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CLIMATE CHANGE: IMPACTS, CHALLENGES AND ADAPTATION STRATEGIES IN INDIA

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I. Introduction

The biggest environmental challenge that the humanity will face in the coming centuries is climate change. According to the Intergovernmental Panel on Climate Change (IPCC), absence of proper policy intervention and unabated climate change might result in alterations in the climate system including variations in temperature, precipitation and sea level (IPCC, 2013).The distribution of effects of climate change is not uniform. Poorer populations, particularly the agrarian civilization will suffer the most (IPCC, 2014). Two industries that are mostly exposed to climate change are agriculture and energy use. Both direct and indirect impacts of climate change have been found to have affected mortality, morbidity, migration, violent conflicts, criminality, and labour productivity (Carleton & Hsiang, 2016)

Climate change is of serious concern having direct and large-scale impacts such as increase in global temperature, increased intensity of rainfall, rising sea level, melting of glaciers, shifting of crop growing season and frequent occurrences of extreme events such as drought and flood. To address the long-term negative impacts of climate change there is a need for sustained research on increased adaptation and mitigation, capacity building, development activities and bringing necessary changes in policies. These actions have to be accompanied by long-term sustained actions towards generation and strengthening of strategic knowledge systems in key impact sectors like water, agriculture, energy, health etc.

United Nations Framework Convention on Climate Change (UNFCCC) made an agreement to tackle climate change and accelerate the actions required for a sustainable low-carbon future at Conference of the Parties (COP-21) in Paris on December 12, 2015. The Paris Agreement brings all nations together for the first time to undertake ambitious measures to prevent climate change and adapt to its impacts, with increased funding to assist developing countries in doing so. The core goal of the Paris Agreement is to improve the global response to the threat of climate change by keeping the global temperature rise this century well below 2 °C and to pursue efforts to limit the temperature increase to 1.5° C (Sharma et al. 2020; Sharif et al. 2020; Chien et al. 2021).

This paper proceeds as follows. Section 2 provides an insight on the assessment of climate change. Section 3 unfolds the challenges posed by climate change. Section 4 discusses the adaptability vis-à-vis policy initiatives to counter the repercussions of climate change. Lastly, the paper concludes to refer adaptation strategies in the micro level for ensuring sustainable development.

II. Important Weather Extremes and their impact on India

In this section impact of climate variation is discussed in agriculture, food production, environmental degradation etc.

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. Huge crop losses were noticed in Maharashtra (India) due to un-seasonal and poor distribution of rainfall during 1997-98. The year 2003 was the year of heat and cold waves across the world. States namely Uttar Pradesh, Bihar, West Bengal, Orissa and Andhra Pradesh experienced summer heat waves while Jammu, Punjab, Haryana, Himachal Pradesh, Bihar, Uttar Pradesh and the North Eastern States experienced unprecedented cold wave from December 2002 to January2003. 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).

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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 (Prasad and Rana, 2006). Untimely rains and hailstorms destroyed wheat crop of 15,000hectares 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 rain during 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.

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. The crop production losses due to climate change may also drastically increase the number of under-nourished people, severely hindering progress in combating poverty and food security. 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 classic 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: Impact on Agriculture and Food Production

Agriculture is not only sensitive to climate change but also one of the major drivers for climate change. The climate sensitivity of agriculture is uncertain, as there is regional variation in rainfall, temperature, crops and cropping systems, soils and management practices. 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).

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.

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 i.e. direct effects from changes in temperature, precipitation or carbon dioxide concentrations and 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).

India is restricted due to its heavy reliance on natural factors and the lack of complementary inputs and institutional support systems. 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.

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Various Findings on climate change by Indian Council of Agricultural research 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 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.
- 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.
- 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 to44°C but above that reduced the yield.
- The oil sardine fish once restricted to southwest coast 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.

III. Challenges of Climate Change

No corner of the world is immune from the devastating consequences of Climate Change and has reached irreversible highs. Environment is bearing an infinite cost for climate change. Human activity is producing high level of greenhouse gas emissions and fuelling environmental degradation. According to a ten-year summary of UNEP Emission Gap reports, billion tons of Carbon Dioxide is released into the atmosphere every year as a result of coal, oil, and gas production. According to World Meteorological Organization (WMO) September, 2019 report, we are at least a degree above preindustrial levels. The last four years were the four hottest years on record. If the global emissions do not slow down, temperatures could rise by three degrees by 2100 causing further irreversible damage to our ecosystems.

The extent of climate change varies across different regions of the country. These are the following challenges of climate change in India (NITI Aayog, 2022).

