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CLIMATE SENSITIVITY OF INDIAN AGRICULTURE

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Abstract: *As the earth continues to warm, there is a growing risk that the climate will change in ways that will seriously disrupt our lives. While on average the globe will get warmer and receive more precipitation, individual region will experience different climate changes and environmental impacts. Climate is a primary determinant of agricultural productivity. Hence, agriculture has been a major concern in the discussions on climate change. In fact, the United Nations Framework Convention on Climate Change (UNFCCC) cites maintenance of our societal ability for food production in the face of climate change as one of the key motivations its existence and for its efforts in stabilizing greenhouse gas emissions (GHGE). Temperature, precipitation, atmospheric carbon dioxide content, the incidence of extreme events and sea level rise are the main climate change related drivers which impact agricultural production. In recent years there has been growing concern that changes in climate will lead to significant change to both market and non market sectors. This paper attempts to examine how climate change will affect agriculture in developing countries by exploring the case of India.*

[Keywords*: Climate change, Temperature, precipitation, atmospheric carbon dioxide content, agriculture production, India]*

I. INTRODUCTION

Over the past two decades the debate on global climate change has moved from scientific circles to policy circles with the world nations more seriously than ever exploring a range of response strategies to deal with this complex phenomenon that is threatening to have significant and far reaching impacts on human society. Global warming is defined as the increase in the average temperature on earth. Over the last 100 years, the average temperature of the air near the earth's surface has risen a little less than 1° Celsius (0.74±0.18°C, or 1.3 ± 0.32° Fahrenheit). It is responsible for the increase in storms, floods and raging forest fires throughout the globe. An increase of one degree Celsius makes the earth warmer more now than it has been in the last thousand years. Out of the 20 warmest years on record, 19 have occurred since 1980. The three hottest years ever observed have all occurred in the last ten years (2010 the warmest year on record). But, it is not only about

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how much the earth is warming, it is also about how fast it is warming. Global warming is increasing rapidly and there is widespread consensus that the current trend is caused by increased emissions of various greenhouse gases (GHGs). Greenhouse gases allow short wave solar radiation to pass into the earth's atmosphere. They absorb some of the long wave thermal radiation that is, otherwise emitted back out to space which results warming effect on our atmosphere. The emissions of greenhouse gases into the atmosphere come with industrialization, through deforestation, shifting cultivation and the expansion of intensive agriculture. Climate change is expected to have an impact on agricultural productivity and crop patterns directly because of alterations in temperature and rainfall and indirectly through changes in soil quality, pests and diseases. The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report observed that, warming of climate system is now unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea level (Solomon et al., 2007). Climate is a primary determinant of agricultural productivity. In turn, food and fiber production is essential for sustaining and enhancing human welfare. Hence, agriculture has been a major concern in the discussions on climate change. In fact, the United Nations Framework Convention on Climate Change (UNFCCC) cites maintenance of our societal ability for food production in the face of climate change as one of the key motivations its existence and for its efforts in stabilizing greenhouse gas emissions (GHGE). In particular, the yield of cereals is expected to decline in India, Africa and Middle East from 20 to 40 per cent. Extreme weather conditions such as high temperature, heavy rainfall, floods, drought etc. will also affect crop production. The policy implications are wide reaching as changes in agriculture could affect food security, trade policy, livelihood activities and water conservation issues impacting large portion of die population. Foodgrains production quadrupled during the post-independence era. The Indian Agricultural Research Institute (IARI) examined the vulnerability of agricultural production to climate change, with the objective of determining differences in climate change impacts on agriculture by region and by crop.

II. REVIEW OF LITERATURE

Rosenzweig and Parry (1994) have estimated significant adverse impact on the agriculture of many developing countries. Kumar and Parikh (2001a) estimated that without considering the carbon dioxide fertilization effects, yield losses for rice and wheat vary between 32 and 40percent, and 41 and 52 percent, respectively; and GDP would drop by between 1.8 to 3.4percent. Kumar and Parikh (2001b) estimated in their study that a 2°C temperature rise and 7 per cent increase in rainfall would lead to almost a 8.4 per cent loss in farm level net revenue (1990 net revenue expressed in 1980s prices) and regional differences are significantly large with northern and central Indian districts along with the

