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Challenges and Opportunities of Climate Change and Sustainable Agriculture: A Review

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ABSTRACT

Climate change is the most significant challenge for achieving sustainable development in present global scenario as it is threatening millions of people to drag into grinding poverty. At the same time, globe has never had better know-how and solutions available to avert the crisis and create opportunities for a better life for billion of people all over the world. Climate change is not just a long-term issue, but is happening today entailing uncertainties for policy makers trying to shape the future with suitable adaptation and mitigation strategies. The paper presents holistic view of challenges and opportunities of changing climate and global and national initiatives to address dangerous anthropogenic interference with the climate system with the aim of sustainable agriculture and food security.

Key words: *Climate change, Challenges, Opportunities, Vulnerability, Food security, Sustainability*

1. Introduction

Climate change is one of the complex problems not only influencing the lives and livelihoods of the people but also socio-economic development as a whole.Observed impacts of climate change have already affected agriculture, human health, ecosystems on land and in the oceans, water supplies, and some people's livelihoods. The striking feature of observed impacts is that they are occurring from the tropics to the poles, from small islands to large continents, and from the wealthiest countries to the poorest.Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, sea level has risen and snow and ice have shown diminishing trend as result of rapid increase in anthropogenic greenhouse gas emissions since the pre-industrial era. The atmospheric concentrations of Green House Gases (GHGs) viz. carbon dioxide, methane and nitrous oxide are unprecedented in the last 800,000 years. The globally averaged surface mole fractions for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) reached new highs in 2015, with CO_2 at 400.0±0.1 ppm, CH_4 at 1845±2 ppb and N_2O at 328.0±0.1 ppb representing increase to 144%, 256% and 121% respectively of pre-industrial levels. CO_2 has crossed the symbolic and significant level of 400 parts per million concentration in the atmosphere. The National Oceanic and Atmospheric Administration (NOAA) Annual Greenhouse Gas Index shows that from 1990 to 2015 radiative forcing by long-lived greenhouse gases (LLGHGs) increased by 37%, with CO2 accounting for about 80% of this increase (WMO GHG Bulletin (2016).

India ranks fourth in terms of aggregate GHG emissions in the world behind China, USA and the EU. India's total CO2 emissions viz. 21, 40, 997.52Gg of CO2 eq. (2,140.99 Million tonne of CO2 eq.) from Energy, IPPU, Agriculture & Waste sectors were about 4% of total global GHG emissions in 2010. While net sink of the order of 18, 88, 465.74Gg of CO2 eq. (1,888.46 Million tonne of CO2 eq.) from LULUCF sector were estimated. Agriculture sector accounts for 18% of the gross emissions of India which is mainly from methane due to livestock rearing (enteric fermentation and manure management) and rice cultivation and N_2O (BUR 2015).

The human interference with the climate system mainly through the emission of LLGHGs and changes in land use has increased the global annual mean air temperature at the Earth's surface by roughly 0.89 °C since the 19th century. This rising trend of temperatures will continue into the future and the world could be warm by another 4 °C or so by 2100, if emissions are not decisively reduced within the next decades (IPCC, 2013). There is broad agreement that a warming of this magnitude would have profound impacts both on the environment and on human societies (IPCC, 2014a), and that climate change mitigation via a transformation to decarbonized economies and societies has to be achieved to prevent the worst of these impacts (IPCC, 2014b).

The newer findings indicate that warming is more pronounced than expected. World Meteorological Organization has reported that globally averaged temperature in 2016 was about 1.1°C higher than the pre-industrial period. It was approximately 0.83° Celsius above the long term average (14°C) of the WMO 1961-1990 reference period, and about 0.07°C warmer than the previous record set in 2015. All the 16 hottest years on record have been this century, apart from 1998 when there was a strong El Niño. Averaged sea surface temperatures in 2016 were the warmest ever recorded (WMO 2017).

The impacts of GHGs together with other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed rapidly changing climate and extremes since and the mid-20th century. New analyses indicate that the global ocean has warmed significantly since the late 1940s: more than half of the increase in heat content has occurred in the upper 300 m, mainly since the late 1950s. Night minimum temperatures are continuing to increase, lengthening the freeze-free season in many mid- and high latitude regions. There has been a reduction in the frequency of extreme low temperatures, without an equivalent increase in the frequency of extreme high temperatures. Over the last 25 years, it is likely that atmospheric water vapour has increased over the Northern Hemisphere in many regions. There has been quite a widespread reduction in daily and other sub-monthly time-scales of temperature variability during the 20th century. Widespread increases are likely to have occurred in the proportion of total precipitation derived from heavy and extreme precipitation events over land in the mid- and high latitudes of the Northern Hemisphere (IPCC 2013).

