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CLIMATE CHANGE & AGRICULTURE IN INDIA- EFFECTIVE IMPLEMENTATION OF NATIONAL MISSION FOR SUSTAINABLE AGRICULTURE

Dr. Amrit Patel [*1]
[*1] Former Deputy General Manager, Agricultural & Rural Credit Department, International Bank of Baroda, INDIA

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ABSTRACT

Climate change has been the most serious challenge affecting agriculture in India where direct effects of climate change are expected to be very harsh. India will need to produce estimated 320 MT of food grains by the year 2025. Acknowledging the significant role of Science & Technology, India has since 2008 established "National Action Plan on Climate Change" which includes "National Mission for Sustainable Agriculture [NMSA]" among eight missions. NMSA aims at developing technologies & innovative agricultural practices and strengthening the capacity of farming communities to cope effectively with both climatic variability and changes. Adaptation and mitigation potential is nowhere more pronounced than in India where agricultural productivity remains low and poverty, vulnerability & food insecurity remain high. Against this background this development perspective article attempts to highlight the impact of climate change on agriculture in general and in India in particular and suggests the priority areas to accelerate the process of effective implementation of NMSA launched on June 26, 2015.

Keywords:
Climate Change; National Mission for Sustainable Agriculture in India.

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1. INTRODUCTION

After many years, developed countries have acknowledged the link between global warming and the human activity responsible for releasing Green House Gas [GHG]. Retreating the glaciers, stronger hurricanes, mild winters, hotter summers, frequent droughts, catastrophic rains causing floods, outbreak of viral diseases and vanishing biodiversity & species are sufficient evidences of the manifestation of global warming. It is now more than 44years since the United Nations

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christened June 5, 1972 as World Environment Day. An agreement was reached at the G8 Summit, that GHG emissions should be reduced by 40% by 2020, so as to limit the maximum rise in temperature to two degree Celsius over the pre-industrial period.

Greenhouse Gases: Greenhouse gases are gases in the atmosphere that absorb & emit radiation within the thermal infrared range. This process is the basic cause of the greenhouse effect. Greenhouse gases greatly affect the temperature of the Earth; without them, the Earth's surface would be about 33 degree Celsius colder than at present. The natural greenhouse gases in the Earth's atmosphere are *water vapor, carbon dioxide, methane, nitrous oxide and ozone.* Some amounts of GHGs are absorbed by the natural systems such as oceans and plant biomass, which are also referred to as sinks of GHGs. However, when plants are cut down and allowed to decay or are burnt; the GHGs absorbed by them from the atmosphere are released back into the atmosphere. The buildup of GHGs in the atmosphere is, therefore, the net emission from sources and removal by sinks. Since the time of Industrial revolution in the mid-18th century large scale burning of fossil fuels, land use change and forestry activities has considerably enhanced the concentration of GHG in the atmosphere, for example, the concentration of carbon dioxide had gone up from 275 to 285 ppm in the pre-industrial era (AD 1000–1750) to 379 ppm in 2005. Additionally, synthetic GHG like perfluorocarbons [PFCs], hydrofluorocarbons [HCFCs] and sulfur hexafluoride [SF6] are also accumulating in the atmosphere. The increased level of GHG in various forms viz. carbon dioxide (CO_2), water vapor (H_2O), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) etc. due to anthropogenic activities has contributed to an overall increase of the earth's temperature, leading to a global warming. The average global surface temperature has increased by 0.74 degree Celsius since the late nineteenth century and is expected to increase by 1.4 degree Celsius in years to come.

Climate Change: Weather is the atmospheric condition prevailing at a particular geographical location/place in a given time and is the effect of several weather parameters viz. temperature, relative humidity, rainfall, intensity & duration of sun shine, wind velocity, among others. Climate is the long term pattern of weather conditions for a given area. Climate change refers to a statistically significant variation in either the mean state of the climate or its variability, persisting for an extended period. India is home to extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall. India's climate is strongly influenced by the Himalayas and the Thar Desert. Four major climatic groupings predominate into which fall seven climatic zones which are defined on the basis of temperature and precipitation.

Climate change includes variation in temperature, changes in precipitation, and higher atmospheric carbon dioxide concentrations all of which affect growth rate, quality & yield of crops, photosynthesis, transpiration rates, moisture availability, through changes of water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers etc. Environmental effects, due to land use pattern, frequency & intensity of soil drainage (leading to nitrogen leaching), soil erosion/run off, reduction of crop diversity etc., also, impact on crop productivity. Farmers in arid regions find it difficult to carry on farm operations under scorching heat when temperature rises.

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According to World Meteorological Organization, *climate change* can adversely impact global environment, quality of human life and productivity of field crops, livestock & fisheries. International Symposium on "*Agro-meteorology and Food Security*" organized in February 2008 in Hyderabad, noted with concern that agricultural productivity has come down over a period of time. Growth of world agricultural output is expected to fall to 1.5% per year by 2030 and further to 0.9% per year in the succeeding 20 years by 2050. Even a two degree Celsius rise in mean temperature will have serious implications for Indian agriculture. Sometime back, the distinguished Indian scientists Dr. Sinha and Dr. Swaminathan showed that a one degree Celsius rise in night temperature in Punjab and Haryana would reduce the duration of wheat crop by about a week. This would reduce yield by four to five quintals per hectare, resulting in a considerable loss to wheat production in the region and more importantly the income of small and marginal farmers owning less than one hectare of land. According to the FAO, farmers would have to produce 40% more grain to meet the increasing global demand for cereals, when the world's population would be 9.0 billion by 2020. The FAO estimated 5m to 170 m people at risk of hunger by 2080. According to the Washington-based IFPRI [2009], climate change in developing countries will cause yield declines in most important crops and South Asia will be particularly hard hit. The World Bank Group currently supports 130 countries including India to study climate related activities and formulate policies & strategies to increase food productivity & ensure food security in the light of impact of climate change.

2. IMPACT ON AGRICULTURE

Agriculture is the sector most vulnerable to climate change due to its high dependence on climate. Climate change is threatening food production system, livelihoods of people engaged actively in agriculture & food security of country's population. A review of indicators [exposure, sensitivity and adaptive capacity] highlights considerable vulnerability of the agricultural sector as a source of livelihood for all those who are engaged in agriculture and as a source of food security for all. The review also exposes the large heterogeneity in farming systems across different agro-ecological regions within the country and highlights many facets of vulnerability to climate change including undernourishment, malnourishment, poverty and slow rate of agricultural productivity growth, all of which will be exacerbated by the effects of climate change. Within agriculture the rain-fed farming will be the most impacted by climate change. Temperature is an important weather parameter that will affect productivity of rain-fed crops. The last several years witnessed a rise in all India mean annual temperature. Though most rain-fed crops are accustomed to tolerate/adjust with high temperatures, rain-fed crops grown during rabi season are vulnerable to changes in minimum temperatures. Thus, studies which assess the impact of climate change on Indian agriculture and vulnerability of the small and medium farmers in rain-fed areas need to focus on farmers' perceptions on the climate change and the factors which influence the farmers to adopt or to follow coping mechanisms.