- Temperature Increase: India has experienced a steady increase in temperatures over the past century. Heat waves have become more frequent and intense, affecting human health, agriculture and water resources.
- Erratic Monsoons: India relies heavily on the monsoon rains, which has become increasingly erratic due to climate change. This has led to uneven rainfall distribution, prolonged dry spells, intense rainfall events, all of which can disrupt agriculture and water availability.
- Glacial Retreat: The Himalayan region, which provides a significant portion of India's freshwater resources, has seen glaciers melting at an accelerated rate due to rising temperatures. This affects the availability of freshwater for irrigation, drinking, and hydropower generation.
- Sea Level Rise: India has a long coastline, and sea level rise is a growing concern. Rising sea levels can lead to coastal erosion, saltwater intrusion into freshwater sources and increased vulnerability to coastal storms and flooding.
- Extreme Weather Events: India is experiencing an increase in extreme weather events such as cyclones, floods, and droughts. These events can cause widespread damage to infrastructure, agriculture, and human settlements.
- Impact on Agriculture: Climate change has disrupted traditional crop calendars and led to increased heat stress, pests, and diseases. This has the potential to reduce crop yields and threaten food security.
- Water Scarcity: Changing precipitation patterns has contributed to water scarcity in many parts of India. This scarcity affects both agriculture and access to clean drinking water.
- Air Pollution: Climate change can exacerbate air pollution problems in cities. Higher temperatures can lead to the formation of ground-level ozone which has adverse health effects.

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- Loss of Biodiversity: Changes in temperature and precipitation patterns can disrupt ecosystems and lead to shifts in the distribution of plant and animal species. This can impact biodiversity and ecosystem services.
- Health Impacts: Climate change can have direct and indirect health impacts, including heat-related illnesses, the spread of vector-borne diseases, and malnutrition due to food insecurity.

Agriculture sector being the worst victim of climate change, face the following adversities (National Action Plan on Climate Change, 2012);

- Water availability as result of changing rainfall patterns, alteration in stream flow and increase in crop water demand
- Deterioration of water quality due to sea water intrusion, transport of salts from the deeper soil layers as a result of over exploitation of aquifers and faulty irrigation practices
- Increased frequency and intensity of extreme weather events such as droughts, floods and cyclones and these would affect the production levels more than the impact of mean changes in the climate
- Heat stress due to higher temperature at critical stage of the crop growth
- Unpredictable change in pest and disease load due to changing climatic patterns.

IV. Adaptation of Indian Agriculture to Climate Change

Potential adaptation strategies to deal with the impact of climate change are developing cultivation tolerant to heat and salinity stresses and resistant to flood and drought, modifying crop management practices, improving water management, adopting new farm techniques such as resource conserving technologies (RCTs), crop diversification, improving pest management, better weather forecasts and crop insurance and harnessing the indigenous technical knowledge of farmers. Some of these strategies are discussed below. Development of new crop varieties with higher yield potential and resistant to multiple stresses (drought, flood, salinity) will be the key to maintain yield stability. Improvement of germplasm of important crops for heat tolerance should be one of the targets of breeding programmes. Similarly, it is essential to develop tolerance to multiple abiotic stresses as they occur in nature. In addition, it is important to improve the root efficiency for the uptake of water and nutrients from soil. Genetic engineering could play a pivotal role for 'gene pyramiding' to pool all desirable traits in a plant to get the 'ideal plant type' which may also be 'adverse climate tolerant' genotype. Efficient use of natural resources such as water is highly critical for adaptation to climate change. With hotter temperatures and changing precipitation patterns, water will further become a scarce resource. Serious attempts towards water conservation, water harvesting and improvement of irrigation accessibility and water use efficiency will highly be essential for crop production and livelihood management. On-farm water conservation techniques, micro-irrigation systems for better water use efficiency and selection of appropriate crop-based irrigation have to be promoted. Principles of increasing water infiltration with improvement of soil aggregation, decreasing runoff with use of contours, ridges, vegetative hedges and reducing soil evaporation with use of crop residue could be employed for better management of soil-water. There is a need for technologies and investments that improve water management efficiency. In non-irrigated areas, water conservation and water harvesting techniques are the only possible alternatives to poor farmers. However, adoption of such practices may not be technology intensive, but will certainly require investment in capacity building and agricultural extension. Rain water harvesting can help in fulfilling water demand in water scarce regions. Improved irrigation methods like drip irrigation, sprinkler irrigation and use of laser-aided land levelling can also help in increasing water-use efficiency. Laser aided levelling provides smooth and levelled field, which allows ideal water distribution with negligible losses of water. It facilitates uniformity in the placement of seed/seedlings and fertilizer which helps good plant stand, enhanced nutrient use efficiency and increased yield (Pathak et al., 2012). In the rural areas rain water harvesting can be carried out through gully plug, contour bund, gabion structure, percolation tank, check dam, recharge shaft and dug well recharge structure. Adjustment of planting dates to minimize the effect of high temperature induced spikelet sterility can be used to reduce yield instability so that the flowering period does not coincide with the hottest period. Adaptation measures to reduce the negative effect of increased climatic variability as normally experienced in arid and semi-arid tropics may include changing the cropping calendar to take advantage of the wet period and to avoid extreme weather events (e.g., typhoons and storms) during the growing season. Cropping systems may have to change to include growing suitable cultivars, increasing cropping