India has also shown warming trends as annual mean surface temperature of the country has increased by 0.64° C over the years 1901 to 2016. The year 2016 has been the warmest on record since 1901. Spatial pattern of trends in the mean annual temperature shows significant positive (increasing) trend over most parts of the country except over parts of Rajasthan, Gujarat and Bihar, where significant negative (decreasing) trends were observed (IMD 2016). Attri and Tyagi (2010) have also reported increasing trends in temperatures and extreme rainfall events. Increasing trend in the observed frequency of heavy precipitation events and a decreasing trend in the light and moderate rainfall events has been observed in India (Goswami et al 2006). De *el al* (2005) have presented increasing trend in extreme weather events over India in last 100 years. Kulkarni *et al* (2012) concluded that though over a century long period, the Indian summer monsoon rainfall (ISMR) series is stable; it does depict a decreasing tendency during the last three decades of the 20th century. Rajeevan *et al* (2008) using 104 years (1901 – 2004) of high resolution daily gridded rainfall data, variability and long-term trends of extreme rainfall events over central India found that frequency of extreme rainfall events shows significant inter-annual and inter-decadal variations in addition to a statistically significant long term trend of 6% per decade. Annual rainfall showed decreasing trends over 16 States and increasing trends over 15 Sates including Islands during 1951-2010 (Rathore *et al*, 2013). Changes in the frequency of different categories of temperature extremes and characteristics of rain events by Dash *et al* (2009) and Dash and Mamgain (2011) and trends in rainfall by Guhathakurta and Rajeevan (2008) have been presented.

Agricultural production is vulnerable to climate variability and change in many parts of the globe. The changing patter in temperature, precipitation and extreme events by the end of this century will have significant implications for rural poverty and for both rural and urban food security and sustainability. At the same time, agriculture also presents new adaptation and mitigation opportunities as large land area falls under crops and rangeland, and the additional mitigation potential of aquaculture. Climate change has become significant threat to agriculture and food security across the globe. Projected changes in temperature, precipitation and CO_2 concentration are expected to significantly impact crop productivity. In India, the estimated countrywide agricultural loss in 2030 may be more than US$7 billion, which will severely affect the income of 10% of the population. It could be reduced by 80% if cost-effective climate resilience measures are implemented (ECA, 2009).

It is now evident that climate change is now a reality and threat to sustainable development in general and agriculture, in particular. This challenge should be addressed jointly by developed and developing countries. There is urgent need of a new economic paradigm, which is global, inclusive, cooperative, environmentally sensitive and, above all, scientific. Various studies and review articles on climate change and agriculture by Gadgil (1995), Kurukulasuriya and Rosenthal (2003), Attri (2006), Mall *et al* (2006), Jayaraman (2011), Senapati *et al* (2013), Kumar and Gautam (2014), Anupama Mahato (2014), Yohannes H (2016) etc have been published in literature. However, this paper presents an holistic view of unprecedented challenges and understanding those challenges and tackling them creatively to help build a more vibrant and sustainable food secured India and world in the near-term and beyond.

2. Challenges

In addition to water, food and energy security, population growth, infectious diseases, and international security as global risks (World Economic Forum 2015), climate change is often regarded as one of the most profound global problems which is mainly due to the sheer scale of climate change impacts – both in terms of its global and temporal spread and of the variety of sectors affected by it. It has potential to impact global water supplies, agricultural production, human health, and our energy infrastructure. In turn, the way in which we produce energy and food has a profound effect on the Earth's climate system. Further, the poorest people on Earth are not significantly contributing to global emissions, but may well feel the impacts most severely. There are complex linkages among emissions, concentrations, climate changes, and the impacts. Projecting future climate change requires understanding of numerous linkages among human activities, greenhouse gas (GHG) emissions, changes in atmospheric composition, the response of the climate system, and impacts on human and natural systems. The basic links in this chain are well understood, but some elements (in particular, projecting specific impacts at specific times and places) are much less so. As a result, the outcomes of actions to reduce emissions or to reduce the vulnerabilities of human and natural systems need to be presented in probabilistic or qualitative terms, rather than as certain predictions.