While in temperate latitudes a rise in temperature would help countries increase food productivity, it will have adverse effects in countries in the tropics including India. The monsoon accounting for 75% of India's rainfall significantly impacts country's agriculture and livelihood of millions of small farmers. Climate change is likely to intensify the variability of monsoon dynamics, leading to a rise in extreme seasonal aberrations, such as increased precipitation and devastating floods in some parts of the country and reduced rainfall and prolonged droughts in

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other areas. The worst sufferers would be millions of small farmers & agricultural laborers and people depending upon forests since they are already vulnerable and food insecure. Impact of climate change on agriculture will affect food grain trading pattern & polices in domestic and international markets in order to ensure food security. The combination of agricultural characteristics in an agrarian economy, namely its importance as an economic sector, its vulnerability to climate change and its contribution to emissions, do necessitate the urgent need to make agriculture resilience to climate change to ensure food security of current and future generations. The wide spread and deep rooted poverty in rural areas and expected impacts of climate change on uncertainty of food output and income require adequate financial investment for developing & spreading mitigation and adaptation strategies. Government in its efforts needs to demonstrate political leadership, effective inter-institutional coordination among ministries & bureaucracies and seek support of individual farmers, community groups and the private sector to formulate and successfully implement comprehensive climate mitigation and adaptation strategies. The State Governments in India in particular while targeting climate change investments should allocate adequate financial & human resources in their annual budgets to meet crucial social development needs.

Climate change will manifest its different types of effects on crops & livestock; fisheries & aquaculture; land; water; biodiversity; and trans-boundary pests and diseases as under.

Crops & Livestock: Weather index based crop insurance scheme is implemented in some countries. It aims at estimating percentage of deviation in crop output due to impact of adverse weather at each critical stage of crop growth. Analysis of data under the scheme in India during 1985 to 2003 revealed that rainfall had profound effect accounting for as high as 95% of insurance claims [85% of deficit & 10% excess rainfall]. Temperature & rainfall influence sowing time of rain-fed crops, crop growth & duration. Temperature & relative humidity influence occurrence of pests & disease on crops, health & productivity of livestock & poultry. Radiation impacts process of photosynthesis in plants & productivity. Wet & dry spells cause significant impact on standing crops, crop physiology, loss of economic prospects [Ex. Fruit drop]. Extreme events [Ex. High rainfall, floods, heat/cold wave, cyclone, hail, frost] cause enormous losses of standing crops & livestock. It will, also, have an impact on the incidence/infestation of pests and diseases, biodiversity and ecosystems. Frequent changes in weather parameters, more importantly temperature and precipitation would not only threaten food production but also access, stability and utilization of food resources.

Studies show that a temperature rise by 0.5 degree Celsius in winter is projected to reduce rain-fed wheat yield by 0.45 tons per hectare in India. Possibly some improvement can be seen in yields of chickpea, rabi maize, sorghum and millets; and coconut in west coast and less loss in potato, mustard and vegetables in north-western India due to reduced frost damage. Increased droughts and floods are likely to increase production variability. Adaptation to climate change will need to strengthen early warning systems; systems to identify climate change "hot spots" & disaster risk management; and evolve appropriate sustainable and eco-friendly farming practices. Other equally important measures call for significant increase in rural investments to reduce the long-term effects of climate variability on food security, through provision for researching new/innovative crop and livestock risk management products including insurance

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and incentives that encourage farmers to adopt farm and social forestry, conserve soil & water resources and better agricultural and land use practices.

Fisheries & aquaculture: Climate change, more particularly harsher weather conditions, will have impact on the productivity, output & quality of fish and economic viability of fish and aquaculture enterprises, thereby affecting fishing community. The small-scale fishers may be faced with greater uncertainty as availability, access, stability & use of aquatic food and supplies would diminish and work opportunities would dwindle/decline. Aquaculture development opportunities will increase in particular in tropical and sub-tropical regions. The climate change in warmer regions offers new opportunities as production in warmer regions will increase because of better growth rates, a longer growing season and the availability of new fish farming areas where it was once too cold.

Land: Rising sea levels owing to climate change would compel communities in low-lying coastal areas and river deltas to move to higher ground level. Similarly, increase in frequency of droughts due to climate change would, also, force farmers and pastoralists [who rely on rainfall to raise their crops & livestock] to migrate to areas in search of land and water. This migration/displacement of people would result in direct conflict and competition between migrants and established communities for access to land and water. It may be difficult for displaced communities to maintain their farming or pastoral traditions. A long-term policy and programs that provide opportunities for the displaced communities to earn livelihood outside the agricultural sector may need to be evolved. Governments would have, also, to face challenge to reconcile competing demand and diverse land use needs. In cases, where land rights are informal and different customary land tenure systems coexist, Government and local communities may need to establish fair and equitable systems of land tenure.

Water: The climate change will have impact on the variability in the availability of water and also increase in frequent occurrences of droughts and floods. Worst sufferers would be farmers of the rain-fed agriculture. The risk of crop failures will increase in semi-arid zones with prolonged dry seasons forcing people to migrate, when stability of food production cannot be assured. Irrigated areas in large river basins and deltas can also be at risk because of a combination of factors, such as reduced runoff, salinity, increasing floods, rising sea level, urban and industrial pollution. All these in one or the other way will affect the land to maintain its level of productivity & farm output, cause loss of biodiversity and reduction in the natural ability of ecosystems to recover. Areas projected to experience lower precipitation will need to improve water storage capacity and efficient water management system that can enhance crop productivity. While large irrigation schemes will need to adapt to changes in water supply regimes, small-scale irrigation schemes will need field-based water control measures.

Biodiversity: According to the "*2005 Millennium Ecosystem Assessment*", the climate change will cause loss of biodiversity by the end of this century. The significance and utility value of biodiversity for food and agricultural purpose will increase as and when climate changes. Genetic resources are the living materials that local communities, researchers and breeders use to develop high yielding crop varieties/strains that can adapt to changing needs. Maintaining and using this reservoir of genetic diversity will be the foundation for coping with climate change.

