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Climate change consequences and its impact on agriculture and food security

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Abstract
Among the most significant impacts of climate change is the potential increase of food insecurity and malnutrition. Increasing Climate change make worse the risks of hunger and undernutrition through Extreme weather events. Climate change increases the frequency and intensity of some disasters such as droughts, floods and storms. This has an adverse impact on livelihoods and food security. Climate-related disasters have the potential to destroy crops, critical infrastructure, and key community assets, therefore deteriorating livelihoods and exacerbating poverty. Long-term and gradual climate risks cause, Sea-level rise as a result of climate change, affecting livelihoods in coastal areas and river deltas. Accelerated glacial melt will also affect the quantity and reliability of water available and change patterns of flooding and drought. Climate change affects all dimensions of food security and nutrition. Changes in climatic conditions have already affected the production of some staple crops, and future climate change threatens to exacerbate this. Higher temperatures will have an impact on yields while changes in rainfall could affect both crop quality and quantity. Climate change could increase the prices of major crops in some regions. For the most vulnerable people, lower agricultural output means lower incomes. Under these conditions, the poorest people who already use most of their income on food sacrifice additional income and other assets to meet their nutritional requirements, or resort to poor coping strategies.

Keywords: accelerated, chronic, deteriorating and community

1. Introduction
The multiple adverse impacts of global warming and climate change on food production involves many factors (fig 1). Global climate change is a change in the long-term weather patterns that characterize the regions of the world. The term "weather" refers to the short-term (daily) changes in temperature, wind, and precipitation of a region. In the long run, the climatic change could affect agriculture in several ways such as quantity and quality of crops in terms of productivity, growth rates, photosynthesis and transpiration rates, moisture availability etc. Climate change is likely to directly impact food production across the globe. Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce the yield. In areas where temperatures are already close to the physiological maxima for crops, warming will impact yields more immediately (IPCC, 2007). Drivers of climate change through alterations in atmospheric composition can also influence food production directly by its impacts on plant physiology. The consequences of agriculture's contribution to climate change, and of climate change's negative impact on agriculture, are severe which is projected to have a great impact on food production and may threaten the food security and hence, require special agricultural measures to combat with, a significant period of time. It is about non-normal variations to the climate, and the effects of these variations on other parts of the Earth. These changes may take tens, hundreds or perhaps millions of year. But increased in anthropogenic activities such as industrialization, urbanization, deforestation, agriculture and change in land use pattern etc. leads to emission of greenhouse gases (fig 2) due to which the rate of climate change is much faster. Climate change scenarios include higher temperatures, changes in precipitation, and higher atmospheric CO_2 concentrations (fig 3). There are three ways in which the Greenhouse effect may be important for agriculture. First, increased atmospheric CO_2 concentrations can have a direct effect on the growth rate of crop plants and weeds. Secondly, CO_2-induced changes of climate may alter levels of temperature, rainfall and sunshine that can influence plant and animal productivity.

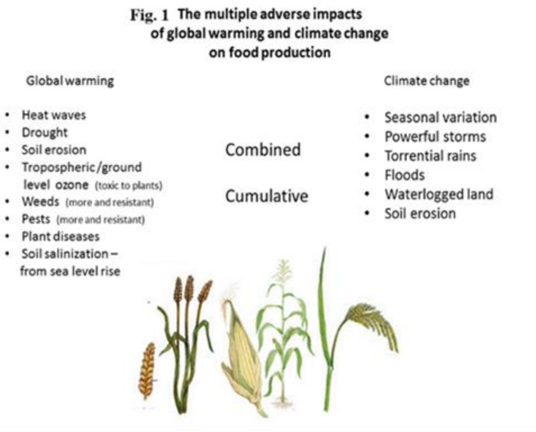


Fig. 1 The multiple adverse impacts of global warming and climate change on food production

http://www.climatechange-foodsecurity.org

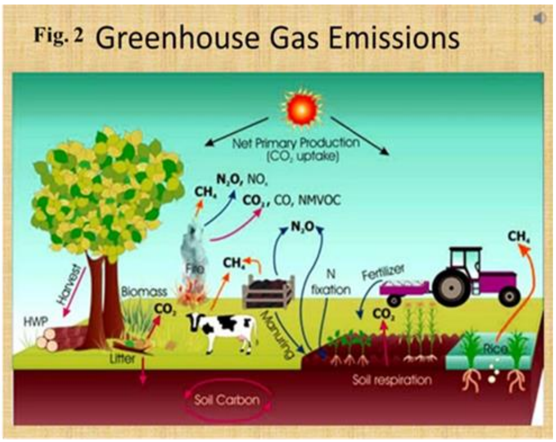


Fig. 2 Greenhouse Gas Emissions

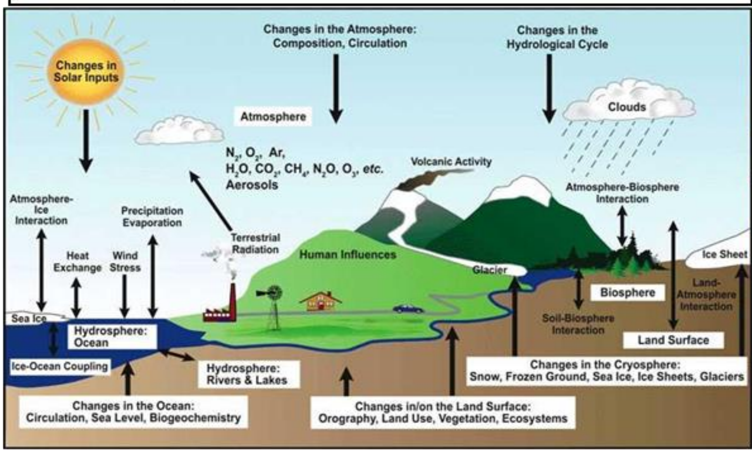
https://mix.office.com/watch/1rcc762pk00ra?lcid=1033