There are significant time lags in the climate system. It takes very long time periods (decades to millennia) for some aspects of the climate system to respond fully to changes in atmospheric GHG concentrations. This is because the world's oceans can store a large amount of heat. So it takes a long time for the climate system to warm up in response to changes in GHG concentrations and because impacts such as sea level rise and the melting of ice sheets can take several centuries or even millennia to be fully expressed. Some GHGs (such as methane) are removed from the atmosphere within about a decade, but CO_2 persists much longer. Approximately 20 percent of the CO_2 emitted today will remain in the atmosphere more than a millennium from now. Thus, a failure to reduce GHG emissions in the near-term will “lock in” a certain amount of future climate change for decades, if not centuries, to come.GHG emissions are to large extent built into societal infrastructure (e.g., buildings, power plants, settlement and transportation patterns) and into human habits and organizational routines, few of which change quickly. Market incentives affecting capital investments leave little room for considering consequences on century or longer time scale. Nevertheless, making major reductions in GHG emissions and preparing to adapt to the effects of climate change will require transformative changes, for instance, in how the country produces and uses energy, builds buildings and transportation infrastructure, and manages water and other natural resources. It will likewise require significant changes in consumer choices, travel behavior, and other individual and household-level decisions. Overcoming the inertia of the status quo in advancing these sorts of transformations will pose challenges for government, industry, agriculture, and individual citizens alike (Public Agenda, 2017).

An issue of particular concern is that much of the equipment and infrastructure that leads to GHG emissions (e.g., roads, vehicles, buildings, power plants) have lifetimes of decades. There are often strong economic pressures to continue use of such equipment and infrastructure, rather than retrofitting or replacing with a lower-emitting option. Making substantial emission reductions within the next few decades will require accelerating this turnover faster than projected business-as-usual rates.

Policy makers all over the world are facing similar challenges. There is broad agreement on certainty of climate change, but there is great uncertainty as to what the local or regional impacts will be and what will be the impacts on societies and economies. Coupled with this, is often great disagreement among policy makers about underlying assumptions and priorities for action. Risks and impacts of Cliamte Change are depicted in Fig 1 (IPCC 2001a).

IPCC assessments have generally concluded that, in the near to medium term, aggregate world food production is not threatened (IPCC, 2001b). However, considerable regional variation in impacts an adaptive capacity suggests that severe impacts and food scarcity could occur in some regions, especially at low latitudes, where large numbers of poorer people are already engaged in agriculture that is not currently viable. In global terms, agriculture has been extremely resilient and world food production has expanded rapidly to keep pace with world population growth. Of course, there is debate on the sustainability of these trends, as they depend in part on the growing demand for meat and meat products as well as potential competition between agricultural resources for producing food versus those used for producing energy. Nevertheless, even where shortages have occurred, the reasons are rarely to be found in an absolute lack of food but are more due to lack of purchasing power and failures of the distribution system (IPCC 2007).

Climate change calls for new approaches to sustainable development that take into account complex interactions between climate and social and ecological systems. Risks, judgments about risk, and adaptation needs are highly variable across different contexts. Different regions, economic and resource sectors, and populations will experience different impacts from climate change, will vary in their ability to tolerate and adapt to such impacts, and will hence differ in their judgments about the potential risks posed by climate change. For instance, coastal communities that are vulnerable to serious disruptions could be expected to view the risks of climate change as quite serious. Actions that are taken in response to climate change will also pose differing types of risks to different regions, sectors, and populations.

World population projected to be 9.1 billion in 2050 will require raising overall food production by some 70% between 2005 and 2050 (FAO 2009). In addition to enhanced agriculture production, it must contribute to economic prosperity and the social well being of rural areas, and help preserve natural resources such as land, water and biodiversity in the changing climate.

Projected changes in crop yields, due to climate change over the 21st century for different emission scenarios, for tropical and temperate regions, and for adaptation and no-adaptation cases combined have been presented by IPCC (2015) and Porter et al., (2014). In brief, in most site-by-crop combinations, yields are reduced with increasing climate changes, but there are some site-by-crop combinations that show increased yield but the frequency of these decreases with progressive climate change (Fig 2). Yield impacts are more negative in tropical vs temperate regions and they vary substantially between crops. Yield variability is likely to increase over the forthcoming decades. Subsequent publications of climate change impacts on crop yield have supported the AR5 analyses, emphasizing the substantial uncertainty in projected crop yield changes and the implications of these on food prices arising through variations in crop, economic and climate model results.