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Trans-boundary pests & diseases: Climate change is altering the distribution pattern of pests & diseases affecting crops & livestock. Changes in temperature and atmospheric moisture & gases influence generation & growth rates of crops, fungi and insects, which alter the interaction between pests, their natural predators and hosts. Changes in land cover, more importantly deforestation or desertification make remaining plants and animals increasingly vulnerable to pests and diseases. In order to contain the spread of pests, there is need for the development of new farming practices, cropping pattern, evolution of different crops and animal breeds, and adoption of integrated pest management techniques. Besides, there is need to introduce biological control agents, develop pest & disease-resistant varieties of crops and breeds of animals and strengthen national animal and plant health care services.

3. IMPACT ON FOOD SECURITY

The Food and Agriculture Organization (FAO) defines food security as a "situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life". It has four key components of food supplies, viz. *availability*, *stability*, *access*, and *utilization*. The FAO- hosted "High-Level Conference on World Food Security" from 3 to 5 June 2008 concluded with the adoption of a Declaration on World Food Security, as "It is essential to address the question of how to increase the resilience of present food production systems to challenges posed by climate change. We urge Governments to assign appropriate priority to the agriculture, forestry and fisheries sectors, in order to create opportunities to enable the world's smallholder farmers and fishers, including indigenous people, in particular vulnerable areas, to participate in and benefit from financial mechanisms and investment flows to support climate change adaptation, mitigation and technology development, transfer and dissemination. We call upon relevant inter-Governmental organizations, including FAO, within their mandates and areas of expertise, with the involvement of national Governments, partnerships, the private sector, and civil society, to foster a coherent, effective and result-oriented international dialogue on bio-fuels in the context of food security and sustainable development needs".

Current Status of Agriculture in India: India, in the context of following ground realities exhibiting low priority for agricultural development, must now necessarily prioritize agricultural development before adverse effects of climate change are self-evident. Agriculture in India has not only to be perceived in the context of attaining food security but also in terms of its growth rate & contribution to the country's growth process through increased GDP share.

- Agricultural growth rate was 1.2% in 2012-13 which increased to 3.7% in 2013-14 but again fell to 0.2% as against country's 7.3% economic growth rate in 2014-15.
- Food output in 2014-15 was 252.02 million tons significantly lower than 265.04 million tons in 2013-14 and 257.13 million tons in 2012-13.
- Growth rate of food output declined marginally from 2.19% during 1990-91 to 1999-00 to 2.11% during 2000-01 to 2013-14 whereas growth rate of yield per hectare significantly declined from 2.40% to 1.70% during the said period.
- Though gross cropped area and net sown area increased to 195.25 million hectares [MHA] and 140.80 MHA till 2011-12, area under food grains has remained almost stagnant, at 120.4 MHA over four-and-a-half decades.

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- The share of agriculture in India's GDP progressively declined from 41% in 1972-73 to 17.60% in 2014-15 but population depending on agriculture as the main source of livelihood declined to 48.9% from 59.9% between 1999-00 and 2011-12.
- India is currently home to the world's largest food insecure population with 190 million people going to bed hungry daily and India ranks 55 on the 2013 Global Hunger Index, according to the Washington based International Food Policy Research Institute. Hunger Index for India was 17.8 in 2014 which in a decade declined from 25.5 in 2000. About one sixth of India's population is undernourished & a total of 30% of children below age of five are underweight.
- Agricultural Census [2010–11] revealed that [i] out of 138.35 million operational holdings in India as high as 85% (which account for 44.6% of the total cultivated area) are less than two hectares characterising India's agriculture a small-scale-farming. Average size of small-holding is only 0.61 hectare whereas overall average size of holdings declined from 1.33 ha in 2000–01 to 1.15 in 2010–11 [ii] Around 98 million women are involved in agriculture & about 63% work as wage earners on land belonging to others. Over 74% of rural women who work as food producers only 13% have ownership rights to land.
- India ranks first among the rain-fed agricultural countries of the world in terms of both extent and value of produce. Rain-fed agriculture is practiced in two-thirds of the total cropped area of **162** million hectares [66%]. Rain-fed agriculture supports **40**% of the national food basket. The importance of rain-fed agriculture is obvious from the fact that 55% of rice, 91% coarse grains, 90% pulses, 85% oilseeds and 65% cotton are grown in rain-fed areas. These areas receive an annual rainfall between 400 mm and 1000 mm, which is highly uncertain, erratic and unevenly distributed in time & space. Certain areas witness significant fall in food output since the total annual rainfall does not exceed 500mm besides being erratic.

Besides, in view of the following facts, for India 4% annual agricultural growth rate and sustained development of agriculture acquires focused attention.

- A combination of indicator values representing exposure [change in temperature and precipitation], sensitivity [share of labor in agriculture] and adaptive capacity [poverty] identifies India, among other countries in Asia Pacific Region, most vulnerable to climate change.
- A global report on poverty eradication of the U.N. Secretary-General [2011] shows that economic growth is one evident for the progress in East Asia, particularly China in reducing extreme poverty and raising living standards whereas out of 900 million who are predicted to be in extreme poverty in 2015, India was expected to be home to more than 300 million in poverty.
- Child undernutrition with stunting rates in India declined from 48% in 2006 to 38.7% in 2015. Yet India continues to be home to a staggering 48 million stunted children under age 5 — the highest in the world. Stunting where children are short for their age, results from severe and persistent undernutrition. Most of them live in rural areas where their main source of income is the agricultural sector. Progress towards the World Food Security goal of reducing their numbers by half by 2015 under the United Nation's Millennium Development Goals has been unsatisfactory.

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- In areas highly dependent on livestock production, overgrazing increases vulnerability to climate change. Rural women will be among the most affected groups given their dependence on subsistence crops & dairy farming, their limited access to resources, and their inability to participate in decision-making process. Adaptation strategies should acknowledge the greater vulnerability of women to climate change.
- In areas highly dependent on livestock production, overgrazing increases vulnerability to climate change. Rural women will be among the most affected groups given their dependence on subsistence crops & dairy farming, their limited access to resources, and their inability to participate in decision-making process. Adaptation strategies should acknowledge the greater vulnerability of women to climate change.
- According to the United Nations World Water Assessment Programme [2015], while globally by 2050 the agricultural sector needs to produce 60% more food, the developing countries including India will need to produce 100% more when climate change would have also its impact on uncertainty of production and even reducing the potential output.
- Sustainable Development Goals adopted by the United Nations General Assembly in September 2015 stipulates developing countries, that include India, to develop agriculture and eliminate hunger by 2030
- World Bank report 2008 revealed that globally GDP growth originating from agriculture is at least twice as effective in reducing poverty as that which originates outside agriculture
- The role of small, marginal & women farmers in boosting food output and reduction of poverty is well recognized.