coastal districts bearing a relatively large impact. Mendelsohn *et al.* (2001) has compared the climate sensitivity of US, Brazilian and Indian agriculture and have argued that using the US estimates for assessing climate change impacts on Indian agriculture would lead to an under-estimation of impacts. Mall *et al.* (2006) reviewed the climate change impact studies on Indian agriculture and observed a significant drop in the yields of important cereal crops like rice and wheat under the changed climatic conditions. Aggarwal, et al. (2009) projected the impacts of climate change on Indian agriculture, he concluded that increase in CO_2 to 550 ppm increases yields of rice, wheat, legumes and oilseeds by 10 to 20 percent, 1°C increase in temperature may reduce yields of wheat, soyabean, mustard, groundnut, and potato by 3 to 7 percent and much higher loses at higher temperatures, and productivity of most crops to decrease only marginally by 2020 but by 10 to 40 percent by 2100. Viraktamath (2009) in his study has analyzed that a large fraction of the world's food is grown as rain fed annual crops in the tropics, where change in climate plays an important role in determining productivity.

III. OBJECTIVES

After reviewing the above studies the present paper has been undertaken to capture the following broad objectives:

- To examine the causes and extent of climate change.
- To study the inter-relation between climate change and agriculture.

IV. DATA SOURCES

The present study is entirely based on secondary data collected from various sources such as Government publications, reports, websites, newspapers and research journals. The data on crop area, production and yield are from the publications of the Directorate of Economics and Statistics, Ministry of Agriculture, State of Environment Report India, Environmental Information System (ENVIS) Ministry of Environment & Forests, Government of India

V. CAUSES OF CLIMATE CHANGE

Unsustainable consumption patterns of the rich industrialised nations are responsible for the threat of climate change. Only 25 percent of the global population lives in these countries, but they emit more than 70percent of the total global CO2 emissions and consume 75 to 80percent of many of the other resources of the world (Parikh et.al., 1991). In per capita terms, the disparities are also large: an Indian citizen emits less than 0.25 tonnes of carbon per year whereas a citizen of the USA, for example, emits more than 5.5 tonnes. Following are some causes of global climate change.

- **Rapid Growth of Economy**- Rapid economic growth will bring about fast changes in the standard of living which in turn will bring about a service and information economy based on clean and efficient technologies. The international community will no doubt formulate policy solutions for the reduction of greenhouse gases. But global warming will still occur, albeit not beyond a range of 1.1 to 2.9 degrees celsius. Sea level will rise between 18 and 38 centimeters until the end of the century.
- **Growth of Population**- Growth of population is another factor for global warming that put pressure on consumption of natural factors, which will change the global climate. This will push the global temperature to rise from 1.4 to 3.8 degree Celsius. As a result sea levels would increase from 20 to 40 centimeters by 2100. Rapid growth of population is likely to decline towards the second half of the century.
- **Use of Coal and Gas**- The world still runs mostly on coal and gas. It is here that predictions are most shocking; temperature gains of 2.4 to 6.4 degrees are predicted. The sea would rise by about 26 to 50 centimeters until the end of the century, flooding large coastal cities and numerous islands.
- **Fossil Fuels**- Petroleum and petrol products are still widely used; they are a part of a more balanced energy mix. It is predicted with their use by the end of the century, temperature will rise by some 1.7 to 4.4 degrees Celsius, with the oceans gaining from 21 to 48 centimeters. Rainfall is likely to decrease by some 20 percent in the subtropics, while more rain will fall in the northern and southern latitudes. The Gulf Stream will not stop, but it will lose about a quarter of its force.

VI. CLIMATE CHANGE SCENARIO IN INDIA

The climate of India may be broadly described as tropical monsoonal type. Its climate is affected by two seasonal winds, the North- East monsoon and the South-West monsoon. The North-East monsoon, commonly known as the winter monsoon blows from land to sea, whereas the South-West monsoon, known as the summer monsoon blows from sea to land after crossing the Indian Ocean, the Arabian Sea, and the Bay of Bengal. The South-West monsoon brings most of the rainfall during a year in the country. In India, climate change could represent an additional stress on ecological and socioeconomic systems that are already facing tremendous pressures due to rapid urbanization, industrialization and economic development. The country's large population and rapidly increasing energy use plays an important and growing role in global warming.