Though, agriculture contributes only about 14% to the overall GDP but its impact is felt in the manufacturing sector as well as the services sector and determines the standard of life for more than 50% of the Indian population. Major challenges of sustainable agriculture are like Small or Marginal Land Holding Size, Lack Irrigation facilities & Dependency on Monsoon, depleting soil fertility and water quality, comprehensive national insurance schemes, pest problems, Low Productivity, Low Profitability, Seed Replacement Rate, Traditional Bound, Lack of Diversification, Lack of Mechanization, Regional variation, Farmers Education, Transportation & other infrastructure, High percentage of employment rate, Lack of Marketing and Storage Facilities, Sustainability in Agriculture, Lack of access to Agricultural Credit etc. Declines in the share of agriculture in GDP were not commensurate with the fall in dependency in agriculture. Such trends have resulted in fragmentation and decreasing dependency in agriculture. Such trends have resulted in fragmentation and decline in the size of land holdings which leads to agronomic inefficiency, a rise in unemployment, a low volume of marketable surplus. These factors could contribute to increase vulnerability to global environmental change (Aggarwal *et al*., 2004).

In India, the estimated countrywide agricultural loss due o climate change in 2030 may be more than US$7 billion, which will severely affect the income of 10% of the population. It could be could be reduced by 80% if cost-effective climate resilience measures are implemented (ECA, 2009). Reduction of monsoon sorghum grain yield by 2 to 14% by 2020, with worsening yields by 2050 and 2080 using the InfoCrop-SORGHUM simulation model has been projected by Srivastava et al., 2010. A 10-15% increase in monsoon precipitation in many regions, a simultaneous precipitation decline of 5-25% in drought-prone central India and a sharp decline in winter rainfall in northern India are also projected. This implies changes in output of winter wheat and mustard crops in northwestern India. A decrease in number of rainy days (5-15 days on an average) is expected over much of India, along with an increase in heavy rainfall days in the monsoon season (NATOCM 2012). In the Indo-Gangetic Plains, a large reduction in wheat yields has also been projected unless appropriate cultivars and crop management practices are adopted (Ortiz et al., 2008). This area produces 90 million tons of wheat grain annually (about 14 to 15% of global wheat production). Climate projections based on a doubling of CO_2using a CCM3 model downscaled to a 30 arc-second resolution as part of the WorldClim dataset showed that there will be a 51% decrease in the most favourable and high yielding area due to heat stress. About 200 million people (using the current population) in this area whose food intake relies on crop harvests would experience adverse impacts (IPCC 2013). A systematic review and meta analysis of data in 52 original publications projected mean changes in yield by the 2050s across South Asia of 16% for maize and 11% for sorghum (Knox et al., 2012).

3. Opportunities

Proper understanding of climate change is a challenge in managing risk which also opens a wide range of opportunities for integrating adaptation with economic and social development and with initiatives to limit future warming. The difficulty of developing sound strategies for responding to climate change, and of building public support for such strategies, stems in part from the inherent complexity of the issue. Some of this complexity relates to the physical science of climate change; but understanding and responding to climate change also raises many social, economic, ethical, and political challenges. Humanity, therefore, has a moral obligation to address the climate challenge. This will have to combine successful negotiations on a binding and effective international climate agreement and bottom-up initiatives from individuals or communities.

Lack of certainty about the details of future climate change is not, however, a justification for inaction. People routinely take actions despite imperfect or incomplete knowledge about the future in situations such as buying home insurance, saving for retirement, or planning business strategies. Likewise, people use probability data from weather forecasts to decide if they should take an umbrella to work, move a scheduled outdoor event indoors, or cancel a ball game. Indeed, it could be argued that uncertainty about future climate risks is a compelling reason for taking proactive steps to reduce the likelihood of adverse consequences.

By 2050 two-thirds of the world's population will be living in cities. Helping developing country cities access private financing and achieve low-carbon, climate-resilient growth and avoid locking in carbon intensive infrastructure would be one of the smartest investments. Further, there is need to make agriculture resilient, more productive in changing landscapes, and aggressively reduce food waste. Climate-smart agriculture should focus on increasing yields and incomes, building resilience, and reducing emissions while potentially capturing carbon.

Global and national plans now need to factor in climate change. To best prepare for, adapt to, and reduce the effects of climate change, there is need to consider not only the changes, but also who and what might be affected, and how and why? It will effect Built systems – roads, utilities, buildings and seawalls; Water supply and treatment, Human/social systems –businesses, emergency response and health care; Natural systems – plants, pests, animals, people, rivers and fires; Economy and future economic opportunities; Current and future generations etc. FAO (2016) has presented five key principles viz. Improving efficiency in the use of resources, Conserving, protecting and enhancing natural ecosystems, Protecting and improving rural livelihoods and social well-being, Enhancing the resilience of people, communities and ecosystems and Promoting good governance of both natural and human systems to cope with climate change impacts.

