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CLIMATE CHANGE AND ITS EFFECT ON ENVIRONMENT AND AGRICULTURE

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Abstract: The climate is the general or average weather conditions of a certain region, including temperature, rainfall, and wind'. The earth's climate is most affected by latitude, the tilt of the Earth's axis, the movements of the Earth's wind belts, and the difference in temperatures of land and sea, and topography. Human activity, especially relating to actions relating to the depletion of the ozone layer, is also an important factor. The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. Increases in temperature coupled with more variable precipitation will reduce productivity of crops, and these effects will outweigh the benefits of increasing carbon dioxide. Livestock production systems are vulnerable to temperature stresses. An animal's ability to adjust its metabolic rate to cope with temperature extremes can lead to reduced productivity and in extreme cases death. Increases of atmospheric carbon dioxide (CO₂), rising temperatures, and altered precipitation patterns will affect agricultural productivity. Prolonged exposure to extreme temperatures will also further increase production costs and productivity losses associated with all animal products, e.g.- meat, eggs, and milk. Climate change will exacerbate current biotic stresses on agricultural plants and animals. Changing pressures associated with weeds, diseases, and insect pests, together with potential changes in timing and coincidence of pollinator lifecycles, will affect growth and yields. The potential magnitude of these effects is not yet well understood.

Opportunities for adaptation are shaped by the operating context within which decision-making occurs, access to effective adaptation options, and the capacity of individuals and institutions to take adaptive action as climate conditions change. The vulnerability of agriculture to climatic change is strongly dependent on the responses taken by humans to moderate the effects of climate change. Adaptive actions within agricultural sectors are driven by perceptions of risk, direct productivity effects of climate change, and by complex changes in domestic and international markets, policies, and other institutions as they respond to those effects worldwide. Anticipated adaptation to climate change in production agriculture includes adjustments to production system inputs, tillage, crop species, crop rotations, and harvest strategies. New research and development in new crop varieties that are more resistant to drought, disease, and heat stress will increase the resilience of agronomic systems to climate change and will enable exploitation of opportunities that may arise.

Keywords: Climate, Environment, Agriculture & crop.

Introduction: Effect of changing climate conditions on crop and livestock development and yield (e.g., changes in temperature or precipitation), as well as through the indirect (i.e., biotic) effects arising from changes in the severity of pest pressures, availability of pollination services, and performance of other ecosystem services that affect agricultural productivity. Climate change poses unprecedented challenges to Indian agriculture because of the sensitivity of agricultural productivity and costs to changing climate

conditions. Adaptive action offers the potential to manage the effects of climate change by altering patterns of agricultural activity to capitalize on emerging opportunities while minimizing the costs associated with negative effects. The aggregate effects of climate change will ultimately depend on a complex web of adaptive responses to local climate stressors. These adaptive responses may range from farmers adjusting planting patterns and soil management practices in response to more variable weather patterns, to seed producers

investing in the development of drought-tolerant varieties, to increased demand for Federal risk management programs, to adjustments in international trade as nations respond to food security concerns. Potential adaptive behaviour can occur at multiple levels in a highly diverse international agricultural system including production, consumption, education, research, services, and governance. Understanding the complexity of such interactions is critical for developing effective adaptive strategies.

This is particularly true for the agricultural sector where climate is a direct input into production. While the salience of this sector in India has declined over the years, it still remains important in the socio-economic fabric of the country. Though agriculture alone (other than forestry and fisheries) accounts for only about 15% of GDP, it employs 55% of the workforce. Moreover, according to the 2011 census 69% of the population remains rural and intimately connected to this sector. Our primary interest in this sector, however, is from the perspective of poverty which remains widespread despite significant progress in reducing it—the country is still estimated to have a third of the world's poor. A key aspect of poverty is its incidence which is rural and concentrated among agricultural labour. Thus, according to the Indian Planning Commission, in the year 2009-10 more than 1 in 3 of the rural population was poor (33.8%) whereas the figure for urban areas was about 1 in 5 (20.9%). Equally important for our analysis, nearly 50% of agricultural labourers were below the poverty line in rural areas.

Crop Response to Changing Climate: Plant response to climate change is dictated by a complex set of interactions to CO₂, temperature, solar radiation, and precipitation. Each crop species has a given set of temperature thresholds that define the upper and lower boundaries for growth and reproduction, along with optimum temperatures for each developmental phase. Plants are currently grown in areas in which they are exposed to temperatures that match their threshold values. As temperatures increase over the next century, shifts may occur in crop production areas because temperatures will no longer occur within the range, or during the critical time period for optimal growth and yield of grain or fruit.