The Intergovernmental Panel on Climate Change, in its 2007 report, predicts that global temperatures will rise by 2-4.5^{o}C by the end of this century, with a 2.7-

4.3°C increase over India by the 2080s. The panel also predicated an increase in rainfall over the Indian sub-continent by 6-8 per cent and that the sea level would rise by 88 centimeters by 2100. An annual mean surface temperature rise by the end of this century, ranging from 3°C to 5°C (under A2 IPCC scenario) and 2.5°C to 4°C (under B2 IPCC scenario), with the warming more pronounced in the northern parts of India. A 20 per cent rise in all India summer monsoon rainfall and a further rise in rainfall are projected over all except Punjab, Rajasthan, and Tamil Nadu, which show a slight decrease. Extreme rise in maximum and minimum temperatures is also expected and similarly extreme precipitation is also projected, particularly over the West Coast of India and West Central India. Some impacts of global warming have already become visible in India. Monsoon rains have become less predictable, glaciers are melting, more floods and droughts occur, and mangrove forests are disappearing at an alarming rate. The table-1, below represents the projected region-wise temperature and precipitation changes for the period 2070-2099 with reference to the base period 1960-1990.

Table 1
Projected Changes in Climate in India: 2070-2099

Region	*Jan.-March*	*April-June*	*July-Sep.*	*Oct.-Dec.*
		Temperature Change (°C)		
Northeast	4.95	4.11	2.88	4.05
Northwest	4.53	4.25	2.96	4.16
Southeast	4.16	3.21	2.53	3.29
Southwest	3.74	3.07	2.52	3.04
		Precipitation Change (percent)		
Northeast	9.3	20.3	21.0	7.5
Northwest	7.2	7.1	27.2	57.0
Southeast	32.9	29.7	10.9	0.7
Southwest	22.3	32.3	8.8	8.5

Source: Cline (2007)

VI. AGRICULTURE'S CONTRIBUTION TO CLIMATE CHANGE:

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Global warming is projected to have significant impacts on conditions affecting agriculture. At the same time, agriculture itself is the major contributor in climate change primarily by increasing methane and nitrous oxide concentration in earth's atmosphere. Agriculture is one of the most weather-dependent of all human activities. It is ironic, then, that a significant percentage of greenhouse gas emissions come from agriculture. Fossil fuel intensive agriculture is contributing to the creation of the unpredictable weather conditions that all farmers will need to battle in the not-too-distant future. The agricultural sector is a driving force in the gas emission through land use change and forestry (LUCF) which affects climate change. Emissions from agricultural activities account for

about 14 per cent of global GHG emissions. Between 1995 and 2005, agricultural greenhouse gas emission in developing countries increased by 32 per cent accounting for about 75 per cent of total agricultural greenhouse gas emissions in 2005. During the same period, agricultural greenhouse gas emissions in developed countries decreased by roughly 12 per cent (UNFCCC, 2008). The FAO (2008) reports that agricultural greenhouse gas emissions growth is and will continue to be driven by greater demand for food as a result of the increasing human population. Figure-1, below represents the share of different sectors in green house gas (GHG) emissions.

