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Review Paper

Impact of Climate Change on Agriculture and their Mitigation Strategies for Food Security in Agriculture: A Review

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Abstract

Global warming is the observed increase in the average temperature of the earth's atmosphere and oceans in recent decades. Global surface temperature increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the last century. The intergovernmental panel on climate change (IPCC) concludes that most of the observed temperature increases since the middle of the 20th century was caused by increasing concentrations of greenhouse gases resulting from human activity such as fossil fuel burning and deforestation.. A rise in earth's temperatures can in turn root to other alterations in the ecology, including an increasing sea level and modifying the quantity and pattern of rainfall. The 2001 IPCC third assessment report concluded that the poorest countries would be hardest hit, with reductions in crop yields in most tropical and sub-tropical regions due to decreased water availability, and new or changed insect pest incidence. Increasing temperature would increase fertilizer requirement for the same production targets; and result in higher emissions. The agricultural sector is both an emitter of greenhouse gases and a victim of global warming. Agriculture accounts for roughly 14% of global GHGs or about 6.8 Gt of CO_2 equivalents (e) per year.Mitigation of global warming involves taking actions to reduce greenhouse gas emissions and to enhance sinks aimed at reducing the extent of global warming. It can be done through conservation by reducing energy needs and efficient recycling and through use of alternate energy sources like nuclear, wind, geothermal, hydroelectric, solar and fusion energy. Soil carbon sequestration off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. It can be done through conservation tillage, residue management, green manuring and agro forestry system. Significant amount of diesel requirement and corresponding emission of CO_2 is reduced in case of zero tillage compared to conventional tillage. Modification of water management from continuous flooding to midseason drainage or alternate flooding will reduce the methane emission by 23 and 61 % respectively. Site-specific nutrient management is a plant need-based approach for 'feeding' rice with nutrients as when needed with the help of leaf colour chart and SPAD meter significantly reducing N_2O loss.

Keywords: Climate change, global warming, mitigation, temperature.

Introduction

Agriculture is important for food security in two ways: it produces the food people eat; and it provides the primary source of livelihood for 36 percent of the world's total workforce. In the heavily populated countries of Asia and the Pacific, this share ranges from 40 to 50 percent, and in sub-Saharan Africa, two-thirds of the working population till make their living from agriculture[1]. If agricultural production in the low-income developing countries of Asia and Africa is adversely affected by climate change, the livelihoods of large numbers of the rural poor will be put at risk and their vulnerability to food insecurity increased.

Agriculture, forestry and fisheries are all sensitive to climate. Their production processes are therefore likely to be affected by climate change. In general, impacts are expected to be positive in temperate regions and negative in tropical ones, but there is still uncertainly about how projected changes will play out at the local level, and potential impacts may be altered by the adoption of risk management measures and adaptation strategies that strengthen preparedness and resilience. The food security implications of changes in agricultural production patterns and performance are of two kinds. Impacts on the production of food will affect food supply at the global and local levels. Globally, higher yields in temperate regions could offset lower yields in tropical regions. However, in many low-income countries with limited financial capacity to trade and high dependence on their own production to cover food requirements, it may not be possible to offset declines in local supply without increasing reliance on food aid. Impacts on all forms of agricultural production will affect livelihoods and access to food. This paper focuses on disentangling the pathways of climate change impacts on food system activities and food security outcomes. Agriculture sector in India contributes 28% of the total GHG emission[2]. The global average from agriculture is only 13.5%[3]. In future, the percentage emissions from agriculture in India are likely to be smaller due to relatively much higher growth in emissions in energy-use transport and industrial sectors. The emissions from agriculture are primarily due to methane emissions from rice fields, enteric fermentation in ruminant animals and nitrous oxides from application of manures and fertilizers to agricultural soils. At world level if we consider on percapita basis India releasing 1.02 tonnes/year whereas, developed countries like USA releases 20.01 tonnes/year.

