The farmers can take timely appropriate measures to optimize farm inputs and minimise the losses. The forecast includes weather parameters like clouds, rainfall, average wind speed, wind direction, relative humidity, maximum and minimum temperature etc.
- **Insurance policy/product based on weather index:** Weather insurance protects the farmers against additional expenses or loss of profit from specific bad weather events.
- **Contingency planning:** It refers to a plan developed for an exceptional risk which may be impractical or impossible to avoid. The Ministry of Agriculture through ICAR and State Agriculture Universities is working on district specific contingency plan for agriculture and allied sectors. The plan was started in March 2010 under Rashtriya Krishi Vikas Yojana (RKVY) and includes fishery and animal husbandry. The contingency plan for about 300 districts out of total 600 districts have already been prepared, validated by experts and hosted in the Department of Agriculture and Cooperation, ICAR, Centre for Research in Dryland Areas website. This comprehensive district-specific document has details on the crops and cultivation practices to be adopted in case of deficient or delay in monsoon/unseasonal rains, frost, unusually high temperature, excessive rains etc.
- **Natural resource management:** Emphasis on interventions is being given in in-situ moisture conservation, rainwater harvesting, improved drainage in flood prone areas, conservation of tillage, groundwater recharge and water saving irrigation methods etc.
- **Crop production:** Efforts are being made for introducing drought/temperature tolerant varieties, water saving paddy cultivation methods, (like System of Rice Intensification (SRI), aerobic, direct seeding) frost management in horticulture through fumigation, community nurseries for delayed monsoon, custom hiring centres for farm machineries, location specific intercropping system with high sustainable yield index besides concerted efforts have also been taken for improving productivity of common property resources, promoting improving feed storage methods, institutional interventions pertaining to seed bank, fodder bank, custom hiring centre, collective marketing, introduction of weather index based insurance and climate literacy through a village level weather station.

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However, extension system needs to focus more on diversifying livelihood options, changing suitable cropping pattern to adjust as per the climate change occurring in the particular location and motivating the farming community for planting more drought tolerant crops.

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