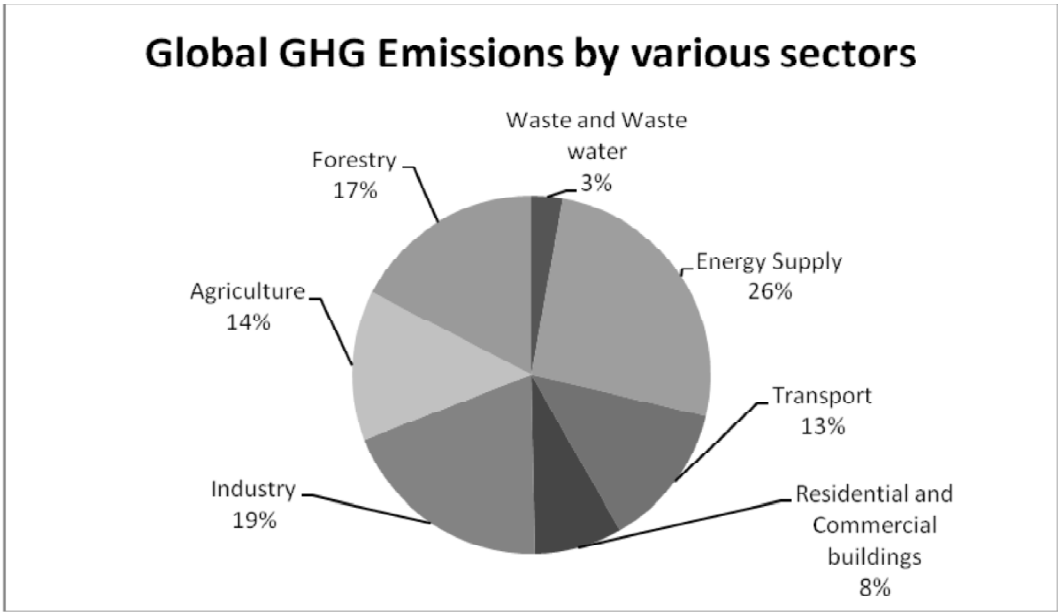

Figure-1

Source: World Development Report, 2010

Emissions from this sector are primarily methane and nitrous oxide, making the agricultural sector the largest producer of non-CO_2 emissions. Indeed, 60 per cent of the total global non-carbon dioxide emissions came from this source in 2000 (WRI, 2008). Apart from this agriculture has a considerable share in CO_2 emission. It contributes 14 percent share in total global CO_2 emissions (Figure-2). Agriculture contributes to CO_2 through deforestation which is driven by the conversion of forest to agricultural lands primarily in developing countries.

While production and transport of chemical fertilizers and pesticides lead directly to creation of greenhouse gases, use of these chemicals also does so indirectly by reducing farm soil's capacity to store carbon. Agriculture activity

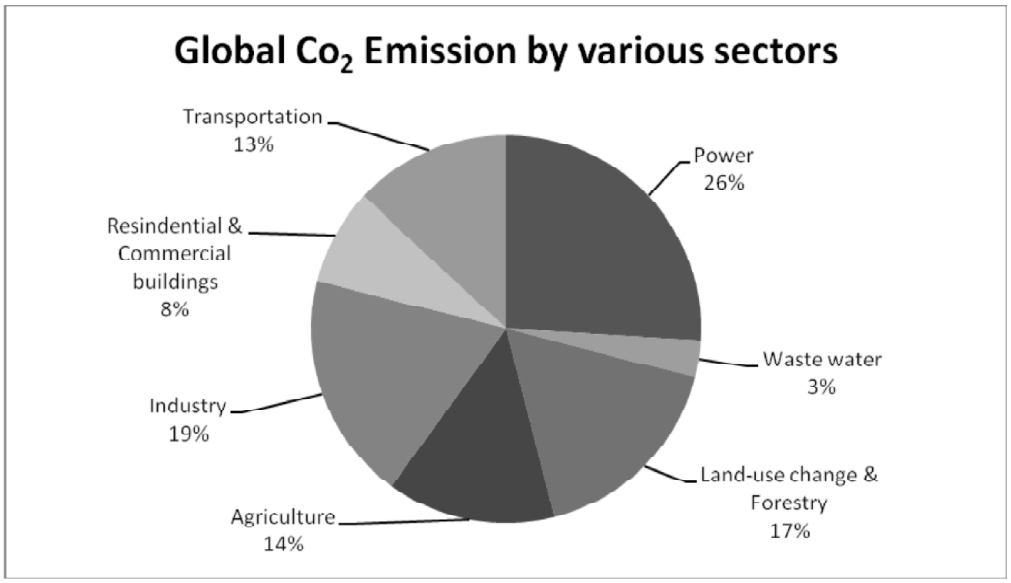

Figure 2

Source: World Development Report, 2010

may add nitrogen to soils through nitrogen fertilizer usage (USEPA, 2002). In India, fertilizer application, both synthetic and organic, is a major source of growth in nitrous oxide emission with 70 percent (IARI, 2008). India has many future developmental targets, several of which are directly or indirectly linked to energy consumption and therefore to GHG emissions. The contribution of India to the cumulative global CO_2 emissions is only 5 per cent (Figure 3). Thus historically, and at present, India's share in the carbon stock in the atmosphere is relatively very small in terms of per capita emissions. India's per capita carbon emissions average is one-twentieth of those of the US.