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intensities or crop diversification. For example, there is an urgent need for diversification of the conventional puddle transplanted rice and intensively tilled wheat to other cropping systems such as maize-wheat, pulse-wheat, maize-pulse, oil seed-wheat and direct seeded rice-wheat. The latter system has less demand for water and nutrients (with legume) and uses resources more efficiently thereby increasing farmers' income and exhorting less pressure to the natural resource base. Changes in temperature and variability in rainfall would affect pests incidence and their virulence on major crops. This is because climate change will potentially affect the pest/weed host relationship. Some of the potential adaptation strategies could be (1) developing crops resistance to pests; (2) integrated pest management with more emphasis on biological control and changes in cultural practices, (3) pest forecasting using recent tools such as simulation modelling, (4) alternative production techniques and (5) identification of crops, as well as locations, that are resistant to infestations and other risks. Climate change will lead to change in the pest and disease infestation of crops. Higher temperature can shorten dormant periods, speed up pest and disease growth and change the dynamics of these populations and their resistance. Crops, varieties, and traits that are resistant to pests and diseases will improve producers' ability to adapt to climate change. Biotechnology stands out as a promising tool to facilitate the development of traits and varieties that could help to mitigate and adapt to climate change (Fedoroff et al., 2010). Herbicides and other inputs that reduce competition from weeds can improve productivity and thereby serve to mitigate GHGs emissions associated with bringing additional land under cultivation. Crop insurance schemes (private and public), should be put in place to help the farmers in reducing the risk of crop failure due to extreme climatic events. However, information is needed to frame out policies that encourage effective insurance opportunities. Micro-finance has been a success among rural poor including women. Low-cost access to financial services could be a boon for vulnerable farmers. Growing network of mobile telephony could further speed up SMS-based banking services and help farmers have better integration with financial institutions. There is a need to develop a sustainable insurance system, while the rural poor are to be educated about availing such opportunities. Conservation agriculture and the resource conservation technologies (RCTs) have proved to be highly useful to enhance resource or input-use efficiency and provide immediate, identifiable, and demonstrable economic benefits such as reductions in production costs, savings in water, fuel and labour requirements and timely establishment of crops resulting in improved yields. Yields of wheat in heat and water-stressed environments can be raised significantly by adopting the RCTs, which minimize unfavourable environmental impacts, especially in small and medium-scale farms. Zero tillage can allow farmers to sow wheat sooner after rice harvest, so the crop heads and fills the grain before the onset of pre-monsoon hot weather. Farmers with awareness of weather events can respond by planting more appropriate crops or varieties. Forecasting of weather events will help farmers in adopting suitable crop management options. Prediction of extreme climatic events should be done well in advance to minimize crop loss. Major innovations in response to climate variability will take the form of improved information through global monitoring and forecasting. Improved micro-climate modelling can also enable more accurate understanding of the dynamics of weather events. This weather based Agro-information can be made available to farmers through audio and visual media and also effectively through mobile phone networks. Weather forecasting and early warning systems will be very useful in minimizing risks of climatic adversaries. Information and communication technologies could greatly help the researchers and administrators develop contingency plans. Farmers in south Asia, often poor and marginal, have been experimenting with the climatic variability for centuries. There is a wealth of knowledge of a range of measures that can help in developing technologies to overcome climate vulnerabilities. There is a need to harness that knowledge and fine-tune them to suit the modern needs. Traditional ecological knowledge of people developed and carried which have stood the test of time could provide insight and viable options for adaptive measures. Anthropological and sociological studies have highlighted the importance of community-based resource management and social learning to enhance their capacity to adapt to the impacts of future climate change. Tribal and hill knowledge systems are charged with potential indigenous practices used for absorption and conservation of rainwater, nutrient and weed management, crop production and plant protection. Their belief systems effectively help in weather forecasting and risk adjustment in crop cultivation.