For example, one critical period of exposure to temperatures is the pollination stage, when pollen is released to fertilize the

plant and trigger development of reproductive organs, for fruit, grain or fibre. Such thresholds are typically cooler for each crop than the thresholds and optima for growth. Pollination is one of the most sensitive stages to temperatures, and exposure to high temperatures during this period can greatly reduce crop yields and increase the risk of total crop failure. Plants exposed to warm night time temperatures during grain, fibre or fruit production also experience lower productivity and reduced quality. Increasing temperatures cause plants to mature and complete their stages of development faster, which may alter the feasibility and profitability of regional crop rotations and field management options, including double-cropping and use of cover crops an increase in winter temperatures also affects perennial cropping systems through interactions with plant chilling requirements. All perennial specialty crops have a winter chilling requirement (typically expressed as hours below 10°C and above 0°C) ranging from 200 to 2,000 cumulative hours. Yields will decline if the chilling requirement is not completely satisfied because flower emergence and viability will be low. Climate change affects winter temperature variability, as well; mid-winter warming can lead to early bud-burst or bloom of some perennial plants, resulting in frost damage when cold winter temperatures return.

Increasing carbon dioxide (CO₂) in the atmosphere is a positive for plant growth, and controlled experiments have documented that elevated CO₂ concentrations can increase plant growth while decreasing soil water-use rates. The effects of elevated CO₂ on grain and fruit yield and quality, however, are mixed; reduced nitrogen and protein content observed in some nitrogen-fixing plants causes a reduction in grain and forage quality. This effect reduces the ability of pasture and rangeland to support grazing livestock.

The effects of elevated CO₂ on water-use efficiency may be an advantage for areas with limited precipitation. Other changing climate conditions may either offset or complement such effects. Warming temperatures, for instance, will act to increase crop water demand, increasing the rate of water crops. Crops grown on soils with a limiting soil water-holding capacity are likely to experience an increased risk of drought and potential crop failure as a result of temperature-induced increases in crop water demand, even with improved water-use efficiencies. Conversely,

declining trends of near- surface winds over the last several decades and projections for future declines of winds may decrease evapotranspiration of cropping regions.

Crops and forage plants will continue to be subjected to increasing temperatures, increasing CO₂, and more variable water availability caused by changing precipitation patterns. These factors interact in their effect on plant growth and yield. A balanced understanding of the consequences of management actions and genetic responses to these factors will form the basis for more resilient production systems to climate change. Due to the complexities of these relationships, integrated research and development of management practices, plant genetics, hydrometeorology, socio-economics, and agronomy is necessary to enable successful agricultural adaptation to climate change.

Livestock Response to Changing Climate:

Animal agriculture is a major component of the U.S. agricultural system. Changing climatic conditions affect animal agriculture in four primary ways: (1) feed-grain production, availability and price; (2) pastures and forage crop production and quality; (3) animal health, growth and reproduction; and (4) disease and pest distributions. Optimum animal core body temperature is often maintained within a 2°C to 3°C range. For many species, deviations of core body temperature in excess of 2°C to 3°C cause disruptions of performance, production, and fertility that limit an animal's ability to produce meat, milk, or eggs. Deviations of 5°C to 7°C often result in death. For cattle that breed during spring and summer, exposure to high temperatures decreases conception rates. Livestock and dairy production may be more affected by changes in the number of days of extreme heat than by adjustments of average temperature. The combined effect of temperature and humidity affect animal response and are quantified through the thermal-humidity index. Livestock production systems that provide partial or total shelter to mitigate thermal environmental challenges can reduce the risk and vulnerability associated with adverse weather events. Livestock such as poultry and swine are generally managed in housed systems where airflow can be controlled and housing temperature modified to minimize or buffer against adverse environmental conditions. Protection of animals against exposure to high temperatures will require

modification of shelter and perhaps even methods of increasing cooling.

