Climate Change Impact on Agriculture in India

D. Raji Reddy[1*] and G. Sreenivas[2]

[1]Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad (500 030), India
[2]Agro Climate research Centre, PJTSAU, ARI, Rajendranagar, Hyderabad (500 030), India

Corresponding Author

D. Raji Reddy
e-mail: dandareddy009@gmail.com

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Abstract

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems. Climate change or global warming is caused by the release of 'greenhouse' gases into the atmosphere. These gases accumulate in the atmosphere and increase the effect of radiative forcing on the climate, resulting in a warming of the atmosphere. The changes in greenhouse gas concentrations are projected to lead to regional and global changes in climate and weather parameters such as temperature, precipitation, soil moisture, and sea level. Agriculture is one sector that is important to consider in terms of climate change. The agriculture sector both contributes to climate change, as well as will be affected by the changing climate. Climate change will have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand and trade. Recent climate changes have had widespread impacts on human and natural systems. Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. Specific measures can only provide a successful adaptive response if they are adopted in appropriate situations. A variety of issues need to be considered, including land-use planning, watershed management, disaster vulnerability assessment, consideration of port and rail adequacy, trade policy, and the various programmes countries use to encourage or control production, limit food prices, and manage resource inputs to agriculture.

Keywords: Climate change, global warming, green house gas, impact

1. Introduction

Climate change or global warming is caused by the release of 'greenhouse' gases into the atmosphere. These gases accumulate in the atmosphere and increase the effect of radiative forcing on the climate, resulting in a warming of the atmosphere. The changes in greenhouse gas concentrations are projected to lead to regional and global changes in climate and weather parameters such as temperature, precipitation, soil moisture, and sea level. Agriculture is one sector that is important to consider in terms of climate change. The agriculture sector both contributes to climate change, as well as will be affected by the changing climate. Climate change will have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand and trade.

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history (IPCC Synthesis report, 2014). Recent climate changes have had widespread impacts on human and natural systems. Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. The key point to remember is that these effects of climate change on agriculture could proceed to dangerous levels, beyond the capacity of meaningful adaptation to such changes, if the emission of greenhouse gases continues unchecked. Beyond a 2 °C rise in temperature, there is increasing damage to agriculture. Unchecked temperature rise of 3–4 °C would lead to severe consequences. Such consequences cannot be considered in the sector of agriculture alone; we would need to consider a range of geophysical and biophysical effects, the combined effects of which would be very serious. Rainfall is projected to increase for India as a whole, while, it is projected to decrease for the drought-prone areas of Andhra Pradesh. This decrease is 5% to 20% during the critical monsoon season with a 5% increase during the dry March-May period. The number of rainy days appears to decrease by about 5 to 10%. Rainfall intensity (mm rain per wet day) appears to remain roughly constant over the year but there may be seasonal changes that do not show up in the published data (World Bank Report, 2006).

2. Climate Change: Impact on agriculture

- Increase in temperature (1.4-6.1 °C), IPCC, 2007
- Change in precipitation and storm activity
- Widespread runoff
- Reduction in first water availability
- Droughts
- Permanent changes in pest distributions following extreme events
- Adverse impact on coastal agriculture due to rise in sea levels (17.5-57.5cm) and sea-water intrusion by 2100 and another 10-20cm rise if ploar ice melting continues, IPCC, 2007

2.1. Extreme temperature

Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906-2005) of 0.74 [0.56 to 0.92]^{0}C is larger than the corresponding trend of 0.6 [0.4 to 0.8)^{0}C (1901-2000) given in the TAR . The linear warming trend over the 50 years from 1956 to 2005 (0.13 [0.10 to 0.16]^{0}C per decade] is nearly twice that for the 100 years from 1906 to 2005. Similarly, thirteen of recent warmest years in India, the nine warmest years were recorded during the first decade of 21st Century and the year 2009 was the warmest.

The annual mean temperature anomaly showed that, during the recent years the increase in temperature was higher compared to the early 20th Century. The increase in trend was higher from late 70's and the magnitude of increase in temperature was 0.4^{o}C over normal during the first decade of 21st century.