The potential yield trend in rice ranged from 0.12 Mg/ha/year at Delhi to 0.05 Mg/ha/year at Kanpur. Negative yield trends were observed in six of the nine data sets, four of which were significantly different from 0 ($P<0.05$). These declining trends were observed throughout all the transects of the IGP, indicating that yield declines were not localized. On the other hand, positive trends were observed at three sites, but none was statistically significant ($P<0.05$). The changes in radiation and minimum temperature are the reasons for the potential yield decline of rice. In Wheat, the rate of annual yield change ranged from -0.07 Mg/ha/year at Delhi to 0.04 Mg/ha/year at Faizabad and Pantnagar. Of the nine sites, six showed a negative trend and three showed positive trends, but none is significantly different from 0. Thus, wheat yield appeared to be more stable than rice yield. When simulation was done keeping the CO_2 concentration constant (330 ppm) over the years, similar negative yield trends of both crops were observed, but the magnitude of decline was higher indicating that increased CO_2 concentration compensated for the decline in crop yield due to decreased solar radiation and increased temperature up to some extent[4].

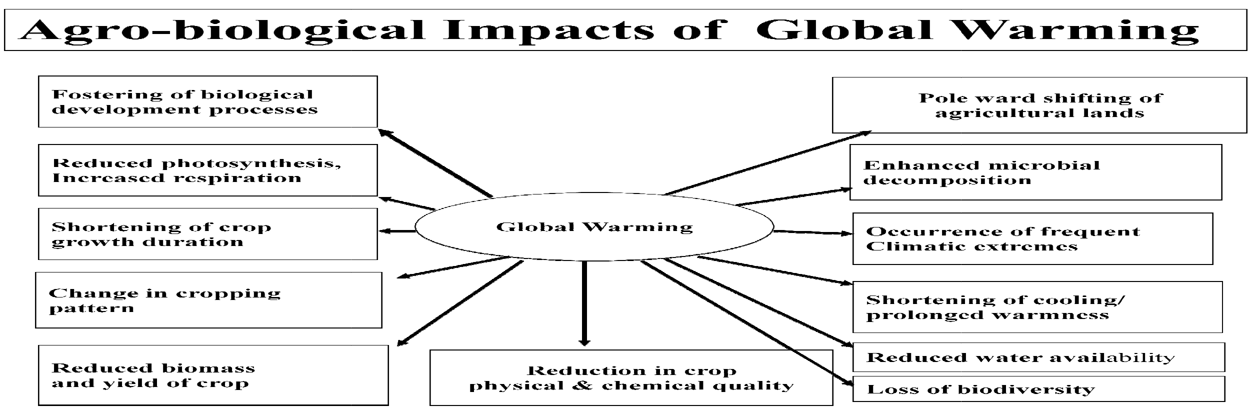

Figure-1
Agro-biological impacts of the global warming

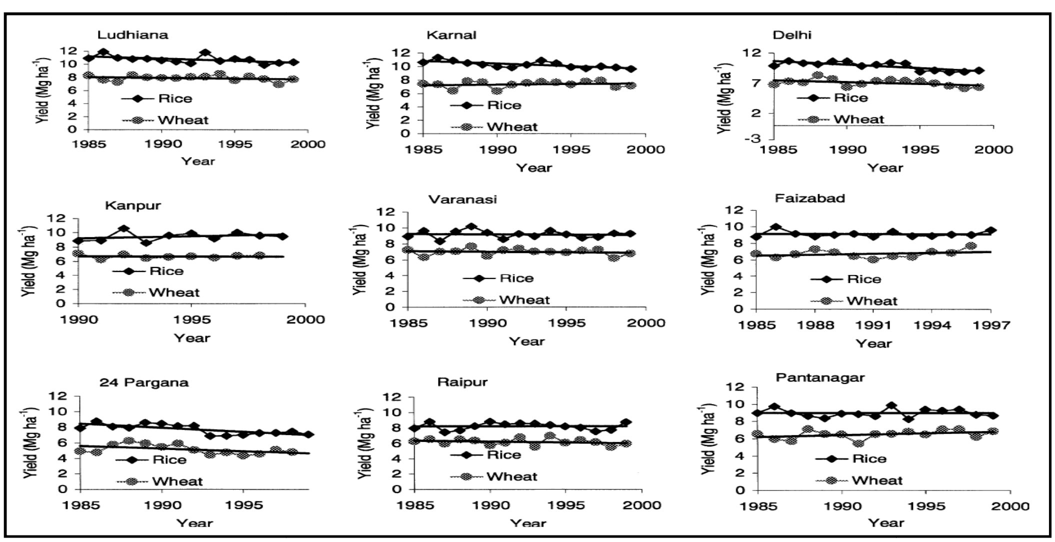

Figure-2
Climatic potential yield trends of rice and wheat at the various sites of the IGP

The general consensus is that extremes of temperature will become more common, with an overall warming trend. In this situation one can expect significant changes in the population trends of various insect pests as experiences at ICRISAT Patencheru location[5] .The status of the pests was shifted over time. Though, the observed pest shifts may not be solely attributable to climate change, the impact of climate change on their status can be observed clearly.

Table-1
Trends of insect pests at ICRISAT Patancheru location

Insect species	Status	
	1978	2009
Helicoverpa armigera	+	+
Spodoptera litura	+	+
Aproaerema modicella	+	-
Holotrichia serrata	+	-
Amsacta albistriga	+	-
Maruca vitrata	-	+
Melanagromyza obtusa	-	+
Caryedon serratus	-	+
Pseudococcus corymbatus	-	+
Aphis craccivora	-	-
Thrips palmi (as vector)	-	+