Finally, rises in mean sea level may lead to loss of farmland by flood and increasing salinity of groundwater in the coming decades and centuries. Sea-level rise will also increase the impact of storm flows which can cause great devastation. The greenhouse effect is a natural process that plays a major part in shaping the earth's climate. It produces the relatively warm and hospitable environment near the earth's surface where humans and other life-forms have been able to develop and prosper. However, the increased level of greenhouse gases (GHGs) (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 (fig 4). The average global surface temperature have increased by 0.74ºC since the late 19th Century and is expected to increase by 1.4ºC - 5.8ºC by 2100 century with significant regional variations (IPCC, 2007). The atmospheric CO_2 concentration has increased from 280 ppm to 395 ppm, CH_4 concentration increased from 715 ppm to 1882 ppm and N_2O concentration from 227 ppm to 323 ppm from the year 1750 and 2012. The Global Warming Potential (GWP) of these gases i.e, CO_2, CH_4 and N_2O are 1, 25 and 310 respectively.

2. Worldwide consequence of climate change

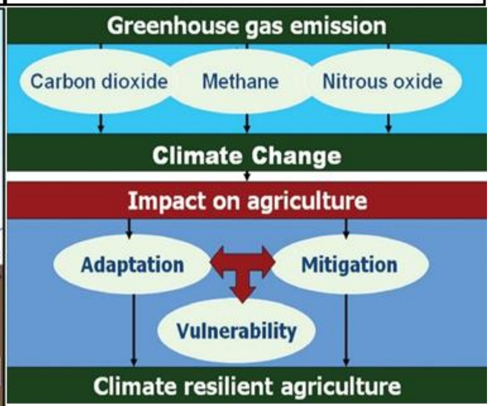
Climate change spurred the rise and fall of ancient civilization (fig 5). The five civilization were already destroyed by climate change (fig 6). Projected scenarios of global warming (fig 7) indicate that the global average surface temperature could rise by 1.4 to 5.8°C by 2100. The projected rate of warming is unprecedented during last 10,000 years. All climate models indicate a rising trend in temperature. Precipitation pattern has changed with decreased rainfall over south and south-east Asia. More intense and longer droughts have occurred since 1970s. Perpetual snow cover has declined on both area and depth of snow cover.

Fig. 3 Impact of various natural and human activity on climate change



http://www.climatecloud.co.nz/Climatechangemodelling

Fig. 4 Greenhouse gases causes climate change and affects agriculture



https://www.linkedin.com/pulse/climate-change-indian-agriculture-sakshi-nigam

Global mean sea level is projected to rise by 0.18 to 0.59 m by the end of the century. Six of the 10 countries most vulnerable to climate change are in the Asia-Pacific. Bangladesh tops the list followed by India, Nepal, the Philippines, Afghanistan and Myanmar. In Bangladesh, for example, about one-fifth of the nation's population would be displaced as a result of the farmland loss estimated for a 1.5 m sea-level rise. The Maldives Islands in the Indian Ocean would have one-half of their land area swamped with a 2 m rise in sea level.