Options for countries all over the world include a mix of technology development that lowers air pollution; increasing investment in renewable energy and energy efficiency, expanding urban public transport; improving waste and water management; and better planning for when disasters strike. There will be costs for taking action, and there would be costs if we did not take action. Investing today in cost effective energy conservation and clean energy development can pay off in lower costs – economic, social and environmental – tomorrow. To move forward on the global level at the required scale, there is need to drive mitigation action in top-emitting countries, get prices and incentives right, get finance flowing towards low-carbon green growth, and work where it matters most.

Following potential approaches are required to address climate change impacts:

i. Decisive local, national and international action to prevent & minimize the worst consequences of climate change.
ii. Make sure that most vulnerable communities adapt to the inevitable changes global warming will cause.
iii. Public and Partnership to lead the way in the search for solutions

Intensification of agricultural activities through enhanced productivity and efficient resource use is the only option available as competition for land and water is increasing from non-farm sectors for producing adequate food from shrinking natural resource base for the ever-increasing population. India also needs to take steps towards a carbon and energy efficient economy. All this calls for a Climate Resilient Agriculture leading to sustainable food security through integrating innovations, technologies, efficient resource use, sound public policies, establishment of new institutions, and development of infrastructure. There is need for collection, collation, analysis, and interpretation of long term weather parameters available for each region to identify the length of the possible cropping period, taking into consideration the availability of water in the era of increasing monsoon variability (BUR 2015). Khajuria and Ravindranath (2012) have identified adaptation and mitigation strategies needed to safeguard the communities, regions, countries and societies from adverse consequences of climate change. Khan *et al* (2009) have presented that vast genetic diversity in crops provides a platform to identify suitable thermal and drought tolerant cultivars for sustained productivity in changing climate. Identification of suitable agronomic management practices can be a potential solution to optimize agricultural production in the changed climate. Tyagi and Goswami (2009) have also presented status of climate change and adaptation strategies in India.

Policy Paper on Climate Resilient Agriculture in India by National Academy of Agricultural Sciences, New Delhi (2013) emphasizes on prioritization of adaptation options in key sectors such as stress tolerant crops, storm warning systems, water storage and diversion, contingency planning and infrastructure strengthening.

4. Response to Climate Change

4.1 International

The first World Climate Conference (WCC) took place in 1979 was the first major global initiative to understand science behind climate change. Details of subsequent major global interaction and initiatives are summarized as under:

- Establishment of the Intergovernmental Panel on Climate Change (1988).
- IPCC's First Assessment Report and Second World Climate Conference (1990).
- The Earth Summit in Rio and the UNFCCC is opened for signature (1992).
- UNFCCC enters into force (1994)
- The first Conference of the Parties in Berlin (1995)
- IPCC's Second Assessment Report (1995).
- Set up of UNFCCC Secretariat to support action under the Convention (1996).
- Adoption of Kyoto Protocol (1997).
- Release of IPCC's Third Assessment Report (2001).
- Entry into force of the Kyoto Protocol (2005)
- IPCC's Fourth Assessment Report released (2007)
- WCC3 in Geneva and proposed Global Framework for Climate Services. (2009)
- Copenhagen Agreement (2009) (Fig 3).
- Cancun Agreements drafted and largely accepted by the COP at COP16 (2010)
- The Durban Platform for Enhanced Action drafted and accepted by the COP at COP17 (2011)
- The Doha Amendment to the Kyoto Protocol adopted by the CMP at CMP8. Inter-Governmental Board for GFCS of WMO formed (2012)
- The Sendai Framework for Disaster Risk Reduction (2015-2030) adopted by UN member states between (2015)
- Paris Agreement on Climate Change at COP 21 (2015) and affirm commitment to full implementation of Paris Agreement at COP 22 (2016).