India's GHG Emissions: Percentage share of the electricity among eight key sectors in the GHG emissions in India [2007] was the highest at 38%, followed by agriculture [18%], other energy industries [12%], other manufacturing industries [9%], cement & transport each [7%] ,iron & steel [6%] and waste [3%]. The energy sector emissions comprise of emissions due to fuel combustion in electricity generation, solid fuel manufacturing, petroleum refining, transport, residential & commercial activities, agriculture & fisheries. It also includes the fugitive emissions due to coal mining, and handling of oil and natural gas. The largest chunk of emissions was from electricity generation amounting to 719.31 million tons of carbon dioxide equivalent which represented 65% of the total carbon dioxide equivalent emissions from the energy sector.

The results of five climate modeling studies in India show that the country's per capita estimated GHG emissions in 2030-31 would be between 2.77 tons and 5.00 tons of carbon dioxide equivalent. Four of five studies estimated that even in 2031, India's per capita GHG emissions would stay below 4.00 of carbon dioxide, which is lower than the global per capita emissions of 4.22 tons of carbon dioxide in 2005. This would mean that even two & half decades from now, India's per capita GHG emissions would be well below the global average of 25 years earlier. In absolute terms, estimates of the country's GHG emissions in 2031 vary from 4.00 billion tons to 7.30 billion tons of carbon dioxide. With four of the five studies estimating that even two & half decades from now, the country's GHG emissions will remain below 6.00 billion tons. All the five studies show evidence of a substantial and continuous improvement in the country's energy efficiency in relation to GDP.

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4. PROJECTED CLIMATE CHANGE SCENARIO & ITS IMPACT

India Meteorological Department [IMD] recorded eight out of 10 warmest years since 1901 and that too all years since 1993, of which all barring only one had mercury level higher than normal confirming beyond doubt that country's climate has already changed because of global warming. This is irrespective of whether the warming is on the long-term ascendant or cyclical in nature. The latest observations of the IMD substantiate the ominous projections made in some earlier studies that temperature in India would soar by 3.0 to 6.0 degrees Celsius and monsoon rainfall would be up to 15% to 50% by the end of the current century. The rise in the sea level as a consequence of the higher temperature [driven by faster melting of glaciers and higher rainfall] may alter the country's geography especially coastline by submerging several low-lying coastal areas, including the mangroves-rich Sundarbans. At another level, the disappearance of the river-feeding glaciers may dry up flows in the country's major rivers, including the mighty Ganga, and adversely impact agriculture to the detriment of the millions of farmers who lack the wherewithal to adjust to the changing climate. Overall farm production is forecast to drop by 10% to 40% due to the temperature rise by the end of this century, making the agricultural sector the worst sufferer, though its contribution to global warming is relatively meager.

Indeed its impact on the wheat crop has already begun since its output remained depressed for several years due to the early onset of summer. Some crops especially kharif crops like paddy may, however, benefit from the higher temperature. Climate models predict that sub-regional variation may increase in more extreme rainfall patterns, resulting in drought and floods, besides rise in sea level and more frequent occurrence of coastal storms and cyclones. The models such as those of the Indian Institute of Tropical Meteorology, predict a significant rise in surface air temperature over the subcontinent in the coming decades. If this happens, much of the country will have to contend with heavy rainfall as well as severe drought, both occurring with greater frequency. The glaciers in the Himalayas, which feed economically important rivers, have lost about 20% of their surface in the past four & half decades. They may retreat sharply because of a further rise in temperature. Studies in the past have shown that India is likely to witness one of the highest agricultural productivity losses in the world in accordance with the climate change pattern observed and scenarios projected. Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-4 degree Celsius with no substantial change in precipitation quantity. Indeed these are very serious indications/signs. It will need more focused attention & high priority for policy interventionists & scientific community to reduce the level of threat to the economy and human well-being.

5. STUDIES ON CLIMATE CHANGE IN INDIA

Agriculture is responsible for around 14% of global emissions. If the emissions from the agriculture are combined with the emissions caused by deforestation for farming, fertilizer manufacturing and agricultural energy use, this sector becomes the largest contributor to global emissions. In India, the agriculture sector in 2007 accounted for 17.6% of total emissions. At the same time, it consumed some one fourth of the electricity, so, it is indirectly responsible for another 10% of the GHG emissions. When these data were combined with the fertilizer industries, catering solely to agriculture, and use of diesel, agriculture was the largest contributor of GHG in India.

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Six of the 10 countries most vulnerable to climate change in the Asia-Pacific are Bangladesh [tops the list] followed by India, Nepal, the Philippines, Afghanistan and Myanmar. India has characteristic features of agriculture that challenges formulation of policies & implementation of programs to significantly reduce GHG emissions as also adaptation & mitigation strategies, viz. large country with diverse climate; 2/3 rain-fed area; higher monsoon dependency; diverse seasons, crops, & farming systems; close link between climate & water resources; small holdings; poor coping mechanisms & capacity; low penetration of risk management products, among others.

A World Bank report on climate change impact based on case studies in drought-prone regions of Andhra Pradesh & Maharashtra and flood-prone districts in Orissa on the extent of climate tolerance limits, highlights the possibility of declining the yields of major dry land crops in Andhra Pradesh, sugarcane yields declining by 30% in Maharashtra and rice production by 12% in the flood-prone coastal regions of Orissa. The worst sufferers would be the poor and marginal farmers who own less than one acre of land and mostly populate these regions.

Climate change and agriculture are interrelated. Agriculture contributes, of course partly, to the global warming by spewing greenhouse gas and in turn gets affected by its consequences. However, greenhouse emissions from different farm sectors and the effect of global warming on these sectors have not been quantified, except in few cases, such as wheat. The ICAR has estimated that annual wheat output may decline by four to five million tons with rise of every one degree Celsius in temperature. The impact of climate change will have to be mitigated by modifying farming practices by farmers as advocated by the ICAR based on various research studies. These studies shed some light on the emissions of greenhouse gases, such as methane, nitrous oxide and carbon dioxide arising from paddy fields and farm animals. They also explain the impact of climate change on some crops and other farm sectors like fisheries.

Studies conducted at the Indian Agricultural Research Institute indicate the possibility of loss of 4-5 million tons in wheat production in future with every rise of 1 degree Celsius temperature throughout the growing period. Rice production is likely to decrease by almost a ton/hectare if the temperature goes up by 2 degree Celsius. In Rajasthan, a 2 degree Celsius rise in temperature was estimated to reduce production of Pearl Millet by 10-15%. If maximum and minimum temperature rises by 3 degree Celsius and 3.5 degree Celsius respectively, then Soybean yields in Madhya Pradesh will decline by 5% compared to that in 1998. Agriculture will be worst affected in the coastal regions of Gujarat & Maharashtra, as fertile areas are vulnerable to inundation & salinization.

