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Study of Climate Change Impact on Crops and Soil Health in India: A Review

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ABSTRACT

Climate change such as rising temperature, atmospheric carbon dioxide levels, rainfall variability and altering soil physical, chemical and biological properties are observed all around the world. A review over impacts of clim ate change with relation to crops and soil health was done at Department of Agricultural Meteorology, CCS HAU Hisar. IPCC, 2021 provides new estimates of the chances of crossing the global warming level of 1.5°C in the next decades and finds that unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limiting warming to close to 1.5°C or even 2°C will be beyond reach. Impacts of climate change on soil properties are long time process as weather elements induce Physio-chemical reaction with soil which happens slowly in relation to weather elements. Climate change is generally expected to increase the crop yields due to CO_2 fertilization, radiation use efficiency and longer growing season but on the other hand, beyond a critical limit it may develop stress conditions like water stress, sun burns, scorching, bark cracking, closure stomata, leaf senescence and abscission *etc*. that can decrease crop production. Acidification, sodicity and salinization problem can develop in soil due to increase in temperature and acidic rainfall. So it can be held that, climate change would have intensive impacts on cereal and horticulture crops health and production as well as on soil properties.

Key words: Cereal, Climate change, Horticulture crop, Physical properties, Soil.

Climate change may be amplified, including heat (since urban areas are usually warmer than their surroundings), flooding from heavy precipitation events and sea level rise in coastal cities (IPCC, 2021). It causes increase in temperature, variation in rainfall pattern, sea level rise, extreme weather activity, generation of floods and droughts *etc* (Shetty *et al.,* 2013; Pathak *et al*., 2012). Climate change is not harmful for all place or territory and the problem that arise of extreme events are not predict easily (FAO, 2001). More variability in rainfall and unpredictable high temperature spell will consequently reduce the crops productivity. The anthropogenic activities are responsible for an increase in gases, *viz*. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) popularly known as the “greenhouse gases”. Drastically increase in concentration of CO_2 in 2019 was 409.8 ppm wit a range of uncertainty of plus or minus 0.1 ppm (NOAA Climate.govt, 2020). Climate change highly impact on agriculture, horticulture, environment and health all over the world. Soil organic matter decomposition, nutrient recycling, nutrient availability and water availability stresses impact on growth of plant due to environmental stresses. It is predicted that by 2080 the cereal production could be reduced by 2%-4%, meanwhile the price will increase by 13%-45% and about 36%-50% of the population will be affected by hunger (FAO, 2009). In fact, the average temperature of the planet has increased by 0.8° Celsius (33.4° Fahrenheit) compared to the end of the 19th century. Each of the last three decades has been warmer than all previous decades since the beginning of the statistical surveys in 1850. At the pace of current CO_2 emissions, scientists expect an increase of between 1.5° and 5.3°C (34.7° to 41.5°F) in average temperature by 2100. If no action is taken, it would have harmful consequences to humanity and the biosphere. Agriculture is one of the basic activity by which humans live and survive on the earth. Assessment of the impact of climate change on agriculture is a vital task. In both developed and developing countries, the influence of climate on crops despite irrigation, improved plant and animal hybrids and the growing use of chemical fertilizers. Anthropogenic warming has resulted in shifts of climate zones, primarily as an increase in dry climates and decrease of polar climates (high confidence). Ongoing warming is projected to result in new, hot climates in tropical regions and to shift climate zones poleward in the mid- to high latitudes and upward in regions of higher elevation (high confidence). Globally, greening trends (trends of increased photosynthetic activity in vegetation) have increased over the last 2-3 decades by 22-33%, particularly over China, India, many parts of Europe, central North America, southeast Brazil and southeast Australia (high confidence).