Increase in temperature due to global warming have likely impact on wheat yield in India. It was projected that the wheat yield would be around 58Mt by 2070 as against the 76 Mt during the year 2000.

Climate change impact on wheat yield can be minimized by adopting certain adaptation strategies like adopting varieties tolerant to extreme events , creating irrigation sources, timely planting etc. (Figure 1).

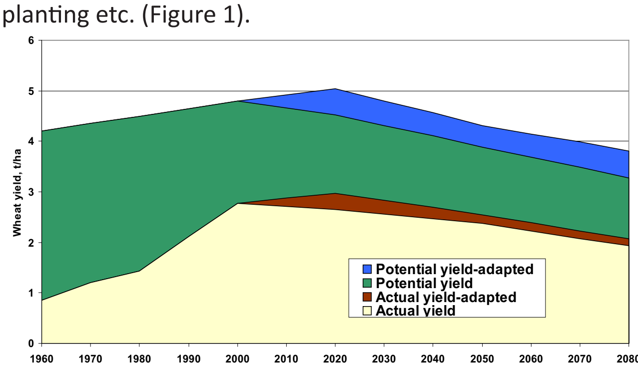


Figure 1: Impact of climate change on future opportunities for increasing wheat production; Source: IARI/ ICAR network

Similarly, decrease in apple yield was also observed in Himachal Pradesh due to lower cold periods (Fig.2). Apple chilling hours are going down in Himachal Pradesh as result the apple cultivation is being shifted to higher altitude.

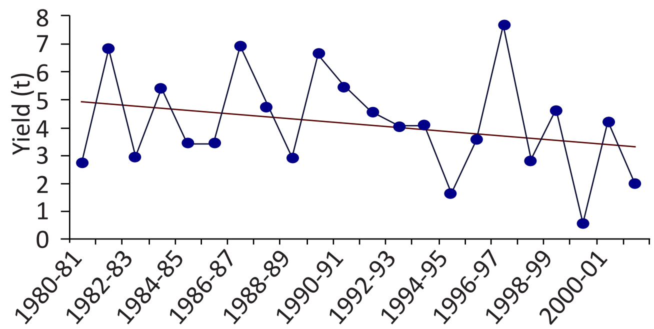
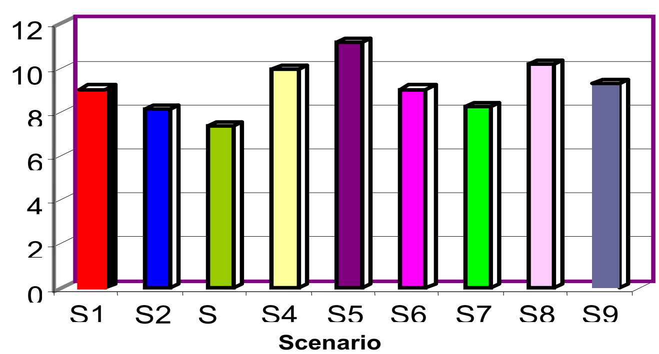


Figure: 2 Apple yield in Himachal Pradesh; Source: HPKVV and ICAR network

In general, an increasing trend in temperature has been observed in southern and central India in recent decades. It was evident in increase in trends of annual mean, maximum and minimum temperatures south of 23^{o}N and cooling trends north of 23^{o}N. Researchers projected that the surface air temperature over the Indian subcontinent (area-averaged for land regions only) is likely to rise from 1.0 ^{o}C (during the monsoon) to 2 ^{o}C (during the winter) by the middle of the next century. Experiments in India reported by Sinha (1994) found that higher temperatures and reduced radiation associated with increased cloudiness caused spikelet sterility and reduced yields in wheat to such an extent that any increase in dry-matter production as a result of CO_2 fertilization nullified the advantage in grain productivity.

Simulated grain yield of rice under changed climate scenarios indicated decrease in grain yield by 9.7% and 18.4%, respectively were noticed with increase in both maximum and minimum temperature by 1 ^{O}C and 2 ^{O}C over normal (Figure 3).