According to the ICAR, medium-term climate change predictions have projected the likely reduction in crop yields due to climate change at between 4.5% and 9% by 2039. The long term predictions paint a gloomy picture with the crop yields anticipated to fall by 25% or more by 2099. Milk output will decline by 1.5 -2.0 metric tons by 2020 & 15 tons by 2050. It will also affect fish breeding, migration & harvests.

Rice: The emissions, from country's 42.21 million hectares of land under rice cultivation, comprise about 2.07 Tg of methane [Tg is the unit of measurement of greenhouse gas emissions

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and is equivalent to 1012 grams], 0.19 Tg nitrous oxide and 72 Tg of carbon dioxide, annually. However, the emission levels vary from region to region depending on cultivation practices and the inherent carbon content of the soils. The methane outflow from the paddy fields of some districts in West Bengal has been observed to be relatively high. This is due to the presence of higher organic carbon content in the soils and the traditional practice of keeping rice fields constantly submerged under water. Similarly, emission of nitrous oxide is higher in paddy fields in Andhra Pradesh and northern States because of application of high doses of nitrogenous fertilizers. On the whole, the eastern and southern parts of the country have a relatively higher global warming potential because of higher discharge of methane and carbon dioxide and the predominance of rice cultivation in these regions.

Coconut: Studies on assessing the impact of climate change on coconut production in different agro-climatic zones indicate that this plantation crop will, by and large, benefit from global warming. Its productivity may rise by up to 4% by 2020 and up to 10% by 2050 in different regions. The coconut plantations in Kerala, Maharashtra, parts of Tamil Nadu and Karnataka stand to benefit more than those elsewhere. The coconut yields in some other States, such as Andhra Pradesh, Orissa and Gujarat may tend to decline marginally by up to 2%.

Water: Studies on the impact of global warming conducted in Andhra Pradesh indicate that the rise in temperature will lead to an increase in water requirement of crops like maize, groundnut, pigeon pea and cotton, though their growing duration will decrease by one to two weeks.

Livestock: In the case of methane emissions from the livestock sector, it has been observed that though cross-bred cattle discharge relatively more methane per animal, the bulk of the total emissions are accounted for by buffaloes and indigenous cattle because of their far larger population. Of the total livestock sector's greenhouse gas emissions, female buffaloes contributed 59.6%, followed by indigenous cows 28.9% and cross-bred cows 11.5%. The total emissions from this sector are reckoned at 9.37 Tg, varying in different years from 7.26 Tg to 10.4 Tg.

Adaptation: Some crops have already begun adjusting to climate change, for example, apple cultivation in Himachal Pradesh. Since temperatures in the traditionally apple-producing regions of this hilly State have risen, with a simultaneous decline in rainfall, apple cultivation is shifting to the higher altitudes in Kinnaur, Lahul and Spiti districts. Similarly, in the case of marine fisheries, species like Indian mackerel have tried to adapt themselves to the warming of the ocean waters by shifting towards the northern latitudes where the warming is less pronounced. Sardines have tended to spend more time in the lower depths of the oceans to escape from warmer surface waters. Such observations are significant as they can help farmers and fishermen modify their cultivation and fishing practices to mitigate the economic consequences of climate change.

Policy Initiatives: India has already initiated steps to address the issue of climate change focusing appropriate policies and investment programs to guarantee clean environment, improved quality of human life & agriculture. The Government of India had constituted a high-level committee in July 2007 and announced a National Action Plan on Climate Change on June 30, 2008. The efforts in this area of significant urgency to de-carbonize energy sources needs to

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be redoubled by serious concern, commitment and accountability and seeking effective coordination among departments, institutions and agencies in the long-term interest of survival and well-being of mankind .

6. NATIONAL MISSION

The National Mission for Sustainable Agriculture [NMSA] launched on June 26, 2015, forming part of the National Action Plan on Climate Change [June 2008], aims at transforming agriculture into an ecologically sustainable climate resilient production system, while at the same time, exploiting its fullest potential & thereby ensuring food security, equitable access to food resources, enhancing livelihood opportunities & contributing to economic stability at national level. Agriculture needs to progressively adapt to anticipated climate change & supported by the convergence and integration of traditional knowledge and practices. The committee has suggested a multi-pronged strategy to make it more resilient to climate change.

The NMSA would focus on four critical areas to agriculture in adapting to climate change viz. rain-fed agriculture, risk management, access to information & biotechnology. It has envisaged the Climate Change & Sustainable Agriculture Monitoring, Modelling & Networking to effectively disseminate climate change related information & knowledge by way of piloting climate change adaptation/mitigation research model projects in the domain of climate smart sustainable management practices. For this, the Union and State Governments must allocate adequate financial & human resources in their annual budgets and facilitate ICAR and State Agricultural Universities. These institutions should commit themselves to prepare a road map for undertaking time bound research & develop appropriate technologies for each of the country's agro-ecological regions and disseminate them among farming communities. The Union Ministry of Agriculture & States must monitor the implementation process on a quarterly basis & outcome discussed in the Parliament annually.

Rain-fed Agriculture: The strategies to minimize the impact of climate change in country's dry land regions include [i] development of drought & pest resistant crop varieties [ii] improving methods to conserve soil & moisture [iii] training farming community and sharing agro-climatic information & disseminating among farmers [iv] provision of financial support [credit & non-credit] to facilitate farmers to invest in and adopt relevant technologies to overcome climatic related stresses.

Risk Management: The risk management strategies emphasize on [i] strengthening of current agricultural & weather insurance mechanisms [ii] development & validation for weather derivative models [iii] creation of web-enabled, regional language based services for facilitation of weather based insurance [iv] development of GIS and remote-sensing methodologies for detailed soil resource mapping and land use planning at the level of watershed or a river basin [v] mapping vulnerable eco-regions and pest & disease hotspots and [vi] developing & implementing region-specific contingency plans based on vulnerability & risk scenarios.

Access to Information: Mission will focus on access to information through [i] improving and expanding the regional data bases on (a) Soil Profile, (b) Area Under Cultivation, Production And Yield, and (c) Cost of Cultivation & [d] weather, genotypes, land use patterns & water

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resources [ii] monitoring of glacier & ice-mass, impact on water resources, soil erosion and associated impact on agricultural production in mountainous regions [iii] providing information on off-season crops, aromatic & medicinal plants, greenhouse crops, pasture development, agro-forestry, livestock & agro-processing [iv] collation & dissemination of block level data on agro-climatic variables, land-use and socio-economic features & preparation of State level agro-climatic atlases [v] digitizing data, maintaining database of global quality, and streamlining the procedure governing access there to [[vi] creating public awareness through "National Portal" on agricultural Statistics.