Green Technology – A Solution for Climate Change Adaptation

Although there are many technology-based solutions available, they are not being deployed fast enough to meet the multiple climate change challenges. Adaptation technologies are generally behind mitigation technologies in terms of policy support and funding. However, adaptation is gaining traction. Several funding and support institutions specifically target adaptation. The private sector is also coming onboard, as more ways of assessing the returns to and impact from adaptation investment are developed. One sector

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seeing remarkable investment growth is Ag-Tech. Many countries have also prepared and are now implementing specific adaptation plans. An increasing portion of climate funds is being allocated to adaptation, although still outweighed by mitigation funding. It should also be noted that many of the technologies classified as adaptation technologies also have mitigation aspects, bridging the well-established dichotomy between adaptation and mitigation. Nature-based solutions, where natural processes are utilized or reinforced in order to, for example, protect against flood waters are gaining ground. Many of those fit under the term "no-regret" solutions providing benefits independent of whether the climate change impacts for which they were designed actually happened as predicted (WIPO, 2022).

Climate-smart agriculture and forestry

Agriculture and forestry are already heavily influenced by climate change. This manifests itself in changes to cropping season length, higher temperatures, and less water, as well as floods, soil salinity and the creation of conditions conducive to pest spread. In response to these risks, significant developments are taking place in relation to optimized and sophisticated practices. They include using remote and in-field sensing data to provide a detailed understanding of the condition and needs of plants and animals. This information can then direct various machineries to dispense an exact dosage of herbicide or water. This reduces the potentially harmful use of such products, saves resources, and helps optimize production in a changing environment. Many of these technologies are best suited to larger operations able to access capital for investment in equipment. However, other advanced technologies may not need such large investments. For example, using almost omnipresent mobile devices, advanced data and control technologies can be made relevant in far smaller and poorer contexts. Moreover, simple improvements in techniques can have a significant effect. For example, by saving on water farmers can reduce their vulnerability to climate change impacts. Many of the practices and technologies that come under the broad term climate-smart agriculture benefit both mitigation and adaptation alike. Modifying plants and animals to better cope with a changing climate is another active innovation area. But one which, depending on the methods applied may carry with it the controversy associated with genetic modification (Lobell, 2011).

Water preservation and coastal protection

Water is fundamental to life. Climate change causes too much or too little. For coastal communities, rising sea levels, violent storms and floods, as well as salt water intrusion, are an increasingly common risk. But so is more acidic and warmer oceans, and this calls for strengthened and innovative approaches to marine ecosystem conservation. Many important innovations can help save water, as well as monitor quality and the state of water reserves. Remote and in-field sensors play an important role in directing other technologies, for example to regulate water use. Improved rainwater harvesting systems and water storage tanks can maintain supply during dry spells. In some countries, an increasing demand for massive water desalination plants is driving innovation toward higher efficiency and lower costs. Water treatment and advanced control of distribution networks combines several innovative technologies to realize impressive water savings. The need for protection against too much water arriving all at once has prompted significant innovation in flood barriers, nature-based storm water storage and early warning systems. Coastal zones are particularly vulnerable to climate change. As they are often densely populated and important economic zones, the impacts can be far reaching. Advanced modelling of water and sediment movements helps determine what the most appropriate protection measure is, be it beach nourishment, dikes, or other hard and soft protection structures. Here also nature-based solutions such as restoring mangrove forests and coral and other reef types can be no-regret solutions with widespread benefits for people and marine ecosystems (IPCC, 2008).

Climate-adapted cities and urban planning

Extreme weather events in recent years have made it abundantly clear that cities and their populations are highly vulnerable to climate change. New thinking – not least new innovation – is required. Heat waves, heavy rainfall, floods, storms, and rising sea levels have already exacted a toll on populations and impacted city budgets. Advances in urban planning may provide some solutions. For example, incorporating green infrastructure like storm water drainage and temporarily transforming underground parking and road networks into reservoirs can reduce a city's vulnerability toward heavy rainfall. New materials and green building

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design can help mitigate heat waves impact and reduce the heat island effect found in most cities. Many options exist for greening the cityscape. These can help increase surface water infiltration, reduce heat, provide shade, and even produce food (Musco & Morello, 2023)

Conclusion

Climate Change is detrimental to development. Soil, water and forest get affected by climatic variations. The evidence of climate change has been felt in all walks of life. Loss of biodiversity, poor quality of air, rise in sea level, erratic monsoon is the major effects of climate change. Mitigating the negative impact of climate change depend on policies and strategies for adaptation. The challenges are not uniform across the world. Micro-level planning is necessary to get rid of the problems arising due to climate change.