Paris Agreement at the COP21 on 12 December 2015 is a landmark global achievement which has set an upper limit on acceptable risk from climate change well below 2°C and as close to 1.5°C as possible above preindustrial levels by the end of this century. This ambitious objective was agreed in Paris very much in the spirit of ensuring that no one is left behind by taking Intended Nationally Determined Contributions (INDCs) elaborated in National Action Plans (NAPs). INDCs will automatically become Nationally Determined Contributions (NDCs) upon ratification of the Agreement. It also contains a commitment for developed country Parties to provide financial resources (Green Climate Fund of 100 billion USD from a variety of sources by 2020) to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations under the Convention. Other Parties are encouraged to provide or continue to provide such support voluntarily. Implementation of the Agreement is essential for the achievement of the 17 Sustainable Development Goals and 169 targets set under "The 2030 Agenda for Sustainable Development" at UN Headquarters in September 2015 for three dimensional viz. economic, social and environmental sustainable development. Out of the 11 percent of the world's land surface suitable for agriculture, 38 % has degraded by poor natural resource management practices. With no significant room to expand areas of cultivation, various global initiatives like improving soil quality, minimizing the use of pesticides and herbicides , employing environmental management systems , ensuring the safe storage, maintaining habitats, good farming practices and stewardship of the available land have been taken to increase agricultural productivity, ensure economic growth, protect biodiversity, maintain sufficient amounts of clean water, and meet the increasing food demands of a growing global population. The UN Secretary-General's Zero Hunger Challenge (ZHC) launched at Rio+20 in 2012 called on governments, civil society, faith communities, the private sector, and research institutions to unite to end hunger and eliminate the worst forms of malnutrition. ZHC focuses on goal of zero stunted children under the age of two, 100% access to adequate food all year round, all sustainable food systems, 100% increase in small holder productivity and income and zero loss or waste of food. An increase in integrated decision-making processes at global, national and regional levels will achieve synergies and adequately address trade-offs among agriculture, water, energy, land and climate change. Building resilience of local food systems will be critical to averting large-scale future shortages and to ensuring food security and good nutrition for all UN Sustainable Development Knowledge Platform (2017).

Global Framework for Climate Services of WMO is focusing on global, regional and national initiatives for climate services applications in agriculture and food security. FAO is focusing on three strategies viz. enhancing institutional and technical capacities of Member States, improving integration of food security, agriculture, forestry and fisheries within the international climate agenda and strengthening internal coordination and delivery of work FAO (2017).

4.2 National

India is committed to address the issue of climate change. It submitted the first National Communication to UNFCCC in 2004 as per Kyoto Protocol and the Second National Communication in 2012. It also adopted the National Environment Policy 2006 which provides for several measures and policy initiatives to create awareness about climate change and help capacity building for taking adaptation measures. Hon'ble Prime Minter of India released National Action Plan on Climate Change (NAPCC) on June 30, 2008 containing priorities and future actions of the government through following eight national missions (NAPCC,2008):

- National Solar Mission
- National Mission on Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Eco-system
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change.

As signatory to latest Paris Agreement on Climate Change, India is committed to invest in tackling climate change while addressing poverty, food security and access to healthcare and education. India's INDC targets on its goal of installing 175 gigawatts (GW) of renewable energy capacity by 2022, out of this, 100 GW has been allocated to solar and 60 GW to wind. It has set a new target to increase its share of non-fossil fuel-based energy from 30 per cent today to about 40 percent by 2030 and committed to reduce its emissions intensity per unit GDP by 33 to 35 per cent below 2005 by 2030 and create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 through additional tree cover (NITI Ayog 2015). The action plan also prioritizes efforts to build resilience to climate change impacts, and gives a broad indication of the amount of financing necessary to reach its goals of addressing climate change threat and achieving sustainable development. A major initiative viz. The International Solar Alliance (ISA) launched during above UNFCCC meet by the President of France and the Prime Minister of India, is a common platform for cooperation among sun-rich countries to massively ramp up solar energy, thereby helping to bend the global greenhouse emissions curve whilst providing clean and cheap energy.

In agriculture, various measures have been undertaken to enhance food security while there have been focused interventions aimed at diversifying into non-food grain crops and promoting animal husbandry and fishing. The new National Food Security Mission aims at increasing cereal and pulses production by 20 million tonnes by concentrating on those areas which have the greatest potential for increase in yields with the given technology. Government of India has launched National Horticulture Mission (NHM) in 2005-06 with an objective to enhance horticulture production and to improve nutritional security and enhance income to farmers. Government have taken various other initiatives like Pramparagat Krishi Vikas Yojana (PKVY), National Innovations on Climate Resilient Agriculture (NICRA), National Mission of Sustainable Agriculture (NMSA), System of Rice Intensification (SRI) cultivation, Crop diversification from transplanted paddy to other food crops, Improvement in energy efficiency through Micro irrigation, Prime Mininter Fasal Bima Yojna (PMFBY), National Agricultural Markets (e-NAM), Soil Health Card Scheme, Per Drop More Crop (PDMC), Har Medh Per Ped (HMPD), Gramin Krishi Mausam Sewa, etc., to address implications of climate change.

5. Conclusions

1. CO2 has crossed the symbolic and significant level of 400 parts per million concentrations in the atmosphere in 2015.
2. Globally averaged temperature in 2016 was about 1.1°C higher than the pre-industrial period and approximately 0.83° Celsius above the long term average (14°C) of the WMO 1961-1990 reference period.
3. Yield impacts are more negative in tropical as compared to temperate regions and vary substantially between crops.
4. Intensification of agricultural activities through enhanced productivity and efficient resource use is the best option available in the era of competition for land and water from non-farm sectors for sustainable food production.
5. Global, Regional and National Frameworks for Climate Services need to be established at the earliest to address climate change implications.