Warmer, more humid conditions will also have indirect effects on animal health and productivity through promotion of insect growth and spread of diseases. Climate affects microbial populations and distribution, the distribution of vector-borne diseases, host resistance to infections, food and water shortages, and food-borne diseases. Earlier springs and warmer winters may enable greater proliferation and survivability of pathogens and parasites. Regional warming and changes of rainfall distribution may lead to changes in the spatial or temporal distributions of diseases sensitive to temperature and moisture, such as anthrax, blackleg, hemorrhagic septicaemia, as well as increased incidence of ketosis, mastitis and lameness in dairy cows.

Effects of Climate Change on Soil and Water:

Climate change effects on agriculture also include the effects of changing climate conditions on resources of key importance to agricultural production, such as soil and water. Seasonal precipitation affects the potential amount of water available for crop production, but the actual amount of water available to plants also depends upon soil type, soil water-holding capacity, and infiltration rate. Healthy soils have characteristics that include appropriate levels of nutrients necessary for the production of healthy plants, moderately high levels of organic matter, a soil structure with good aggregation of the primary soil particles and macro-porosity, moderate pH levels, thickness sufficient to store adequate water for plants, a healthy microbial community, and absence of elements or compounds in concentrations toxic for plant, animal, and microbial life. Several processes act to degrade soils including, erosion, compaction, acidification, toxification, and net loss of organic matter.

Several of these processes are sensitive to changing climate conditions. Changes to the rate of soil organic matter accumulation will be affected by climate through soil temperature, soil water availability, and the amount of organic matter input from plants. Erosion is of particular concern. Changing climate will contribute to the erosivity from rainfall, snowmelt, and wind. Changes in production practices can also have effects on soil erosion that may be greater than other effects of climate change. Tillage intensity, crop selection, as well

as planting and harvest dates can significantly affect runoff and soil loss. Though the magnitude of these effects is still highly uncertain, studies have shown potential for significant increases of erosion loss, in part due to a reduction of projected crop biomass, which results in less overwintering residue available to protect the soil.

Climate change will affect surface-water resources, which account for 58% of water withdrawals for irrigated production nationally. Rising temperatures and shifting precipitation patterns will alter crop-water requirements, crop-water availability, crop productivity, and costs of water access across the agricultural landscape. Temperature and precipitation shifts are expected to alter the volume and timing of storm and snowmelt runoff to surface water bodies. Higher temperatures are projected to increase both evaporative losses from land and water surfaces, and transpiration losses from non-crop land cover, potentially reducing annual runoff and stream flow. The resulting shifts of water stress, crop yields, and crop competitiveness, in turn, will drive changes of cropland allocations and production systems within and across regions.

Agriculture, Energy and Climate Change: Agriculture has a major role in producing and using energy in ways that mitigate climate change. The production and use of agriculture-based fuels, such as biomass and biofuels, must be accompanied by careful consideration of environmental and social responsibility and rigorous and comprehensive assessment of the GHG emission from production of the biobase energy. The biophysical effects of climate change on yields and production costs are regionally variable and have the potential to significantly alter patterns of agricultural productivity in the provision of food, feed, fiber, and fuel products worldwide. Because the agricultural economy is a complex, self-adjusting set of relationships, ultimately climate change effects will depend on how production and consumption systems adjust, or adapt, in response to those biophysical effect.

A. Low Carbon Energy: Solar and Wind

- Low-carbon alternatives to fossil fuels include wind (to generate electricity or power pumps) and solar (to generate electricity and heat water or buildings). On-farm energy production eliminates the need to run electric lines or pipelines to remote locations. It also allows farmers to decrease their reliance on

increasingly expensive fossil fuels, produce energy from low carbon sources with fewer GHG emissions, develop new value-added revenue sources, reduce on-farm costs, and complement organic and sustainable farming practices. The National Sustainable Agriculture Information Service (ATTRA) provides extensive resources on renewable energy options for farms and ranches.

- Farmers and ranchers who own one acre of land or more and live in an area with good wind resources may consider harnessing wind energy to meet their energy needs in a cost-effective and environmentally responsible way. Wind turbines convert the kinetic energy in wind to mechanical energy, which can then be used to generate electricity. Farmers and ranchers who live in a state with net metering programs may be able to sell excess energy.