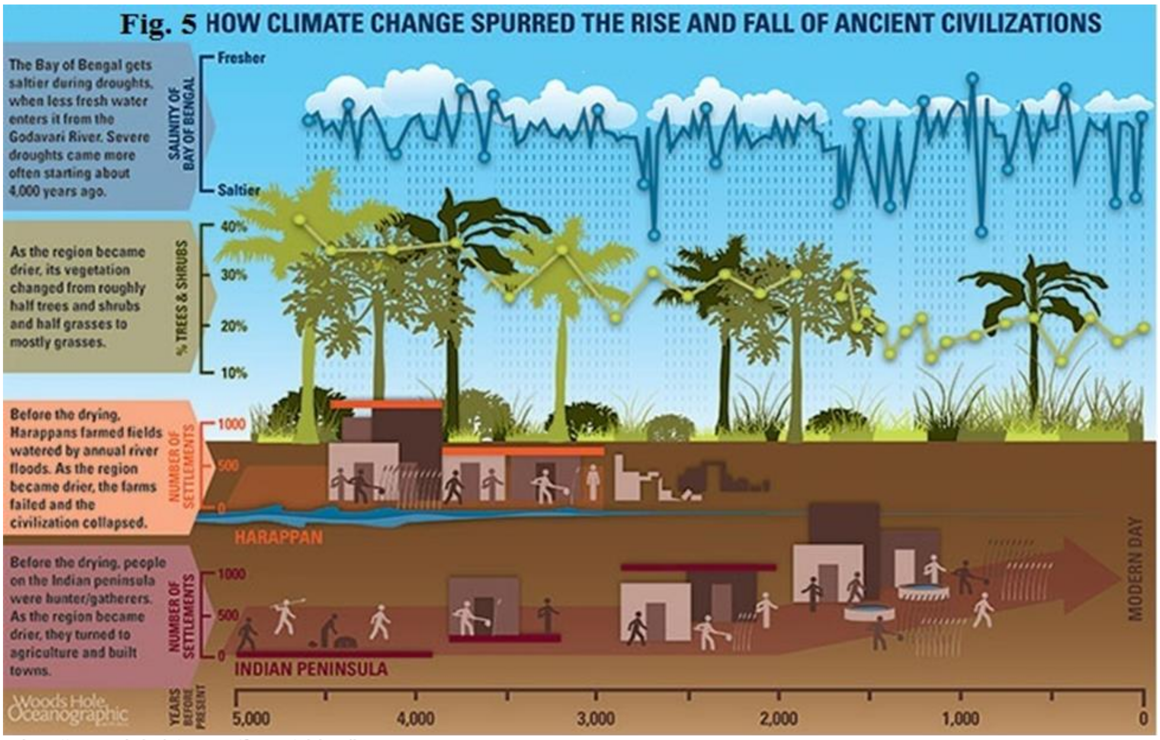


Fig. 5 HOW CLIMATE CHANGE SPURRED THE RISE AND FALL OF ANCIENT CIVILIZATIONS

https://www.whoi.edu/oceanus/feature/LiviuIndia

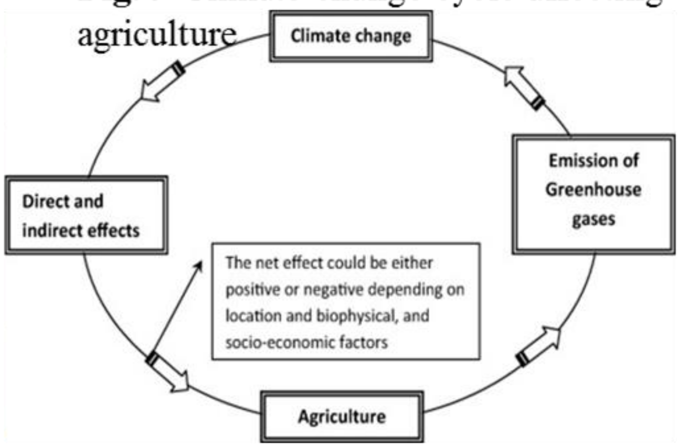
3. India's situation on climate change

The warming may be more pronounced in the northern parts of India. The extremes in maximum and minimum temperatures are expected to increase under changing climate, few places are expected to get more rain while some may remain dry. Leaving Punjab and Rajasthan in the North West and Tamil Nadu in the South, which show a slight decrease on an average a 20 percent rise in all India summer monsoon rainfall over all states are expected (fig 8). Number of rainy days may come down (e.g. Madhya Pradesh) but the intensity is expected to rise at most of the parts of India (e.g. North East). Gross per capita water availability in India will decline from 1820 m^3/year in 2001 to as low as 1140 m^3/year in 2050.

Corals in Indian Ocean will be soon exposed to summer temperatures that will exceed the thermal thresholds observed over the last 20 years. Annual bleaching of corals will become almost a certainty from 2050. Currently the districts of Jagatsinghpur and Kendrapara in Odisha; Nellore and Nagapattinam in Tamilnadu; and Junagadh and Porabandar districts in Gujarat are the most vulnerable to impacts of increased intensity and frequency of cyclones in India (NATCOM, 2004). The past observations on the mean sea level along the Indian coast show a long-term (100 year) rising trend of about 1.0 mm/year. However, the recent data suggests a rising trend of 2.5 mm/year in sea level along Indian coastline.

Fig. 6 Five civilizations destroyed by climate change

Fig. 9 Climate change cycle affecting agriculture



https://www.sciencedirect.com/science/article/pii/S2212096316300250

The sea surface temperature adjoining India is likely to warm up by about 1.5–2.0°C by the middle of this century and by about 2.5–3.5°C by the end of the century. A 1 meter sea-level rise is projected to displace approximately 7.1 million people in India and about 5764 square km of land area will be lost, along with 4200 km of roads (NATCOM, 2004). Over 50% of India's forests are likely to experience shift in forest types, adversely impacting associated biodiversity, regional climate dynamics as well as livelihoods based on forest products. Even in a relatively short span of about 50 years, most of the forest biomass in India seems to be highly vulnerable to the projected change in climate. Further, it is projected that by 2085, 77% and 68% of the forested grids in India are likely to experience shift in forest types.

4. Agricultural comebacks to probable climate change dynamics

Climate change scenarios include higher temperatures, changes in precipitation, and higher atmospheric CO_2 concentrations which may effect on yield (both quality and quantity), growth rates, photosynthesis and transpiration rates, moisture availability, through changes of water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers etc. Environmental effects such as frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion, land availability, reduction of crop diversity may also affect agricultural productivity (Fig 9). An atmosphere with higher CO_2 concentration would result in higher net photosynthetic rates (Cure & Acock 1986, Allen *et al*. 1987). Higher CO_2 concentrations may also reduce transpiration (i.e. water loss) as plants reduce their stomatal apertures, the small openings in the leaves through which CO_2 and water vapor are exchanged with the atmosphere. The reduction in transpiration could be 30% in some crop plants (Kimball 1983). However, stomatal response to CO_2 interacts with many environmental (temperature, light intensity) and plant factors (e.g. age, hormones) and, therefore, predicting the effect of elevated CO_2 on the responsiveness of stomata is still very difficult (Rosenzweig & Hillel 1995). For every 75 ppm increase in CO_2 concentration rice yields will increase by 0.5 t/ha, but yield will decrease by 0.6 tons/ha for every 1°C increase in temperature (Sheehy *et al*., 2005). CO_2 enrichment have generally shown significant increases in rice biomass (25-40%) and yields (15-39%) at ambient temperature, but those increases tended to be offset when temperature was increased along with rising CO_2 (Ziska *et al*., 1996a,b; Moya *et al*., 1998). Yield losses caused by concurrent increases in CO_2 and temperature are primarily caused by high-temperature-induced spikelet sterility (Matsui *et al*., 1997a). Increased CO_2 levels may also cause a direct inhibition of maintenance respiration at night temperatures higher than 21°C (Baker *et al*., 2000).