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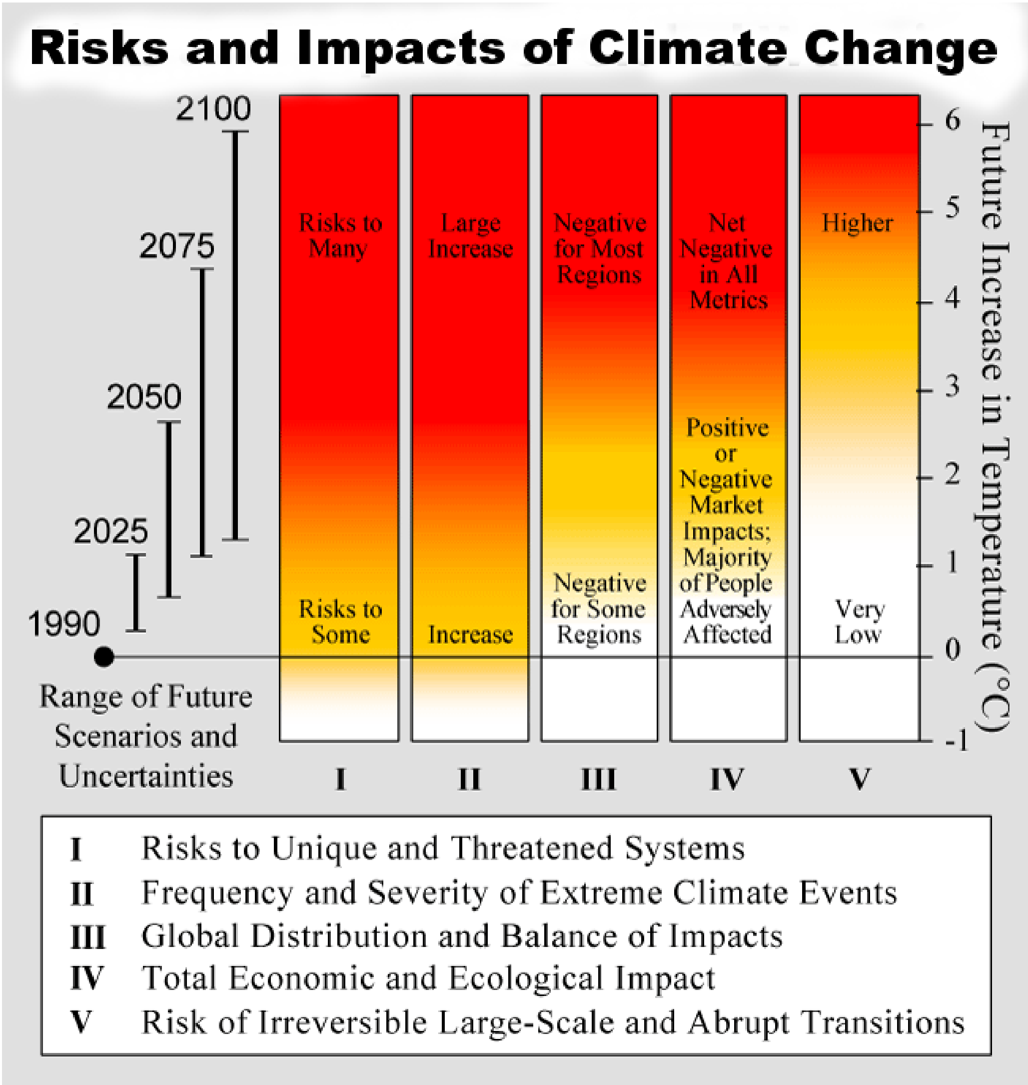

Figure 1. Risks and impacts of Climate Change (IPCC 2001)