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Climate change impact the ecosystem in all over the world as showed in Fig 2. The frequency and intensity of some extreme weather and climate events have increased as a consequence of global warming and will continue to increase under medium and high emission scenarios (high confidence). The total net land-atmosphere flux of CO_2 on both managed and unmanaged lands very likely provided a global net removal from 2007 to 2016 according to models (-6.0±3.7 $GtCO_2$ yr^{-1}, likely range). These regions differ significantly in their biophysical characteristics of climate and soil, and in the vulnerability of their agricultural systems and people to climate change.

In Fig 1 shows that change in surface air temperature over land has risen considerably more than global mean surface (land and ocean) since pre-industrial period (1850-1900). From 1850-1900 to 2006-2015 mean land surface air temperature has increased by 1.53°C (very likely range from 1.38°C to 1.68°C) while GMST increased by 0.87°C (likely range from 0.75°C to 0.99°C).

Climate change impact on soil

Climate change impact is continuously watching on the weather phenomena by meteorologists and climatologists around the world. And the impact is huge: more droughts and heatwaves, more precipitations, more natural disasters like floods, hurricanes, storms and wildfires, frost-free season, *etc*. Climate impacts on agriculture lies the biophysical processes are highly dependent on climate variables such as radiation, temperature, and moisture that vary regionally. For example, rates of plant photosynthesis depend on the amount of photosynthetically active radiation and levels of atmospheric carbon dioxide (CO_2).

Climate change will also have an impact on the soil. Higher air temperatures will cause higher soil temperatures, which should generally increase solution chemical reaction rates and diffusion-controlled reactions as showed in Fig 3. Furthermore, higher temperatures will accelerate the decay of soil organic matter, resulting in release of CO_2 to the atmosphere and decrease in carbon/nitrogen ratios (Buol *et al.,* 1990). The largest producer of GHG emissions are China and United States (accounting for around 42%) (http://cdiac.ornl.gov/trends/emis/tre_coun.html) and the third is India where agriculture is responsible for 18% of total national emissions. Soil organic matter decomposition is temperature sensitive and loss of SOC due to changes in C and N dynamics, altered nutrient bioavailability and reduction in soil biodiversity as result of climate change. This would result in poor soil health and in turn soil fertility. Few studies on the effect of top soil warming on SOC stocks for example in grassland, grazed pasture and forest (Ross *et al*., 2013; Dawes *et al.,* 2013). Kirschbaum, (1995) reported that loss of SOC will be 10% due to increase in temperature as an annual mean temperature of 58°C. Zhou *et al*., (2018) revealed that old SOC decomposition is more sensitive to temperature than younger components.

Mitran *et al*.,(2018) reported that the total carbon is stored in large amounts in Alfisols (0.49 Pg C) followed by Inceptisols (0.35 Pg C) and Entisols (0.27 Pg C) in the southern states of India. Guo*et al*., (2019) showed that soil structure is strongly influenced by the OC status in soil, so, any practice that leads to decline in OC will decrease in soil aggregate stability, infiltration rate and increase in susceptibility to compaction, runoff. In the ultisols of south-eastern China, with farmyard manure. Climate change causes changes in the intensity and volume of rainfall as so increase the erosive power to detach and carry soil particles and the prediction of average global soil erosion to increase by 9% for 2090 (Yang *et al.,* 2003).

Impact of climate change on crops

Parry *et al*. (1988a) report on integrated agricultural sector studies in high-latitude regions in Canada, Iceland, Finland, USSR and Japan, concluding that warmer temperatures may aid crop production by lengthening the growing season, but