Fig. 7 Flow chart of climate change and food security

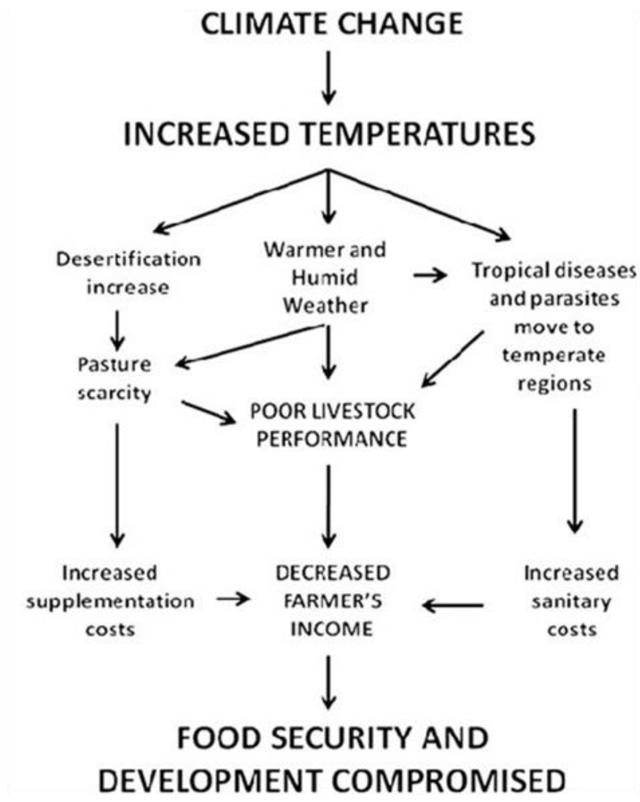
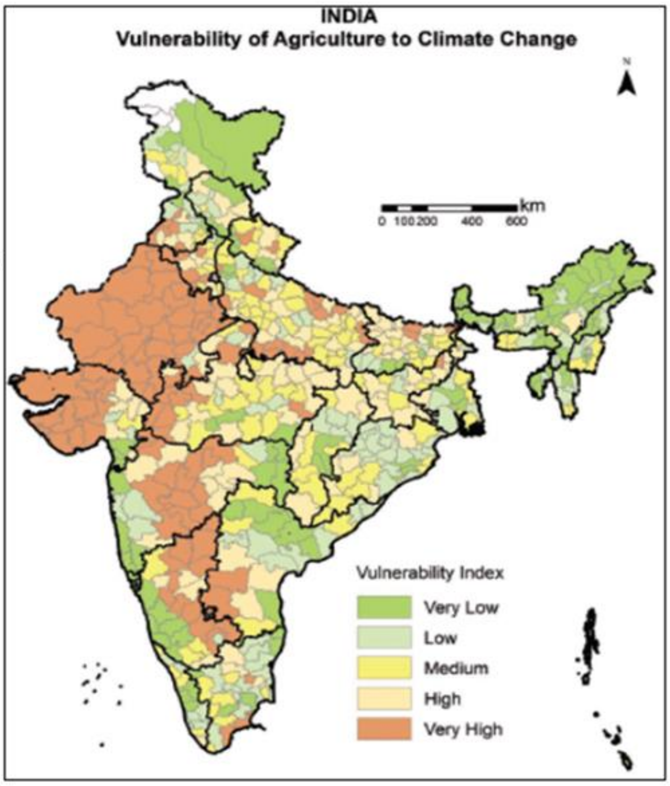


Fig. 11 Susceptible agriculture to climate change in India



http://www.orfonline.org/research/climate-change-and-food-security-in-india

https://www.researchgate.net/figure/Schematic-view-of-the-expected-outcome-of-climate-change-as-a-consequence-of-global_fig3_233426652

In rice, extreme maximum temperature is of particular importance during 3 flowering which usually lasts two to three weeks. Exposure to high temperature for a few hours can greatly reduce pollen viability and, therefore, cause yield loss. Spikelet sterility is greatly increased at temperatures higher than 35°C (Osada *et al*., 1973; Matsui *et al*., 1997b) and enhanced CO_2 levels may further aggravate this problem, possibly because of reduced transpirational cooling (Matsui *et al*., 1997a). A key mechanism of high temperature-induced floret sterility in rice is the decreased ability of the pollen grains to swell, resulting in poor thecae dehiscence (Matsui *et al*., 2000). Significant genotypic variation in high-temperature induced floret sterility exists. Variation in solar radiation, increased maintenance respiration losses or differential effects of night vs. day temperature on tillering, leaf-area expansion, stem elongation, grain filling, and crop phenology have been proposed as possible causes (Peng *et al*., 2004; Sheehy *et al*., 2005). In a recent climate chamber study, there was first evidence of possible genotypic variation in resistance to high night temperatures (Counce *et al*., 2005) High CO_2 levels and temperature are likely to affect crop development rates.

Projected effects of climate change on farming over the next 50 years (Source: Climate change and Agriculture, MAFF (2000)

Climatic component	Projected changes by 2050's	Assurance in estimate	Effects on farming
CO2	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, salinization of groundwater
Temperature	Rise by 1-2oC. 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
Precipitation	Seasonal changes by ± 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
Variability	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

Warming will accelerate many microbial processes in the soil-floodwater system, with consequences for the C and N cycle. Crop residue decomposition patterns may change. Increased soil temperature may also lead to an increase in autotrophic CO_2 losses from the soil caused by root respiration, root exudates, and fine-root turnover. Climate change impacts will also impact on rice production through rising sea level rise. Most studies project decreased yields in non-irrigated wheat and in rice, and a loss in farm-level net revenue between 9% and 25% for a temperature increase of 2–3.5°C. Aggarwal and Mall (2002) observed that a 2°C increase resulted in a 15–17% decrease in grain yield of rice and wheat. Fungal and bacterial pathogens are also likely to increase in severity in areas where precipitation increases. Under warmer and more humid conditions cereals would be more prone to outbreaks of pest and diseases thereby reducing yield.