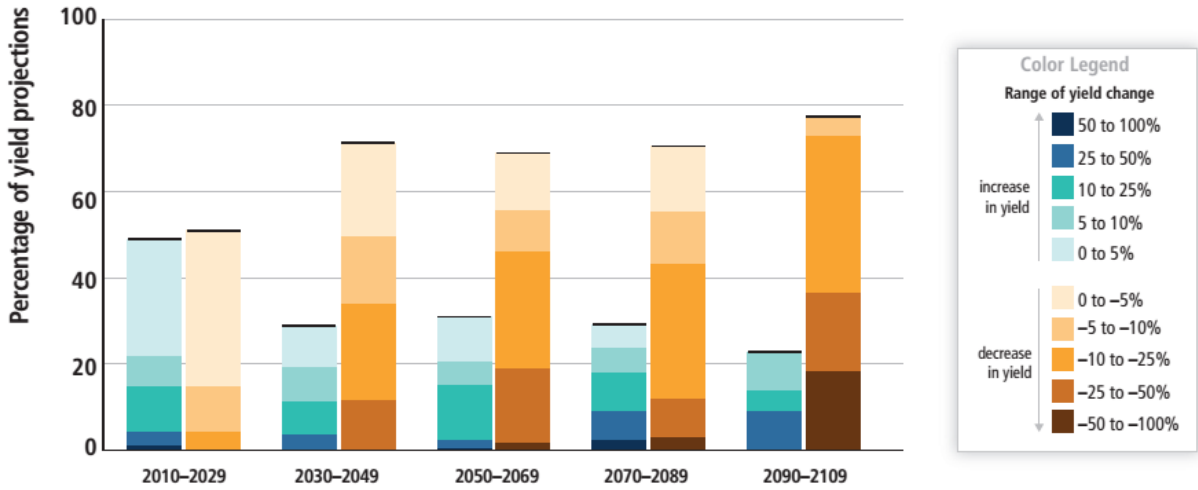

Figure 2. Projected changes in crop yields, due to climate change over the 21st century (IPCC 2015)

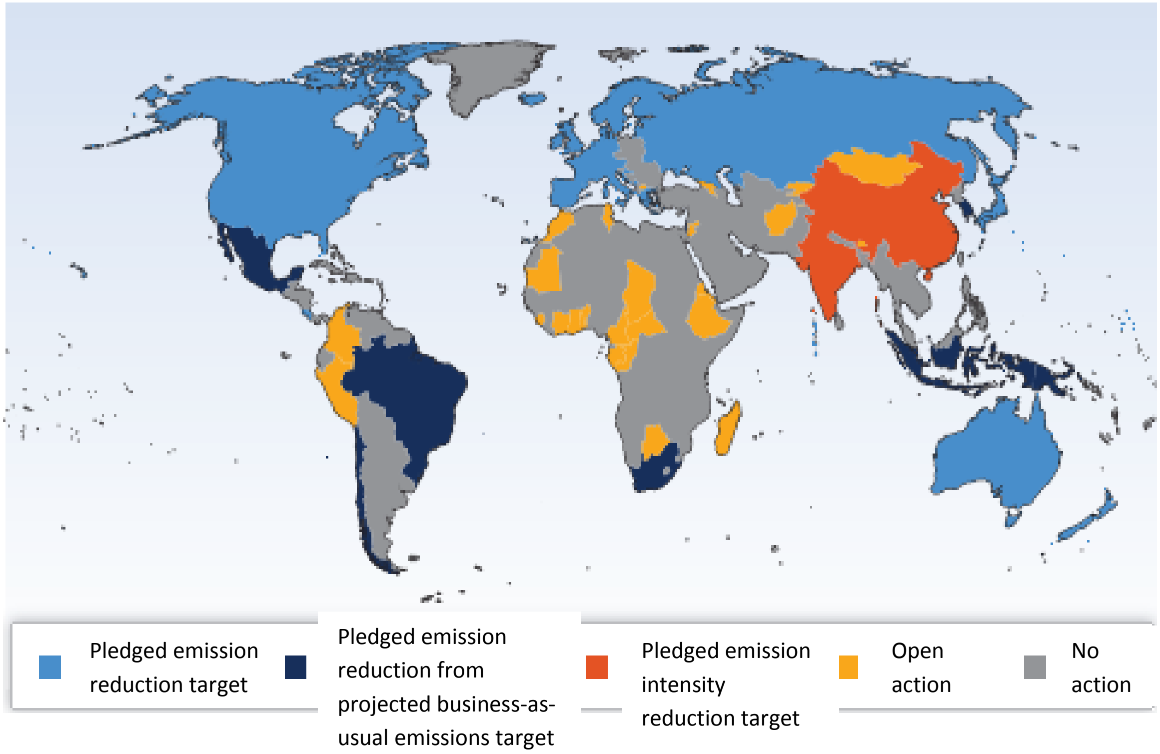

Figure 3: Pledges by Annex 1 and Annex 2 countries in response to the Copenhagen Accord (http://unfccc.int/meetings/copenhagen_dec_2009/items/5264.php,http://unfccc.int/meetings /cop_15/copenhagen_accord/items5265.php).