Use of Biotechnology: Mission would intensify research on biotechnology [i] use of genetic engineering to convert C-3 crops to the more carbon responsive C-4 crops to achieve greater photosynthetic efficiency for obtaining increased productivity at higher levels of carbon dioxide in the atmosphere or to sustain thermal stresses [ii] development of crops with better water & nitrogen use efficiency which may result in reduced emissions of greenhouse gases or greater tolerance to drought or submergence or salinity [iii] development of nutritional strategies for managing heat stress in dairy animals to prevent nutrient deficiencies leading to low milk yield and productivity [iv] development of salt tolerant and disease resistant fresh water fish and prawn.

Research & Development: It is necessary to suitably increase funding & technological capabilities of the ICAR & State Agricultural Universities to intensify research on assembling genetic material for a warming India, develop through the tools of recombinant DNA technology novel genetic combinations for tolerance to higher temperature and moisture stress, and evolve flood and salinity tolerant strains of major crops. To successfully address the emerging challenges of climate change Indian farming system has to become knowledge-and-technology-intensive In this endeavor priority should be accorded to establish Research & Training Institute on Climate Change at the national level with its center in each of country's agro-climatic regions to conduct fundamental and applied research addressing the existing & emerging new issues on climate change, develop training modules and build a cadre of climate risk managers well versed in the science and art of climate management for every tehsil/.taluka/block. As suggested by Dr. Swaminathan, national cadre of grass-root climate risk managers will help, among others, trigger the proactive action needed to minimize human suffering and ensure livelihood, food and drinking water security in the emerging era of global warming and climate change.

Training of Farmers: Farmers need to be trained and their capacity & skill developed such that they are able to successfully manage monsoon both by art and science that hold the key to adaptation to adverse changes in temperature and precipitation caused by climate change, leading to more frequent occurrence of drought and floods.

Mitigation Strategy: Agriculture is one of the major sources of greenhouse gas emissions. Climate change has been a cause of serious concern if the agricultural sector has to grow in the context of country's overall economic growth, to respond to rural households' livelihood, country's food security and poverty alleviation. It may take some years to fully experience the devastating effects of climate change on agriculture but the time is ripe for the Government, private sector and public to have adequate concern, commitment and accountability to mitigate the effects of climate change. Evolving policy and programs to manage and mitigate risks due to

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climate change, among others, include [i] Significantly investing in expanding, modernizing and equipping agricultural meteorology facilities in all 127 agro-ecological regions to make it world class, thereby continuously improving weather and climate forecasting system.[ii] Improving early warning systems followed by effective monitoring and evaluating its impact [iii] Developing climate impact modules that give a better understanding of how climate change may affect crop, livestock, fish farming and forestry at a local level in order to be well prepared.[iv] Diversifying pattern of livelihoods and adapting agricultural, fishing and forestry practices to efficient water management &soil conservation practices and growing resilient crops and trees.[v] Developing a database on climate, soil and water use and crop yields to assess, map and monitor land-use performance under given technology conditions.. Assessment of how vulnerable our food system is and how we can adapt agriculture, livestock, fisheries and forestry to future climate-related disasters. Increasing coastal inundation, salinization and erosion as a consequence of sea-level rise and human activities may contaminate and reduce the size of productive agricultural lands, thereby threatening households' livelihood and country's food security. Steps in this case to mitigate the impact of climate change on agriculture need top priority [vi] Building sufficient resilience of the food systems to avoid enormous future economic losses in agriculture, livestock, fisheries and forestry [vii] Evolving comprehensive climate resilience strategies comprising risk assessment, development of varieties that can perform well in stressful conditions, better land, water and livestock management and bringing about specific changes in agricultural practices that can respond to climate change [viii] Agricultural research to evolve drought-resistant and saline-resistant crop varieties for the arid regions and rainfall-tolerant and short-duration varieties for flood-prone regions require significant amount of investment in financial & human resources which Government and private sector will have to make on one hand and motivate/train farmers to take better advantage of these researches and help them supplement their income through non-farm activities on the other.

Adaptation Strategy: While there is greater need now than before for effective implementation of "National Adaptation Program of Action on Climate Change" Important ongoing development initiatives need to be reviewed & redesigned to reduce vulnerability of agriculture to climate change. These, include restructuring agricultural market system, reducing market distortions and subsidies, effective implementation of liberalized trade policies, enhancing provision for social protection and micro-finance programs and preparing for disaster management. Adaptation will require continuous improvement in the existing development policies & introducing innovative policies from time to time that, *inter alia*, *emphasize* [i] reviewing & balancing investment allocation within and across sectors of socio-economic development [ii] increasing the focus to risk-sharing and risk-reducing investments [iii] improving spatial targeting of investments [iv] reducing GHG emissions from agriculture and increasing the value of sustainable farming practices through the valuation of carbon and other forms of agricultural ecosystem services, such as water purification and biodiversity. Key components of new and innovative adaptation measures to climate change, among others, include [i] appropriate changes in current farming practices to significantly improve soil productivity/fertility and enhance carbon sequestration [ii] changes in current water management policy & practices emphasizing pricing of water to facilitate more efficient water use [iii] intensive search for diversification of agriculture toward enhanced climate resilience [iv] attracting public & private investment in agricultural science and technology development, reinventing agricultural advisory & extension education services and information system [v] effective risk management policy & practices including crop, livestock

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& fishery insurance which can be shared from international experiences [vi] developing land use plans, food security, fisheries & forestry programs that can help farming community suitably adapt to climate changes [vii] undertaking cost-benefit analyses of climate change risks for irrigation management & coastal protection [viii] promotion of " best crop-livestock-fish farming practices" through farmers' capacity building and networking [ix] developing contingency plans to cover new and evolving risk scenarios

Risk-sharing & Risk-reducing investments: High degree of variability in weather and its impact on crop production requires priority to risk-sharing and risk-reducing investments, which include financial market innovations, weather-based crop insurance and broad-based social safety nets that protect farmers against the adverse impacts of increased risk and encourage them to take decisions that are not excessively risk-averse. Since international agricultural trade is one of the important mechanisms for sharing & minimizing climate change risk, open trading regimes needs to be supported. Investment policy to put in place hydro-meteorological infrastructure, efficient functioning financial markets, responsible institutions and appropriate agricultural advisory services can help farmers minimize the risks when they have to take decisions about agricultural production plans. Institutional innovations, such as contract farming, value chain, warehouse receipts, lease finance & integrated agricultural credit system can facilitate participation of small holders in export markets.

Adequate investment to upgrade the efficiency of the physical & institutional infrastructure for sustainable agricultural growth, such as modernizing irrigation system, constructing arterial paved roads connecting villages with urban centers, improving communication, transport & food processing facilities are, among others, areas that are directly related to managing risk. Besides, investment in capacity building of farmers is necessary to encourage them to adopt modern agricultural practices, such as integrated nutrient & pest management, conjunctive use of surface & groundwater resources. Since women contribute significantly to agriculture, risk management calls to empower women household specifically in terms of their legal rights to hold, acquire, possess & control over assets including agricultural land and enable them to participate in decision-making process for activities related to crop farming, livestock farming, fish harming & forestry.