4.1 Influence of weather alteration on world's agriculture

Climate change is likely to directly impact on food production across the globe. Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce final yield. In areas where temperatures are already close to the physiological maxima for crops, warming will impact yields more immediately (IPCC, 2007). World agriculture faces a serious decline within this century due to global warming. Overall, agricultural productivity for the entire world is projected to decline between 3 and 16 % by 2080. Developing countries, many of which have an average temperatures that are already near or above crop tolerance levels, are predicted to suffer an average 10 to 25% decline in agricultural productivity the 2080s. Rich countries, which have typically lower average temperatures, will experience a much milder or even positive average effect, ranging from an 8% increase in productivity to a 6% decline. Individual developing countries face even larger declines. India, for example, could see a drop of 30 to 40%.

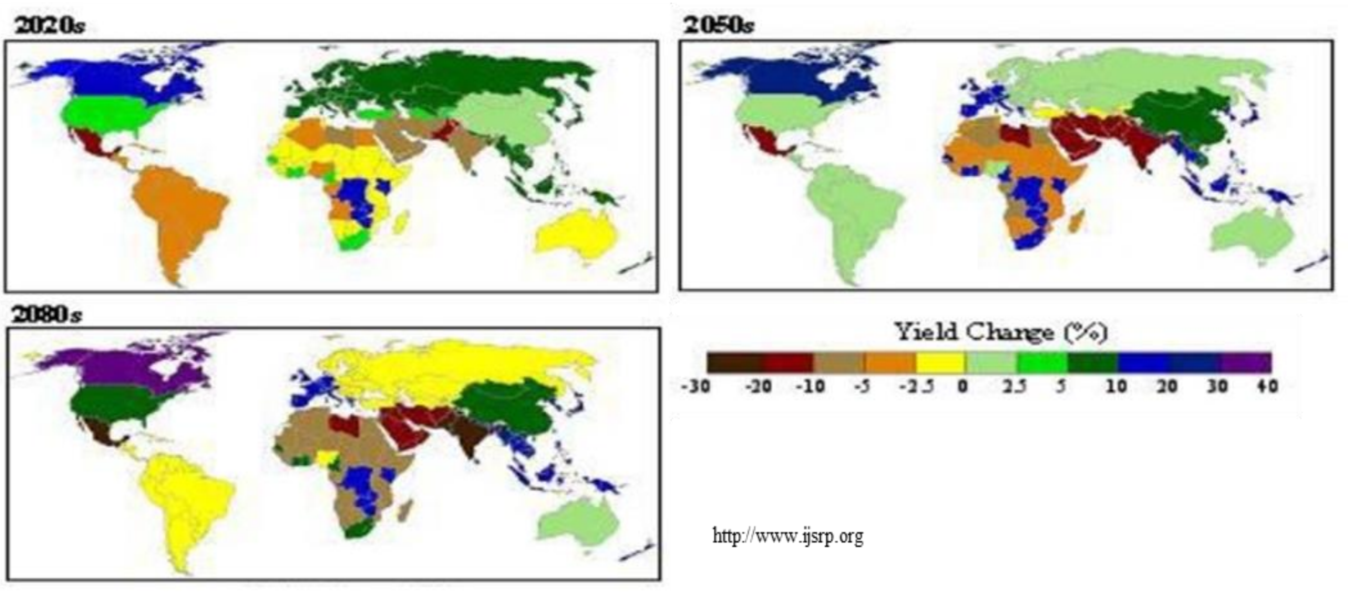


Fig 10: Results of models showing possible crop yields in the future

Impacts of climate change in 2020, 2050, 2080 scenario on various crops

Crop	Climate Change Impact
Rice	Projected reduction in rice productivity (2020 to 2080): 4-10% in irrigated rice & 2.5 to 6% in rainfed rice
	Pollen sterility and poor germination of pollen due to high temperatures, adverse effect on basmati rice
Wheat	Projected reduction in wheat yield (Global - MIROC3.2.HI, Regional - PRECIS): 6-23% by 2050; 15-25% by 2080
	High thermal stress during post flowering period reduced wheat yield by 18%
Mustard	60% reduction (projected)
Potato	12% reduction (projected)
Apple	1°C increase in the Himalayan region is adversely affecting apple yield
Sorghum	2-14% reduction in Kharif sorghum yield by 2020 Worsening impact by 2050 and 2080
Maize	18% reduction at regional level in irrigated kharif maize by 2050 due to warming which can be partly off-set by increased rain
Milk	Annual loss (production) of 1.8 mt by 2020 based on ambient THI with maximum impact in U P, Tamil Nadu, Rajasthan and West Bengal

http://www.google.co.in/search/slideplayer.com/slide/3844425

The figure shows the results obtained using the Hadley climate model for the years 2020, 2050 and 2080. The maps show that increased temperatures in many parts of Africa will reduce food production. The decrease in rainfall in Australia will reduce crop yields but this decline can be overcome by irrigation in some cases. The increase in rainfall combined with a moderate increase in temperatures in North America may benefit food production. The burden of climate change is likely to fall disproportionately on the poorer countries of the world. To interpret the maps we have to remember that the results obtained depend on climate, the effect of CO_2 levels on crop growth and changes in socioeconomic conditions. For example, in developed countries lower rainfall levels can be overcome through irrigation but these technological solutions are not necessarily possible in less developed countries.