B. Energy from Agricultural Biomass

- Agricultural biomass is being targeted as a “second generation” agricultural source for bio energy, following on the heels of corn starch based ethanol. Much of the biomass being targeted is crop residues. Use of biofuels could substantially reduce gaseous emissions, provided that appropriate sources of feedstock are identified, especially those which do not degrade soil and environment quality.
- Recent research by a team of USDA Agricultural Research Service scientists led by Wally Wilhelm, a scientist with the Agro ecosystems Management Research Unit in Nebraska, indicates that the corn Stover needed to replenish soil organic matter was greater than that required to control either water or wind erosion in the ten counties investigated. Before major decisions are made about the percent of corn biomass or other crop residue that can be designated for energy production, efforts will be needed to explore less conventional crops that could supply a more sustainable supply of cellulosic feedstock without reducing soil.

C. Agricultural Bio-energy Crops: A primary objective is to supports the production of bio energy, especially bio fuels using agricultural resources, is to reduce global GHG emissions. The reasoning is that bio fuels are derived from plant-based carbon, which is drawn from atmospheric CO₂ during photosynthesis. When biofuel is combusted, CO₂ is released back into

the atmosphere, with no net increase in atmospheric CO₂.

There is significant controversy, however, regarding the overall “carbon neutrality” of bioenergy – particularly when derived from oilseeds (biodiesel), feed corn starch (ethanol) or even from some cellulosic sources. The controversy focuses on which factors should be included in the life cycle analysis for bioenergy, with much attention on the issue of indirect land conversion. If large amounts of agricultural land are used for bioenergy production, in the face of growing world population and increased food prices, the pressure increases to convert other land in grasslands or forests to agricultural food production. When land is broken for cultivation, a large amount of soil carbon is released. The released CO₂ could exceed the amount of net GHG emission reductions, relative to fossil fuel production and use, from the system for production of the bioenergy feedstock GHG increases from land conversion cannot be limited just to a local assessment because rapid climate change is a global phenomenon. The determination of bioenergy GHG emissions requires careful life-cycle analysis of the biofuel under consideration, including analysis of global land use change implications of establishing the specific biofuel feedstock. Life-cycle GHG emission analysis should also include GHG emissions from synthetic fertilizer and pesticides and other inputs used to produce the bioenergy feedstocks.

Agricultural bioenergy production could have some advantages. The establishment of a perennial crop such as switch grass may require less synthetic fertilizer and pesticides than corn. An annual biofuel crop could improve the conservation performance of an annual crop production system.

Climate Change and Agriculture in India:

India’s climate system has unique features that are often not well captured by global climate models; the most widely used being coupled atmosphere-ocean-sea-ice-land-surface models (AOGCMs) with a resolution of 250-300 km grids. India’s climate is dominated by the summer or southwest monsoon (and to a lesser extent the winter or northeast monsoon) and by the country’s physiological features such as the western and eastern ghats, the central plateau and the Himalayas. The summer monsoon and the rains that it brings are a major weather

phenomenon in the Indian subcontinent and deeply influence the lives of its inhabitants.

Out of the total net sown area of 141.0 million hectares (Mha) in India, rainfed area accounts for 85.0 Mha spread over 177 districts. This constitutes approximately 60 percent of the total farming area in the country. Rainfed agriculture contributes 44% of the total food grain production of the country and produces 75% of pulses and more than 90% of sorghum, millet and groundnut from arid and semiarid regions. Even after half a century of lopsided policies that have focused on pockets of the country and specific crops, rainfed regions provide livelihood to nearly 50% of the total rural workforce and sustain 60% of cattle population of the country^[2].

India as a whole mean annual temperature shows a significant warming trend of 0.51 degrees Celsius per 100 years during the period 1901-2007^[3]. More important, accelerated warming has been observed in the last approximately 40 years (1971-2007), mainly due to intense warming in the recent decade 1998-2007-10. Increases in the mean have been accompanied by a rise in both maximum and minimum temperatures at the all India level—by 0.71 and 0.27 degrees Celsius, respectively, per 100 years during the period 1901-2007. Also, as with mean temperature, there has been acceleration in trends of both maximum and minimum temperatures during 1971-2007. At the regional level, the homogenous regions 11 of east coast, west coast and the peninsula show an increasing trend in the frequency of hot days but northern India (north of 22 degree N) does not. With respect to the frequency of cold days, however, all seven homogenous regions show a decreasing trend (in the frequency of cold days).