VII. CLIMATE CHANGE AND AGRICULTURE IN INDIA

India is a large developing country with nearly 700 million rural population directly depended on climate sensitive sectors (agriculture, forests and fisheries) and natural resources (such as water, biodiversity, mangroves, coastal zones, grasslands) for their subsistence and livelihoods. Agriculture represents a core sector of the Indian economy and provides subsistence and livelihood to the majority of the population. It provides employment to around 60 percent of the total work force in the country. Many of industries depend on agriculture for raw material. Agriculture growth has a direct impact on poverty eradication. It is also an important factor in containing inflation, rising agricultural wages and employment generation. The rural areas are the biggest markets of low and medium priced consumer goods

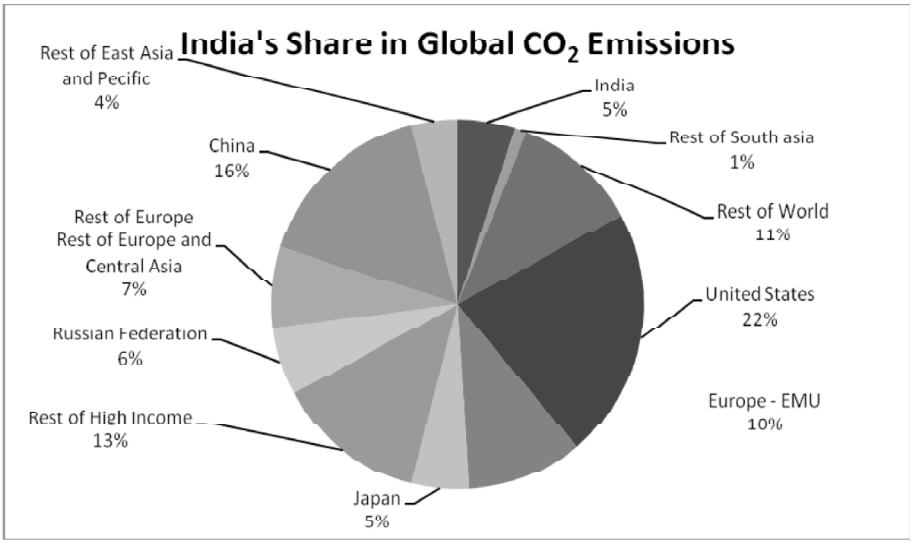

Figure 3

Source: World Development Indicators, 2007

and consumer durables. Rural domestic savings are an important source of resource mobilization. The contribution of agriculture to GDP is also substantial. Its share in GDP is 17.2 percent in 2008-09 (Economic Survey, 2009).

Climate change is a serious emerging threat to both mankind and any life form existing on planet earth. Climate change is likely to impact all the natural ecosystems as well as socio-economic systems as per the National Communications Report of India to the United Nations Framework Convention on Climate Change. It is expected to increase the average global temperature between 1.5°C to 4.5°C by 2050. This in turn will lead to decrease in yield of crops; forest fires, floods due to high precipitation; extreme weather leading to increase in the intensity of hurricane/cyclones; rise in sea levels due to the faster rate of melting of ice; glacier melting; ocean acidification due to increased level of carbon dioxide, delay in winter and increase in summer span, certain vector--borne diseases and adverse impact on natural ecosystems, such as wetlands, mangroves and coral reefs. Climate change, induced by global warming, will affect agriculture sector in the Indian sub-continent in many ways (Babu and Bhalachandran, 2009). Agriculture is more affected than other sectors of the economy by extreme weather events and adverse trends; flooding, drought, cold spells, heat waves, cyclones, typhoons, salinity intrusion, and soil degradation. Unfortunately, these are becoming more frequent and widespread. Indian agriculture depends heavily on vagaries of nature, particularly on the amount and distribution of rainfall, as more than 60 per cent of the area under cultivation does not have access to irrigation. Due to this, there are