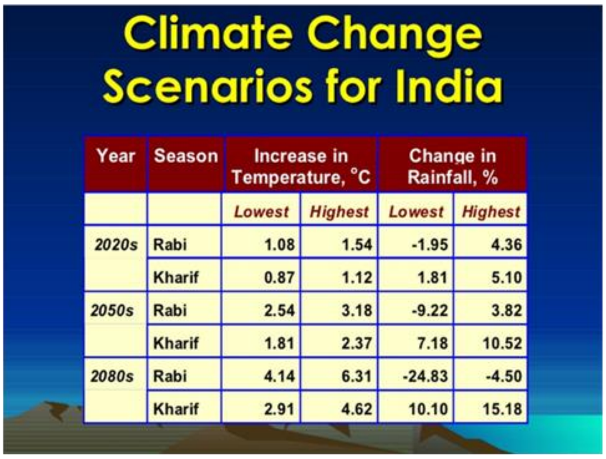
4.2 Impression of Climate modification on India's Farming

India's agriculture is more dependent on monsoon from the ancient periods. Any change in monsoon trend drastically affects agriculture. Even the increasing temperature is affecting the Indian agriculture. In the Indo-Gangetic Plain, these pre-monsoon changes will primarily affect the wheat crop (>0.5ºC increase in time slice 2010-2039; IPCC 2007). In the states of Jharkhand, Odisha and Chhattisgarh alone, rice production losses during severe droughts (about one year in five) average about 40% of total production, with an estimated value of $800 million (Pandey, 2007). Increase in CO_2 to 550 ppm increases yields of rice, wheat, legumes and oilseeds by 10-20%. A 1ºC increase in temperature may reduce yields of wheat, soybean, mustard, groundnut, and potato by 3-7%. Much higher losses at higher temperatures. Productivity of most crops to decrease only marginally by 2020 but by 10-40% by 2100 due to increases in temperature, rainfall variability, and decreases in irrigation water. The major impacts of climate change will be on rain fed or un-irrigated crops, which is cultivated in nearly 60% of cropland. A temperature rise by 0.5ºC in winter temperature is projected to reduce rain fed wheat yield by 0.45 tons per hectare in India (Lal *et al*., 1998). Possibly some improvement in yields of chickpea, rabi maize, sorghum and millets; and coconut in west coast. 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 (fig 11). Recent studies done 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 1ºC temperature throughout the growing period. Rice production is slated to decrease by almost a tons/hectare if the temperature goes up by 2ºC. In Rajasthan, a 2ºC rise in temperature was estimated to reduce production of Pearl Millet by 10-15%. If maximum and minimum temperature rises by 3ºC and 3.5ºC respectively, then Soya bean yields in M.P will decline by 5% compared to 1998. Agriculture will be worst affected in the coastal regions of Gujarat and Maharashtra, as fertile areas are vulnerable to inundation and salinization.

5. Farming production and food security

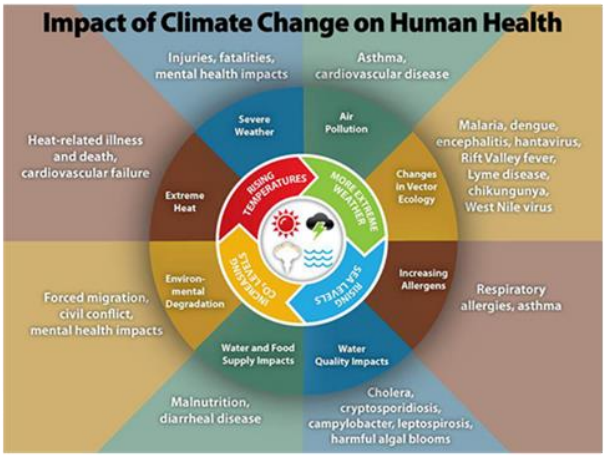
Food security is both directly and indirectly linked with climate change. Any alteration in the climatic parameters such as temperature and humidity which govern crop growth will have a direct impact on quantity of food produced. Indirect linkage pertains to catastrophic events such as flood and drought which are projected to multiply as a consequence of climate change leading to huge crop loss and leaving large patches of arable land unfit for cultivation and hence threatening food security. 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. On a global level, increasingly unpredictable weather patterns will lead to fall in agricultural production and higher food prices, leading to food insecurity. Food insecurity could be an indicator for assessing vulnerability to extreme events and slow-onset changes. This impact of global warming has significant consequences for agricultural production and trade of developing countries as well as an increased risk of hunger. The number of people suffering from chronic hunger has increased from under 800 million in 1996 to over 1 billion recently.

Fig. 8 Climate change scenario


Climate Change Scenarios for India

Year	Season	Increase in Temperature, °C		Change in Rainfall, %	
		Lowest	Highest	Lowest	Highest
2020s	Rabi	1.08	1.54	-1.95	4.36
	Kharif	0.87	1.12	1.81	5.10
2050s	Rabi	2.54	3.18	-9.22	3.82
	Kharif	1.81	2.37	7.18	10.52
2080s	Rabi	4.14	6.31	-24.83	-4.50
	Kharif	2.91	4.62	10.10	15.18

Fig. 12 Relation between human health and climate change



https://www.slideshare.net/soumyashree85/global-climate-change-its-impact-on-indian-agriculture-presentation
https://www.cdc.gov/climateandhealth/effects/default.htm