To develop crop genotypes which can perform better under the predicted climate change, it is essential to understand the plant traits that are linked to adaptation. It is well understood that pattern of plant adaptation is a response to determined environmental condition. Finding and quantifying these patterns in relation to plant functioning has been the focus of research in this area. Plant traits which favour yield and also which have a direct effect on the mechanism of tolerance is one of the important characteristic that has to be considered when developing climate ready varieties and crops[6]. These traits have the ability to directly or indirectly control yield over a time scale influencing either water use, water use efficiency and partitioning of biomass to grain.

With the advent of molecular biology techniques it was presumed that developing stress-tolerant cultivars would be convenient and relatively less time consuming. However, the progress so far does not seem to be rapid as it was envisaged. An effective integration of transgenic, OTL, MAS and genomic approaches into conventional breeding program seems to be the most essential requirement in developing climate ready genotypes with multiple stress tolerance.

WTGROWS was run for Pantnagar (eastern UP) and Saharanpur (Punjab) locations, with normal weather and adequate inputs, and with different dates of sowing under normal and temperature-rise scenarios. The results clearly indicate the delay in sowing under temperature-rise situations for achieving maximum benefits. This may be one of the adaptation strategies to sustain the yield under climate-change situation. The simulation was run for attainable yields under irrigated and non-limited production environment, and the results might be slightly different under limited irrigation and rainfed situations. It has been noticed recently, that the interception of solar radiation on the earth surface has been disturbed due to gases and particulate matter (aerosols) emitted in the atmosphere by anthropogenic activities[7].

Table 2 shows that buying insurance, planting contingency crops, changing planting dates of groundnut, augmenting water availability through improved storage, constructing water harvesting structures, improving drought forecasting and working as labour in that order of magnitude are the major adaptation measures followed by farmers towards climate change in Ananthapur (Andhrapradesh)[8].

Mitigation strategies

A major emphasis on improving the productivity of agricultural systems, leading to the understanding that increasing soil carbon stocks in degraded lands is essential for enhanced productivity. Agroforestry provides a unique opportunity to reconcile the objectives of mitigation of, and adaptation to, climate change. Worldwide it is estimated that 630 x 106 ha are suitable for agroforestry. Carbon is particularly useful in agricultural systems, making agro forestry a quantitatively important carbon sink[9].