wide yearly fluctuations in total output. Early signs of decrease in yields due to changing weather have started becoming visible. Climatic conditions are major factors in agricultural production in terms of plant growth and productivity. Yield of any crop is related to environment conditions in critical stages of plant growth. Therefore, agricultural production is influenced by climate factors such as amount of rainfall, distribution of rainfall and heat. In India, the direct impact of climate change would affect plant growth, development and yield due to changes in rainfall and temperature. Increase in temperature would reduce crop duration, increase crop respiration rates, change the pattern of pest attack and new equilibrium between crops and pests hasten mineralization in soils and decrease fertilizer use efficiency. All these could considerably affect crop yields in long run. In general, the simulation results indicate that increasing temperature and decreasing solar radiation levels pose a serious threat in decreasing growth and yield of agricultural crops. But the main culprit in climate change carbon emissions can also assist agriculture by increasing photosynthesis in many important, so called C_3, crops [such as wheat, rice, and soybeans] . The science, nevertheless, is far from certain on the benefits of carbon fertilization. On the other hand, it is well known that this phenomenon does not much assist C_4 crops [such as sugarcane and maize], which account for about one fourth of all crops by value. Increased CO_2 levels are expected to favor growth and increase crop yields and therefore, will be helpful in counteracting the adverse effects of temperature rise in future.

(a) Impact on Rice Production

According to various agricultural scientists, temperature increases are predicted to reduce rice yields. An increase of 2 to 4°C is predicted to result in reduction in yields. In this respect the Eastern regions are predicted to be the most impacted by increased temperatures and decreased radiations, resulting in relatively fewer grains and shorter grain filling duration. By contrast, potential reduction in yields due to increased temperatures in Northern India is predicted to be offset by higher radiation lessening the impacts of climate change. Sinha and Swaminathan (1991) showed that an increase of 2°C in temperature could decrease the rice yield by about 0.75 ton/ha in the high yield areas and in case of rice the yield in central region will be about 0.06 ton/ha.

(b) Impact on Wheat Production:

Studies shows that increase in temperature by about 2°C reduce potential grain yields in most places. Regions with higher potential productivity (such as Northern India) are relatively less impacted by climate change than areas with lower potential productivity. Reduction in yields as a result of climate change are predicted to be more pronounced for rain fed crops as (opposed to irrigated crops) and under limited water supply situations because there are no coping mechanisms for rain

fall variability. In sub-tropical environments there is a decrease in potential wheat. Sinha and Swaminathan (1991) showed that a 0.5°C increase in winter temperature would reduce wheat yield by 0.45 ton/ha.

Some efforts to mitigate climate change in the agricultural sector have also been undertaken, they are:

- Standardization of fuel-efficient pump sets and rectification of existing pump sets.
- Rationalization of power tariffs.
- Better cultivation practices which will help in reducing NO_2 emissions.

VIII. CONCLUSION AND SUGGESTIONS

The evidence presented in this paper suggests that climate change impacts are increasing over time indicating the increasing climate sensitivity of Indian agriculture. Being primarily an agrarian economy, it becomes very difficult for India to cope with such a challenge. It is clear that climate shift is due to manmade activities. As a result of increased GHGs, there would be increasing warmth in the earth, which may tilt modem agriculture and cause severe land loss due to sea level rise. There is negative correlation between agriculture and climate change which in turn affect human well-being. The cross sectional studies reveal that the effect of climate change is not uniform across India, some areas would lose heavily, most would be moderately damaged and some areas would benefit slightly. Warming would damage the western coastal districts heavily; districts in several eastern states along the coast would benefit. The greenhouse effect can be reduced by fol1owing measures–

- The small change in climate parameters can be managed reasonably well, and the losses minimized, by changing the planting schedules, spacing of the crop plants and input management.
- Better management of water and fertilizers in the paddy fields and changes in the diet livestock's herds. Such measure helps to cut down CH_4 & N_2O.
- Take up natural resources conservation activities like forestation, soil and water conservation and tillage on croplands.
- Adopt risk mitigation tools e.g. crop insurance, weather insurance and alternative options for livelihood.
- Innovative and improved fanning systems through small and micro enterprises policies could help boost local agricultural production by speeding up irrigation investment and subsidizing farm implements and high yield seeds.
- To curb methane emissions, enhance the efficiency of digestion with improved feeding, practices and dietary additives and managing rice paddies.

- Concessional and cooperative arrangements for technology development and transfer. Research and development in carbon saving and sequestration technologies should be promoted.
- Most important, if management of climate change becomes everybody's business, there can be safeguard ecological, food and livelihood security to the maximum extent possible.

Climate change is one of the major challenges of our time and adds considerable stress to our societies and to the environment. From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale. Without drastic action today, adapting to these impacts in the future will be more difficult and costly.

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