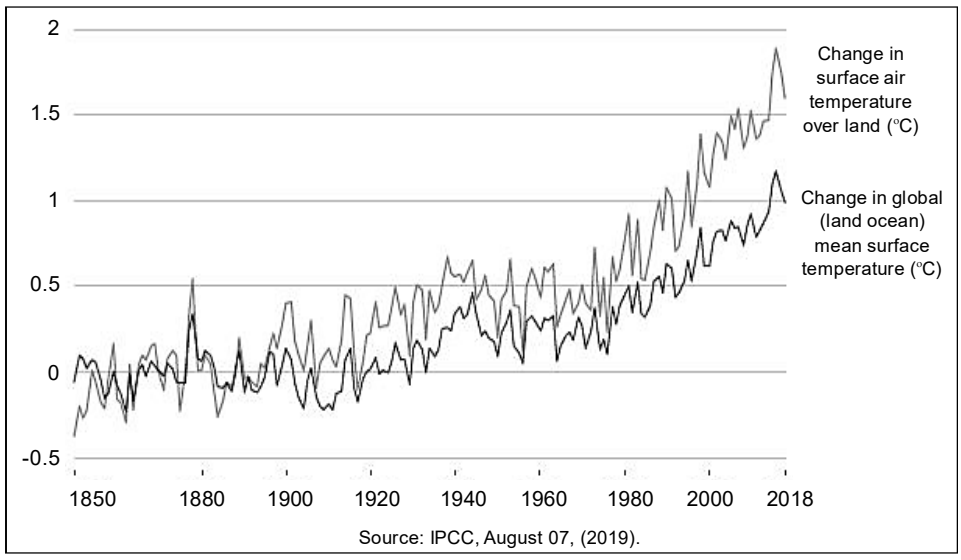
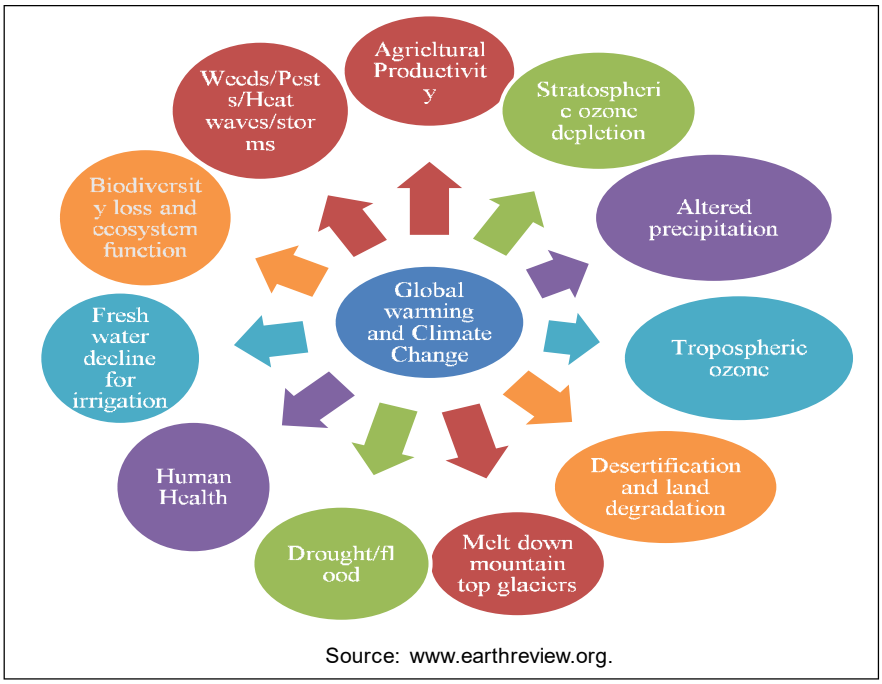
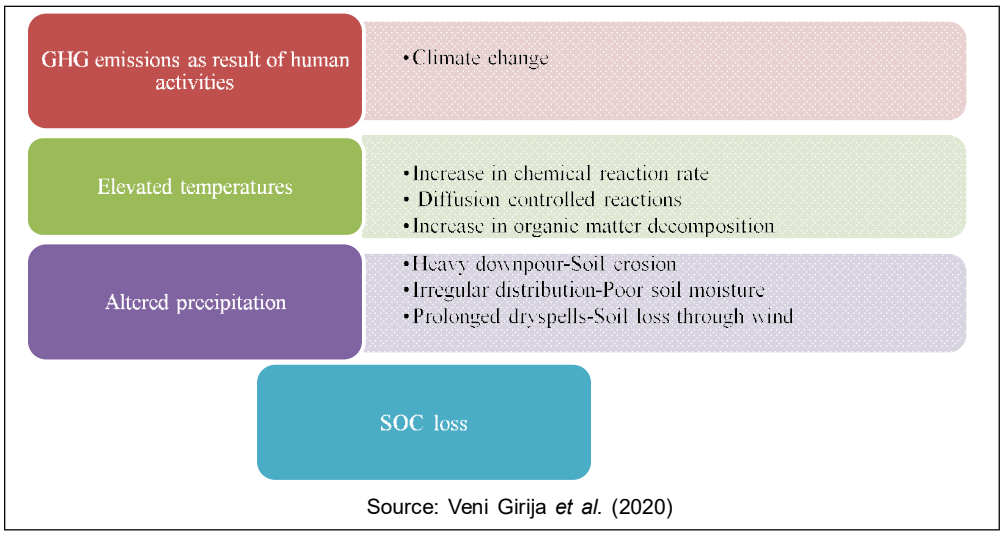