Eliminating existing detrimental policies: Experience suggests that with the availability of subsidies farmers have been using fertilizers, diesel, electricity and water indiscriminately that results in the increased emission in the atmosphere. This, therefore, emphasizes that provision of subsidies for water, energy and fertilizers should be rationalized and reduced and the savings invested in propagating adaptation strategies that boost farm income. These subsidies have not only distorted production decisions, but also encouraged carbon emissions beyond economically appropriate levels. As the real price of natural resources rises market-based approaches for managing environmental services in response to climate change [such as through water pricing, payment for environmental services and carbon] will become increasingly important. Studies show that cost-effective & efficient delivery of institutional services on time & on payment to farmers have proved better than providing subsidy in any form. Effective implementation of market-based approaches to climate change policy including payment for environmental services will necessitate clear definition & explanation to protect land & water property rights. One way to levy or improve upon payment for environmental services is to create awareness among

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farmers & local communities and seek their participation/involvement to negotiate to determine the terms of the payments.

Synergies between Adaptation and Mitigation: Asia Pacific Region is a key emitter of agricultural GHG through fertilizers & soils [nitrous oxide] and livestock and rice production [methane]. Emissions in Asian agriculture are expected to increase due to the growth in food production required to feed growing population. The global technical mitigation potential of all strategies in the agriculture sector is estimated at 5,500 to 6,000 megatons of carbon dioxide equivalent per year [MTCDEPY] by 2030. Of this estimate, carbon sequestration accounts for nearly 90% of the potential, and methane mitigation and soil nitrous oxide emission reductions account for 9% and 2% respectively. Across the sub-regions of Asia, up to 50% of these emissions can be mitigated by 2030 for all GHG, much of which can be achieved through the implementation of zero and low-cost technologies that enhance carbon sequestration. Key low or no cost GHG mitigation activities in Asia Pacific Region include low or no tillage and other sequestration methods, as well as reducing methane emissions from rice fields. The China and India each could reduce methane emissions from rice fields by 26% over the base line scenario at low cost [that is less than $ 15 per ton of carbon dioxide equivalent] by 2020. Using high yielding varieties, shifting to rice and/or wheat production systems, and alternating dry/wet irrigation are strategies that both mitigate emissions and build resilience by conserving water, reducing land requirements and reducing fossil-fuel use. Asia could potentially reduce emissions by 276.79 MTCDEPY at a carbon price of $20 per ton of carbon dioxide equivalent, which accounts for approximately 18% of the total global economic potential [including soil carbon sequestration]. At this price, the benefit stream from agricultural mitigation in Asia could amount to more than $ 5.5 billion a year.

Biofuels: The use of high-yielding feedstock crops grown on existing crop land or degraded lands for biofuel production has the potential to other carbon savings compared with the use of conventional fossil fuels. The potential of biofuels to reduce carbon emissions, however, is highly dependent on the nature of the production process. The current generation of crop-based biofuels has had a low or even negative effect on carbon mitigation when land use change for biofuel production is taken into account. Ensuring that biofuel production does not create negative tradeoffs with food and land markets, land use change, biodiversity and environmental degradation, will require careful policy design as well as subsequent monitoring. From the farmer's point of view, biofuels are a cash crop that would generate higher incomes. Yet, while biofuel producers will likely benefit from the creation of new markets for their crops, the competition between food and fuel markets and the subsequent impact on food prices may outweigh the benefits of income generation under the current biofuel technologies.

Reduced release of methane from human waste: This can be achieved by [i] composting organic household garbage to make bio-fertilizer and [ii] treating all sewage water before releasing into oceans and rivers.

Property rights: A lack of appropriate legal framework & policy on property rights makes farmers [tenant farmers, share croppers, oral lessees, women headed households in particular] ineligible to borrow from formal financial institutions to invest in land for soil & moisture conservation, irrigation development, reclamation of land etc. which have direct relationship to

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improve farm productivity as they cannot secure future rights. Insecure land tenure reduces incentives to improve practices to cope with environmental degradation, which intensifies the adverse impacts of climate change and variability on crop production. Unsustainable land practices increase land degradation, which can further contribute to climate change. Increasing the profitability of land through its potential use for income from carbon markets and biofuels, may actually worsen the position of farmers with insecure property rights, as the land may be expropriated by landlords seeking to increase their share of new income streams. Meeting the challenges of climate change adaptation in agriculture requires long-term investment by farmers. Secure property rights are needed for these investments [such as integrated soil fertility management, tree planting, and water harvesting] that can guarantee farmers incentive and authority to make the investments. A clear policy & legal framework to protect land and water property rights of tenant farmers including women headed households is therefore an essential component in effective and equitable adaptation and market-based approaches to climate change policy.

Investment for Adaptations: Investment policy on climate change adaptation & its implementation has been extremely slow in the light of competing demand on country's annual budget and inadequate capacity in key ministries to assess adaptation requirements. To mainstream climate change adaptation, country needs to undertake multifaceted risk assessments that incorporate not only climate risk but also existing vulnerabilities, such as low levels of development, poor governance, political consensus, and expected future trends such as population growth, rapid urbanization & industrialization, and increasing pressure on scarce land and water resources. Qualitative and quantitative scenario will need to be developed at the country level and potentially at the regional or State levels. Combined with detailed economic analysis of adaptation options, these multifaceted risk assessment scenarios should serve as the basis for developing comprehensive and robust adaptation plans.

7. INVESTMENTS

Country has chronically invested inadequately in science, technology and innovation. Development of appropriate types of seeds using irradiation techniques, biotechnology and genetic modification is an essential component of adaptation to key biotic and abiotic stresses related to climate change, including drought, heat, floods, salinity, pests, and disease. These should be combined with tapping of traditional knowledge on crop varieties and adaptation. Policies that favor private sector investment in crop improvement program targeted to climate change are critical. These policies include [i] decreasing the bureaucratic hurdles to business formation [ii] developing infrastructure that enables the production and distribution of improved seeds and other agricultural inputs [iii] developing appropriate regulatory and biosafety protocols for the introduction of transgenic cultivars, and [iv] reforming intellectual property rights that could encourage private investment in crop improvement. A growing number of food companies are successfully adopting various sustainable pathways as new marketing strategies. This includes growing crops organically, offsetting GHG, sourcing fair trade, and promoting biodiversity. These companies' experience should be documented and lessons should be extracted on how the public sector can facilitate scaling up these initiatives.