United Nations population data and projections (UN 2009) show the global population reaching 9.1 billion by 2050, an increase of 32 percent from 2010. The world's population is expected to grow by 2.2 billion in the next 40 years to 2050, and a significant part of the additional population will be in countries that have difficulties feeding themselves. Preliminary estimates for the period up to 2080 suggest a decline of some 15–30 per cent of agricultural productivity in the most climate-change-exposed developing country regions – Africa and South Asia. Even the IPCC, scarcely alarmist, says 0.5ºC rise in winter temperature would reduce wheat yield by 0.45 tons per hectare in India. Rice and wheat have a total share in total food grain production in India. Any change in rice and wheat yields may have a significant impact on food security of the country. And this when Indian agriculture has already pushed into crisis, and 2.56 lakh farmers have committed suicide since 1995. According to A K Singh, deputy director-general (natural resource management) of the Indian Council of Agricultural Research (ICAR), medium-term climate change predictions have projected the likely reduction in crop yields due to climate change at between 4.5 and 9 percent by 2039. The long run predictions paint a frightening picture with the crop yields anticipated to fall by 25 percent or more by 2099. With 27.5% of the population still below the poverty line, reducing openness to the impacts of climate change is essential. Indian food production must increase by 5 million metric tons per year to keep pace with population increase and ensure food security. Coping with the impact of climate change on agriculture will require careful management of resources like soil, water and biodiversity. To cope with the impacts of climate change on agriculture and food production, India will need to act at the global, regional, national and local levels.

6. Overview: Effect of environmental variation on food security

Food Security: Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns. Evidence indicates that more frequent and more intense extreme weather events (droughts, heat and cold waves, heavy storms, floods), rising sea levels and increasing irregularities in seasonal rainfall patterns (including flooding) are already having immediate impacts on not only food production, but also food distribution infrastructure, incidence of food emergencies, livelihood assets and human health in both rural and urban areas. In addition, less immediate impacts are expected to result from gradual changes in mean temperatures and rainfall. These will affect the suitability of land for different types of crops and pasture; the health and productivity of forests; the distribution, productivity and community composition of marine resources; the incidence and vectors of different types of pests and diseases; the biodiversity and ecosystem functioning of natural habitats; and the availability of good-quality water for crop, livestock and inland fish production.

Arable land is likely to be lost owing to increased aridity (and associated salinity), groundwater depletion and sea-level rise. Food systems will be affected by internal and international migration, resource-based conflicts and civil unrest triggered by climate change.

6.1 Mean temperature

Average temperatures are expected to increase across the globe in the coming decades. In mid to high latitudes, increasing temperatures can have a positive impact on crop production, but in seasonally arid and tropical regions, the impact is likely to be detrimental.

6.2 Mean precipitation

On average, an increase in global precipitation is expected, but the regional patterns of rainfall will vary: some areas will have more rainfall, while others will have less. There are high levels of uncertainty about how the pattern of precipitation will change, with little confidence in model projections on a regional scale. Areas that are dependent on seasonal rainfall, and those that are highly dependent on rain-fed agriculture for food security, are particularly vulnerable.

6.3 Extreme Events

Recurrent extreme weather events such as droughts, floods and tropical cyclones worsen livelihoods and undermine the capacity of communities to adapt to even moderate shocks. This results in a vicious circle that generates greater poverty and hunger. The impacts on food production of extreme events, such as drought, may cancel out the benefits of the increased temperature and growing season observed in mid to high latitudes.

6.4 CO_2 Fertilization

Carbon dioxide (CO_2) concentrations are known to be increasing. However, the effect of CO_2 fertilization on crop growth is highly uncertain. In particular, there is a severe lack of experimental work in the Tropics exploring this issue. There is some evidence that although CO_2 fertilization has a positive effect on the yield of certain crops, there may also be a detrimental impact on yield quality.

6.5 Drought

Meteorological drought (the result of a period of low rainfall) is projected to increase in intensity, frequency and duration. Drought results in agricultural losses, reductions in water quality and availability, and is a major driver of global food insecurity. Droughts are especially devastating in arid and semi-arid areas, reducing the quantity and productivity of crop yields and livestock. Seven hundred million people suffering from hunger already live in semi-arid and arid zones.

6.6 Heat Waves

In all cases and in all regions, one in 20-year extreme temperature events are projected to be hotter. Events that are considered extreme today will be more common in the future. Changes in temperature extremes even for short periods can be critical, especially if they coincide with key stages of crop development.

6.7 Heavy Rainfall and Flooding

While uncertain, it appears that there will be more heavy rainfall events as the climate warms. Heavy rainfall leading to flooding can destroy entire crops over wide areas, as well as devastating food stores, assets (such as farming equipment) and agricultural land (due to sedimentation).

6.8 Melting Glaciers

Melting glaciers initially increase the amount of water flowing in systems and enhance the seasonal pattern of flow. Ultimately, however, loss of glaciers would cause water availability to become more variable from year to year as it will depend on seasonal snow and rainfall, instead of the steady release of stored water from the glacier irrespective of that year's precipitation.

6.9 Tropical Storms

For many arid regions in the Tropics, a large portion of the annual rain comes from tropical cyclones. However, tropical cyclones also have the potential to devastate a region, causing loss of life and widespread destruction to agricultural crops and lands, infrastructure, and livelihoods. Some studies suggest tropical cyclones may become more intense in the future with stronger winds and heavier precipitation. However, there is a limited consensus among climate models on the regional variation in tropical cyclone frequency.

6.10 Sea-Level Rise

Increases in mean sea-level threaten to inundate agricultural lands and salinize groundwater in the coming decades and centuries. Sea-level rise will also increase the impact of storm surges which can cause great devastation.