S_1: Normal; S_2: Increase in maximum and minimum temperature by 1 °C; S_3: Increase in maximum and minimum temperature by 2 °C; S4: Increase in CO_2 level to 450 ppm; S_5: Increase in CO_2 level to 600 ppm; S_6: S2+S4; S_7: S_3+S_4; S_8: S_2+S_5; S_9: S_3+S_5

Figure 3: Studies on influence of weather factors on growth and yield of Samba Mahsuri using CERES-Rice model under Rajendranagar conditions

Increase in grain and biomass yield was noticed with increase in levels of CO_2 (450 and 600 ppm). The decrease in yield of rice due to increase in temperature by 1°C is compensated by increase in CO_2 level to 450 ppm. However, increase in temperature by 2°C with 450ppm of CO_2 decreased the yield by 9%. The increase in yield of rice was observed with increase in temperature by 1°C and increase in CO_2 level to 600 ppm. It clearly indicates that, the increase in yield due to increase in CO_2 levels will be nullified by increased temperature levels in the long run.

Sorghum (*Sorghum bicolour* (L.) Moench) is one of the main staple foods for the world's poorest and most food-insecure people across the semi-arid tropics of world. *Rabi* sorghum is predominantly grown on residual moisture in medium deep vertisols in Deccan Plateau regions of Maharashtra, Karnataka, and Andhra Pradesh. In order to understand the yields of the crop under climate change scenarios yield was simulated using CERES- Sorghum model. Results indicated that timely sowing of the crop both under 450 and 600ppm CO_2 level found ideal in producing the optimum yield. At both levels of CO_2 with increase in temperature by 1°C the decrease in sorghum yield was found in all the sowing dates and there was chances of increase in yield due reduce in temperature by 1°C in all the sowing times (Table 1).

Table 1: Combined effect of changes in temperature and CO2 levels on grain yield of Rabi jowar simulated using CERES-Sorghum at Solapur in Maharashtra

CTDL	Simulated grain yield (kg ha^{-1})			% Change from normal		
450 ppm	Early	Timely	Late	Early	Timely	Late
1	4136	4717	5207	-12	-12	-9
Normal	4695	5360	5727	0	0	0
-1	5390	6302	6230	15	18	9
600 ppm	Early	Timely	Late	Early	Timely	Late
1	4572	5185	5606	-12	-11	3
Normal	5169	5826	5449	0	0	0
-1	5866	6512	6463	13	12	19

Changes in temperature (°C) and CO_2 at different level

2.2. Heat-waves

Heat waves resulting in abnormally high temperatures not only take their toll on human lives but also affect agriculture. The historical record of heat waves show that, districts of Guntur, Krishna and Prakasam in South Coastal Andhra Pradesh and Hyderabad, Mahaboobnagar and Ranga Reddy districts in Telangana are more prone to heat waves than other parts of the state.

Records of the past 16 years demonstrate a shift in the spatial patterns of heat waves. The incidence of heat waves in coastal areas has increased in frequency. About 115 such events are recorded in the coastal areas as against 88 in the interior Telangana region. Of these events in the coastal areas, 37% were severe. Therefore, both the frequency of incidence as well as the intensity of the heat waves have increased in the coastal areas in the last one and a half decades (Fig. 4).

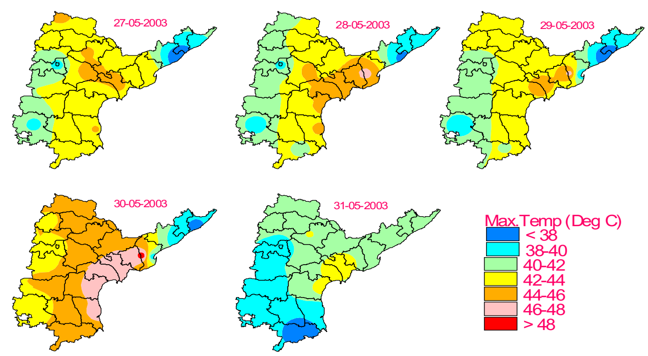


Figure 4: Maximum temperature distribution during severe heat wave conditions of 2003 in A.P., India

The heat wave in Andhra Pradesh during the year 2003 (May-June), created climatological records. The temperatures recorded in various parts of the state ranged from 42 °C to 47 °C. These spells continued for a record 27 days and caused large scale causalities. Heat wave claimed more than 3000 lives and several hundred suffered from heat strokes. Orchards of sweet orange, mango, acid lime etc., in an extent over 23,000 hectares dried up due to moisture stress (Figure 5). About 20 lakh poultry birds (worth 27 crores) died all over the state, most affected being coastal districts.