Fig 1: Change in temperature relative to 1850-2018.



Source: www.earthreview.org.

Fig 2: Impact of climate change and global warming.



Source: Veni Girija *et al.* (2020)

Fig 3: Schematic diagram showing climate change impact on soil organic carbon loss.

that potential for higher evapotranspiration and drought conditions may be detrimental. Parry *et al.* (1988b) studies the impact of climate changes on agriculture in Kenya, Brazil, Ecuador, India and Australia. The impacts of past climatic variations, rather than projections of future climate, to provide insights into the sensitivity of agriculture to climate change.

Liverman and O'Brien (1991) have described how global warming may affect Mexican agriculture, using GCM output to project declines in moisture availability and maize yields at several sites in Mexico.

Kumar and Parikh (2001) showed that rice and wheat yield reduction, which in turn would adversely impact on production by 2060 and may affect the food security of more than one billion people in India, projected on large-scale changes in climate. Different study was conducted in yield reduction by drought in different growth stages in field crops as shown in Table 2.

Wheat, barley, sorghum, arhar and maize food grain crops get negatively affected due climate sensitivity or the fluctuations in temperature and rainfall pattern and thus it may threaten food security in India (Kar and Kar, 2008; Ranuzziand Srivastava, 2012).

Singh, (2012) showed that climatic change have negatively affect on cash crop production and empirical result showed that increments in maximum temperature have a negative impact on non food grain (commercial) and statistically significant on sugarcane, cotton and sesamum crop. Any variation in minimum temperature from normal

has a negative and statistically significant impact on and linseed productivity and any fluctuation in rainfall from average has negatively affected the sugarcane productivity. Kumar *et al.* (2011) mentioned that decline in the irrigated area for maize, wheat and mustard in northeastern and coastal regions and for rice, sorghum and maize in Western Ghats of India may cause loss of production due to climate change.

Hundal and Kaur (2007) concluded that rice and wheat productivity declining upto 3% and 10% due to increase in minimum temperature up to 1.0°C to 3.0°C above normal respectively, in Punjab. Kaul and Ram (2009) found that excessive rains and extreme variation in temperature have adversely affected the productivity of Jowar crop, thereby this has affected the incomes as well as food security of farming families in Karnataka (India). Geethalakshmi *et al.* (2011) concluded that rice productivity has declined up to 41% with a 40°C increase in temperature in Tamil Nadu. Saseendran *et al*., (2000) analyzed the projected result showed that increment in temperature up to 50°C could lead to a continuous decline in the yield of rice and every 10°C increment in temperature will lead up to 6% decline in yield for duration 1980-2049 in Kerala (India). Srivastava *et al.* (2010) found that climate change will reduce monsoon sorghum productivity up to 14% in the central zone and up to 2% in the south central zone by 2020. Climate change has shifted and shortened crop the ration in major crops the ice and sugarcane and it has significantly affected cane productivity in Uttar Pradesh and Uttarakhand (Boopen and Vinesh, 2011). The impact of rainfall is not significant for sugarcane crop in Andhra Pradesh (Ramulu, 1996). In India, projected surface warming and shift in rainfall may decrease crop yields by 30% by the mid of 21st century; due to this reason, there may be a reduction in arable land resulting into pressures on agriculture production (Kapur *et al.,* 2009).