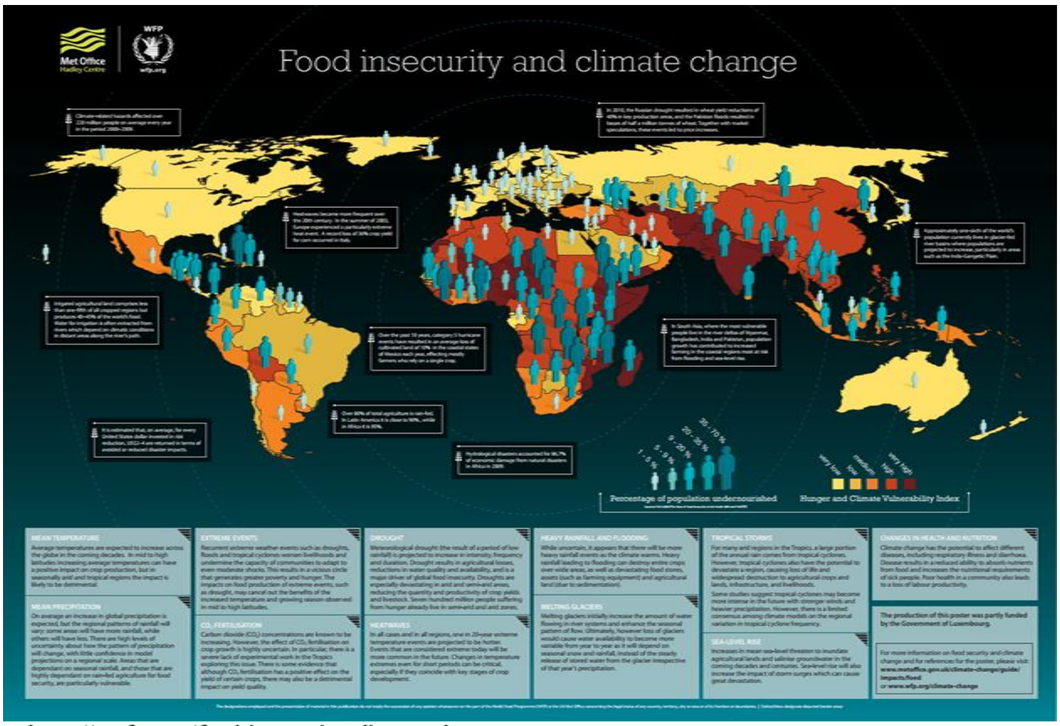
6.11 Changes in Health and Nutrition

Climate change has the potential to affect different diseases, including respiratory illness and diarrhea (fig 12). Disease results in a reduced ability to absorb nutrients from food and increases the nutritional requirements of sick people. Poor health in a community also leads to a loss of labour productivity.

7. Vulnerability and Adaptation Approaches

1. Assist farmers in coping with current climatic risks by providing value-added weather services to farmers. Farmers can adapt to climate changes to some degree by shifting planting dates, choosing varieties with different growth duration, or changing crop rotations.

Overview



https://awfw.org/food-insecurity-climate-change

2 An Early warning system should be put in place to monitor changes in pest and disease outbreaks. The overall pest control strategy should be based on integrated pest management because it takes care of multiple pests in a given climatic scenario.
3 Participatory and formal plant breeding to develop climate-resilient crop varieties that can tolerate higher temperatures, drought and salinity.
4 Developing short-duration crop varieties that can mature before the peak heat phase set in.
5 Selecting genotype in crops that have a higher per day yield potential to counter yield loss from heat-induced reduction in growing periods.
6 Preventive measures for drought that include on-farm reservoirs in medium lands, growing of pulses and oilseeds instead of rice in uplands, ridges and furrow system in cotton crops, growing of intercrops in place of pure crops in uplands, land grading and leveling, stabilization of field bunds by stone and grasses, graded line bunds, contour trenching for runoff collection, conservation furrows, mulching and more application of Farm yard manure (FYM).
7 Efficient water use such as frequent but shallow irrigation, drip and sprinkler irrigation for high value crops, irrigation at critical stages.
8 Efficient fertilizer use such as optimum fertilizer dose, split application of nitrogenous and potassium fertilizers, deep placement, use of neem, karanja products and other such nitrification inhibitors, liming of acid soils, use of micronutrients such as zinc and boron, use of Sulphur in oilseed crops, integrated nutrient management.
9 Seasonal weather forecasts could be used as a supportive measure to optimize planting and irrigation patterns.
10 Provide greater coverage of weather linked agriculture insurance.
11 Intensify the food production system by improving the technology and input delivery system. 12. Adopt resource conservation technologies such as no tillage, laser land leveling and direct seeding of rice and crop diversification which will help in reducing in the global warming potential. Crop diversification can be done by growing non-paddy crops in rain fed uplands
12 to perform better under prolonged soil moisture stress in kharif.
13 Develop a long-term land use plan for ensuring food security and climatic resilience.
14 National grid grain storages at the household/community level to the district level must be established to ensure local food security and stabilize prices.
15 Provide incentives to farmers for resource conservation and efficiency by providing credit to the farmers for transition to adaptation technologies.
16 Provide technical, institutional and financial support for establishment of community banks of food, forage and seed.
17 Provide more funds to strengthen research for enhancing adaptation and mitigation capacity of agriculture.

8. Conclusion
Animal agriculture continues to be under-represented in thoughts and policies geared at shortening climate change, and the world's hungriest people will suffer more as a result. 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. 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. 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. Socio-economic aspects of climate change are relatively weak, and future scenarios are to be generated for various agro-ecological regions for subsequently linking with other relational layers to work out the impact.

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