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The growth of public investment in agricultural research slowed down after the 1980s. Investments in biotechnology and biosafety regulatory system have been inadequate to address pressing needs in both areas, especially when focused on resolving national constraints. The country needs to develop the infrastructure and scientific capacity to assess risk assessments and prescribe biosafety regulations to enable effective development and adoption of biotechnology.
Huge amount of investments in irrigation and water resources may be needed to expand large-scale storage to deal with the increased variability of rainfall and runoff. On the other hand, in agro-ecological regions where changes in precipitation are highly uncertain, investments may need to be better distributed in a variety of small catchments. Climate change and variability in water supply, together with potential long-term changes in the cost of energy, could also dramatically change the cost-benefit calculation for big dams & reservoirs for storage, irrigation, and hydropower, making these investments more attractive despite the environmental and human relocation issues that dams raise. The appropriate level and location of future irrigation investments could also change dramatically.

Bank Finance: Though India has a robust banking sector in terms of resources, size, spread & ownership, Banks, in the absence of a national policy and regulator for carbon credits are reluctant to finance projects taken up by industrial units to bring down carbon/GHG emissions. With climate change and its adverse effect on economies, health, food production and security etc. a sound policy framework on carbon credits, formal mechanism for trading in carbon emission reduction [CER] units, or carbon credits and a nodal agency for the development of the carbon credit market in India is a need of the hour. Banks' exposure to CDM projects can be classified as priority sectors lending which can facilitate charging of lower rate of interest. Besides, tax incentives will motivate banks to lend such projects. HSBC Global Research, in a report on investment opportunities in climate change in India, observed that climate change [three key climate change themes, viz. renewable, low carbon power and energy efficiency] presents long-term growth opportunity for investors in India, focusing on mitigation potential from curbing carbon emissions with Rs7.6 trillion [$150 billion] between 2008 and 2017.

8. TRIPLE WINS

Whether the world as a whole decides to lower carbon emissions by at least 50% by 2050, farmers and the farming system around the world need the support from policy interventionists and scientific community to lower the GHG emissions since agriculture alone accounts for nearly 15% of global carbon emissions and deforestation & forest degradation contribute another 15% emissions. Agriculture manifests four unique characteristics, viz. [i] it is a part of the problem as a GHG emitter [ii] a sector that is highly vulnerable to climate change, a vulnerability that can lead to reduced productivity [iii] a sector that provides livelihoods to 70% of the world's poor who largely depend on agriculture and [iv]provides food to all. And more importantly, agriculture is also a part of the solution by making it the *'triple wins'* i.e. increasing farm productivity, making agriculture more resilience to climate change and reducing carbon emission. It is possible for agriculture to actually sequester or absorb carbon into the soil rather than emitting it. Would it be possible to have higher yields, more carbon in the soil and greater resilience to droughts and heat? This is the territory of that golden '*triple win'* interventions that can increase farm output [to ensure food security and reduce poverty], make yields more resilient in the face of extremes [through adaptation] and make the farm a solution to the climate change

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problem rather than part of the problem [through mitigation]. The scientific community and policy interventionists have, therefore, an important role to make the agriculture sector and soil carbon part of the solution to climate change. The '*triple wins'* would require a package of interventions, which would be country-and locality specific in their application. China, Brazil and Kenya have made humble beginning in this direction through pilot projects researching new farming techniques that hold more carbon in the soil to increase the productivity of the soil. This necessitates preparing the Roadmap focusing concrete actions that link agriculture-related investments and policies with the transition to climate-smart growth and highlight a '*triple win'* approach. It should advocate getting the right policies and programs in place that will increase farm productivity and incomes; make agriculture more resilient to variations in climate [and thus promote stability and security]; and make the sector part of the solution to climate change by sequestering more carbon into the soil and biomass.

9. MAKING IMPLEMENTATION OF NMSA EFFECTIVE

Agriculture development in India needs to sharply focus on reducing GHG emissions through measures, such as significant reduction of deforestation; improving forest cover, conservation and management; control of wildfires; promotion of farm forestry for food, fodder & fuel ; soil carbon sequestration; restoring land through controlled grazing; improving nutrition for ruminant livestock; efficient management of livestock waste [through biogas recovery]; and developing strategies that conserve soil and water resources by improving their quality, availability and efficiency of use. For this, immediate need is to effectively implement the NMSA sharply focusing on following areas.

- From 16th October 2016 when India observes World Food Day the country's effort to meet the challenges of climate change should, therefore, become an integral part of the individual State Government's economic planning process & effective monitoring the implementation of four critical components of the NMSA.
- With the inclusion of the NMSA in India's National Action Plan on Climate Change as back as in 2008, national & State level research institutes have already concentrated to intensify research on developing technologies & innovative farming practices to cope with the changing climate. As the NMSA has been since 2008 [for more than eight years] It is now high time to mount in each agro-ecological region the Action Research Project seeking active participation of resourceful farmers to [i] evaluate the current status [2008 to 2016] of four critical components of the NMSA viz. dry land agriculture, risk management, access to information & biotechnology [ii] assess their impact of each component of NMSA on agriculture [iii] identify the factors responsible for better impact as also constraints inhibiting the progress [iv] formulate a road map crystalizing the strategy to achieve the expected results by 2030 under each component of the NMSA along with installation of robust monitoring & management information system [v] monitor & review the performance under each of four components half yearly at the State level & annually at national level [vi] discuss once in a year in the legislative assembly & parliament [vii] train farmers & build capacity of village/block/district panchayat to cope with the climate change through effective adaptation & mitigation strategies effects
- While a National Network Project "Impact, Adaptability and Vulnerability of Indian Agriculture to Climate Change" has been launched with focus on impact of climate change on different sectors of agricultural production it is necessary to estimate the need

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for public & private financial investments required by 2020 & 2030 to support intensification of research & put in place programs/projects on climate change adaptation, mitigation, technology development, transfer and dissemination strategies among farmers. The required funds & expertise can be sourced from World Bank, Asian Development Bank, International Fund for Agricultural Development, among others.

- Research & extension personnel need be trained & exposure visits organized to share & exchange knowledge & experiences.
- Other measures include Creating massive awareness among small farmers in particular on likely impact of climate change & adopting adaptations & mitigation strategies; Significant improvement in weather forecasting & early warning systems and water & energy use efficiency; Establishing hazard & vulnerability mapping; Effective regulatory framework to meet climate change related challenges to agriculture
- While State Agricultural Universities need to be adequately financially & organizationally strengthened to intensify researches on climate change in agriculture there is immediate need to establish Indian Institute of Climate Change in Agriculture at national level along with Regional Institute of Climate Change in Agriculture in each agro-ecological region equipped with state-of-the-art-technology & trained professional.

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