Figure 5: dried mango and tolerant Annona trees due to heat wave conditions in Andhra Pradesh during May, 2003

2.3. Impacts of climate change on insect-pests

Insects being poikilotherms, temperature is probably the single most important environmental factor influencing their behaviour, distribution, development, survival, and reproduction. Therefore, it is highly expected that, the major drivers of climate change i.e. elevated CO_2, increased temperature and depleted soil moisture can impact population dynamics of insect-pests and the extent of crop losses, significantly.

The climate change is likely to alter the balance between insect pests, their natural enemies and their hosts. The rise in temperature will favour insect development and winter survival. Rising atmospheric carbon dioxide concentrations may lead to a decline in food quality with leaf nitrogen decreasing and phenolics increasing. Herbivores respond to increased levels of CO_2 by increasing their food consumption, prolonging development time, and reducing their growth rates and food conversion efficiency (Figure 6).

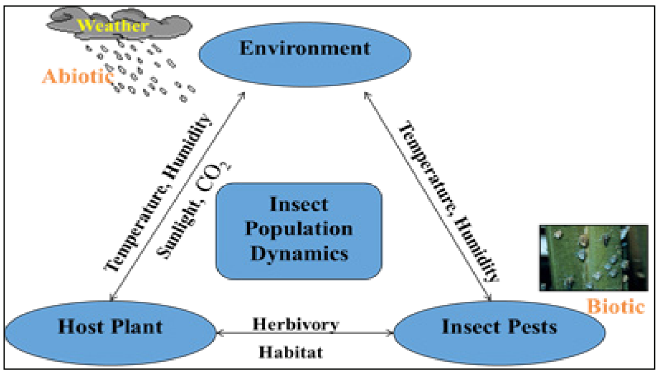


Figure 6: Abiotic and biotic factors affecting insect population dynamics

The above facts demand urgent measures from the scientific community and the government.

3. Strategies for facing the challenge

Specific measures can only provide a successful adaptive response if they are adopted in appropriate situations. A variety of issues need to be considered, including land-use planning, watershed management, disaster vulnerability assessment, consideration of port and rail adequacy, trade policy, and the various programmes countries use to encourage or control production, limit food prices, and manage resource inputs to agriculture. Important strategies for improving the ability of agriculture to respond to diverse demands and pressures include:

Improved training and general education of populations dependent on agriculture to cope up with extreme weather events.
Research on new variety development, incorporating various traits such as heat and drought tolerant, salt and pest resistant should be given prime importance.
Food programmes and other social security programmes, to provide insurance against local supply changes.
Infrastructure facilities like transportation, distribution and market need to be improved.

Existing policies may limit efficient response to climate change. Changes in policies such as crop subsidy schemes, land tenure systems, water pricing and allocation, and international trade barriers could increase the adaptive capability of agriculture.

4. Strategic Research Issues

Identification of areas prone for climate change and variability in different agro-eco regions
Assessing the impacts of climate change in regions of horticultural production system experiencing climate variability
Impacts of climatic variability on agricultural and horticultural crops in relation to variations in
Rainfall and thermal regimes
Soil carbon storage and land use
Studies on pattern of drought intensity and development of region-specific management strategies
Development of genotypes to withstand higher ranges of climate parameters.
Improving seasonal climate forecasts
A re-look at crop improvement and water management strategies in relation to climatic variability.
Develop production systems suitable for changed climates.
Studies on climate change impacts on pests and diseases

5. Conclusion

This can be conclude from the above part that the effects of climate change on agriculture could proceed to dangerous levels, beyond the capacity of meaningful adaptation to such changes, if the emission of greenhouse gases continues unchecked. Beyond a 2 °C rise in temperature, there is increasing damage to agriculture. Unchecked temperature rise of 3–4 °C would lead to severe consequences.

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