Climate Change Effects and the Environment:

Meeting food demand in the future will involve multiple strategies, including intensification of production on existing land, expansion of agricultural land, and reduction of waste along the food supply chain^[4]. Reliance on specific adaptation mechanisms will depend on regional patterns of climate change; however, intensification and expansion of agriculture can have significant environmental implications. A multitude of concerns are linked with climate change, including increased water stress and competition with downstream aquatic systems, increased GHG emissions associated with land clearing, increased pesticide use, increased

nutrient loading, and loss of natural systems and the ecosystem services they provide^[5, 6, 7]. Potential environmental effects are associated with both intensification of agriculture and expansion of cropland. Identifying and incentivizing the adoption of environmentally friendly management practices that deal effectively with climate-change-related challenges, such as shifting diseases and pests and increased incidence of flooding and other extreme events, will be a critical and challenging element of a sustainable agricultural adaptation strategy for climate change. Environmental effects may also be reduced through adaptation and agronomic advancements that result in increased yields per acre^[8 & 6]). Suggest that incorporating environmental affects into decision making may fundamentally change agricultural systems by directing crop production toward areas where environmental effects from production are relatively low.^[4]

Economic Impacts and Agricultural Adaptation: Agricultural production is chronically vulnerable to stress factors like dry spells, weed competition, and insect damage. Local farm production patterns and practices have evolved in response to weather conditions and stress factors that have historically prevailed for that region. As growing conditions and stress factors change, so too will farm production decisions. Adaptation behaviours such as changing crops and crop varieties, adjusting planting and harvest dates, and modifying input use and tillage practices can lessen yield losses from climate change in some regions and potentially increase yields in others where climate change creates expanded opportunities for production^[9]. Capacity for adaptation is therefore a critical determinant of the net economic effects of climate change and of the regional distribution of those effects. Adaptive behavior can significantly mitigate the potential effects of climate change on food production, farm income, and food security by moving

Table-1. Predicted effects of climate change on agriculture over the next 50 years

Climatic element	Expected changes by 2050's	Confidence in prediction	Effects on agriculture
CO ₂	Increase from 360 ppm to 450 - 600 ppm (2005 levels now at 379 ppm)	Very High	Good for crops: increased photosynthesis; reduced water use
Sea level rise	Rise by 10 - 15 cm Increased in south and offset in north by natural subsistence/rebound	Very High	Loss of land, coastal erosion, flooding, salinisation of groundwater
Temperature	Rise by 1-20 C. Winters warming more than summers. Increased frequency of heat waves	High	Faster, shorter, earlier growing seasons, range moving north and to higher altitudes, heat stress risk, increased evapotranspiration

agricultural production out of regions with newly reduced comparative advantage in specific production sectors and into areas with improved relative productivity^[9 & 10].

Conclusion: Climate changes—temperature increases, increasing CO₂ levels, and altered patterns of precipitation, water resources, agriculture, land resources, and biodiversity. The literature reviewed for this assessment documents many examples of changes in these resources that are the direct result of variability and changes in the climate system, even after accounting for other factors. The growth of many crops and weeds is being stimulated. Migration of plant and animal species is changing the composition and structure of arid, polar, aquatic, coastal, and other ecosystems,^[11, 12]. Climate change, the outcome of the “Global Warming” has now started showing its impacts worldwide. Climate is the primary determinant of agricultural productivity which directly impact on food production across the globe^[13]. Agriculture sector is the most sensitive sector to the climate changes because the climate of a region/country determines the nature and characteristics of vegetation and crops. Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce final yield. Food production systems are extremely sensitive to climate changes like changes in temperature and precipitation, which may lead to outbreaks of pests and diseases thereby reducing harvest ultimately affecting the food security of the country. The net impact of food security will depend on the exposure to global environmental change and the capacity to cope with and recover from global environmental change^[14].

Coping with the impact of climate change on agriculture will require careful management of resources like soil, water and biodiversity. To cope with the impact of climate change on agriculture and food production, India will need to act at the global, regional, national and local levels.

Precipitation	Seasonal changes by $\pm 10\%$	Low	Impacts on drought risk' soil workability, water logging irrigation supply, transpiration
Storminess	Increased wind speeds, especially in north. More intense rainfall events.	Very low	Lodging, soil erosion, reduced infiltration of rainfall
	Increases across most climatic variables. Predictions uncertain	Very low	Changing risk of damaging events (heat waves, frost, droughts floods) which effect crops and timing of farm operations

Source: Ministry of Food and Fisheries 2000: Good Practice Guide for Handling Soils, Cambridge.

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