Climate change impact on horticulture crop

Climate change is directly related to change in weather pattern and arises of abiotic stress. Its directly impact on plant architecture and growth. Abiotic stress is the primary causes of low production for most of the fruit crops and vegetables on all over the world as shown in Table 3.

High temperature causes an array of morpho-anatomical changes in plants which affect on seed germination, growth, flower shedding, pollen viability, fruit setting, fruit size, weight and quality *etc*. heat stress on fruit crops causes physiological disorders and their associated problems. In many crops like sweet corn, lettuce, carrot, cucurbits, tomato *etc*. is poor pollination under low humidity and high temperature with the reduction of the number of pollination insect species (Deuter, 2008). In tomato, pollen germination is affected by temperatures above 27°C or

Table 1: Climate change projection for India. (Prasantakumar *et al*., 2016).

Year/ Scenarios	Season	Temperature change (°C)		Rainfall change (%)	
		Lowest	Highest	Lowest	Highest
2020s	Annual	1.0	1.41	2.16	5.97
	Rabi	1.08	1.54	1.95	4.36
	Kharif	0.87	1.17	-1.81	5.10
2050s	Annual	2.23	2.87	5.36	9.34
	Rabi	2.54	3.18	-9.92	3.82
	Kharif	1.81	2.37	7.18	10.52
2080s	Annual	3.53	5.55	7.48	9.90
	Rabi	4.14	6.31	-24.83	-4.50
	Kharif	2.91	4.62	10.10	15.18

The analysis concentrated on maximum and minimum temperature and rainfall showed the projection of maximum temperature increase within range of 1.17-6.31°C and also rainfall within range 15-24% from all the six models for the whole India.

Table 2: Yield reduction by drought in different growth stages in field crops.

Crops	Growth stages	Yield reduction	Reference
Barley	Seed filling	49-57%	Samarah (2005)
Rice	Reproductive	48-94%	Lafitte *et al.* (2007)
Rice	Grain filling	60%	Basnayake *et al.* (2006)
Maize	Vegetative	25-60%	Atteya *et al.* (2003)
Maize	Reproductive	63-87%	Kamara *et al.* (2003)
Maize	Grain filling	79-87%	Monneveux *et al.* (2005)
Cowpea	Reproductive	60-71%	Ogbonnaya *et al.* (2003)
Sunflower	Reproductive	60%	Mazahery-Laghab *et al.* (2003)
Pigeonpea	Reproductive	40-55%	Nam *et al.* (2001)
Chickpea	Reproductive	45-69%	Nayyar *et al.* (2006)

Table 3: Abiotic stress susceptible horticultural crops.

Abiotic stress	Crops
High temperature	Peas, tomato, potato, beans, capsicum, banana, papaya, litchi, citrus, rose.
Low temperature	Tomato, brinjal, onion, drumstick, Indian gooseberry, ber, senna, phalsa, gonad, rose, jasmine, tropical orchids, carnation.
Drought	Chilli, turnip, tomato, onion, pomegranate, custard apple, fig, grape, mango, banana, guava, black pepper, cardamom.
Salinity	Onion, radish, potato, beans, melons, peas, mango, fig, citrus, grape, guava, custard apple, apple, pear, strawberry.
Flooding/excess moisture	Chilli, onion, tomato, papaya, early cauliflower, banana.

Source: Singh (2010); Muthukumar and Selvakumar (2013).

causes reduced fruit set, smaller size and lower quality fruits (Stevens, 1978). Floral abortion will occur in capsicum when temperatures exceed 30°C (Erickson and Markhart, 2002). In beans, high temperature delays flowering because they enhance the short day photoperiod (Davis, 1997). Drought-stress causes an increase in solute concentration in the environment (soil), leading to an osmotic flow of water out of plant cells. This leads to an increase in the solute concentration in plant cells, thereby lowering the water potential and disrupting membranes and cell processes such as photosynthesis. Water-stress condition affects the plants in terms of narrow leaf orientation, lesser germination, delayed maturity, small and delayed flowering, decline in chlorophyll content, reduced rate of transpiration, less uptake of nutrients, and severe reduction in yield (Bhardwaj, 2012). Under saline condition, pea shows poor seed germination (Kumar *et al*., 2012). In coconut, arecanut and cocoa, increased CO_2 led to higher biomass production and total dry matter content (Singh *et al*., 2010).

High temperature has big influence on fruit growth, a large number of furit crops production timing will change including mango, citrus, banana and guava crops will develop more rapidly and mature earlier due to rise in temperature (Malhotra, 2017). High temperature with moisture deficit causes cracking and sun burning in apple (Rai *et al.,* 2015) and increase in temperature during maturity stage will cause cracking in litchi (Kumar and Kumar, 2007). Low temperature (4-11°C), high humidity (80%) and cloudy weather during the month of January caused delayed panicle emergence in mango. Strong wind and cyclone during mango fruit season reduced yield by shedding of fruits and also affect the fruit size and quality (Chadha, 2015).

Adaptation and mitigation strategies

Adaptations to climate change exist at the various levels of agricultural organization. At farm-level adaptations include changes in planting and harvest dates, tillage and rotation practices, substitution of crop varieties or species in contrast to the changing climate regime, increased fertilizer or pesticide applications, and improved irrigation and drainage systems. Governments can facilitate policy to adaptations climate change through water development projects, agricultural extension activities, incentives, subsidies, regulations and provision of insurance.

Adaptation	Mitigation
Altering date of planting and spacing	Afforestation
Alternate crops or cultivars	Watershed management
Change in cropping system	Organic agriculture
Zero tillage/direct seeding	Changing land use-Horticulture, Agroforestry
Reduction in summer fallow	Silviculture
Conservation of soil moisture	Integrated farming system
Crop diversification	Use of nitrification inhibitors
Forage in rotations	and fertilizers placement practices
Integrated farming system	Improved management of livestock population
Integrated nutrient management	Feed and fodder storage
Improved land use	Solar power
Risk management-early warning system and crop insurance	Improved stress tolerance through grafting
Combat desertification	Preserving and restoring natural ecosystems
	Soil carbon sequestration

Kumar *et al.* (2019).

CONCLUSION

In general, the tropical regions appear to be more vulnerable to climate change than the temperate regions on the biophysical side, temperate C_3 crops are likely to be more responsive to increasing levels of CO_2 and tropical crops are closer to their high temperature optima. High temperature experience stress, despite lower projected amounts of warming or insects and diseases, already much more prevalent in warmer and more humid regions, may become even more widespread. At the regional level, those charged with planning for resource allocation, including land, water and agriculture development should takes climate change into account. In coastal areas, agricultural land may be flooded or salinized, in continental interiors and other locations, droughts may increase. As climatic factors change, a host of consequences will ripple through the agricultural system, as human decisions involving farm management, grain storage facilities, transportation infrastructure, regional markets and trade patterns respond. Consequences of these management decisions could result in local and

regional alterations in farming systems, land use and food availability. Ultimately, impacts of climate change on agriculture may reverberate throughout the international food economy and global society.

Conflict of interest: None.

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