The age of seedlings also influenced the plant parameters[10]. During both wet and dry seasons, the 35-day old seedlings revealed better plant height. A 20-day old seedling of rice cv. Lalat had more tillers as compared to 35-day old seedlings in both wet season, 2002 and dry season, 2003. In Gayatri where early transplanted 35-day old seedlings emitted more CH_4 than late transplanted 45-day old seedlings. Among the different plant parameters, tiller number showed a positive relationship with CH_4 emission but it was not significant ($r = 0.369$, $p < 0.05$, $n = 6$). Other parameters such as root length, root volume and dry root weight did not show any relation with CH_4 emission.

Conclusion

The magnitude of the challenge to stabilize greenhouse gas (GHG) concentrations in the atmosphere and limit average temperature increases makes it imperative that the contributions of all sectors with significant mitigation potential be tapped to the fullest extent possible. Agriculture is recognized as a sector with such potential and farmers, ranchers, herders and other land users around the world can and should be part of the solution to climate change. Magnitude of impact varies greatly by region. Major impacts will be on rain fed crops. The loss in farm-level net revenue by 9 - 25%. Indian agriculture is likely to suffer losses in long run due to heat, erratic weather, and decreased irrigation availability. Adaptation strategies can help minimize negative impacts to some extent; however, mitigation should be the long term strategy of combating it. There is need for in depth research to quantify impacts and adaption/ mitigation options on agriculture. A strong policy support to combat climate changes is required.

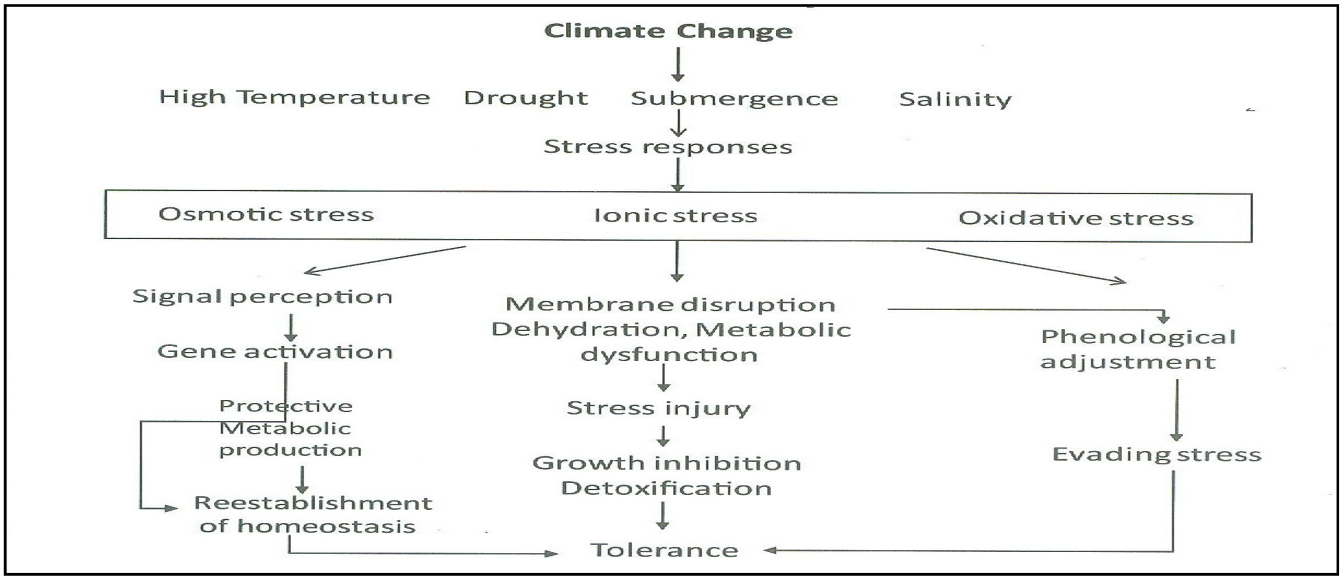

Figure-3
Physiological and biochemical events in plants resulting in adaptation to abiotic stresses exacerbated due to climate change

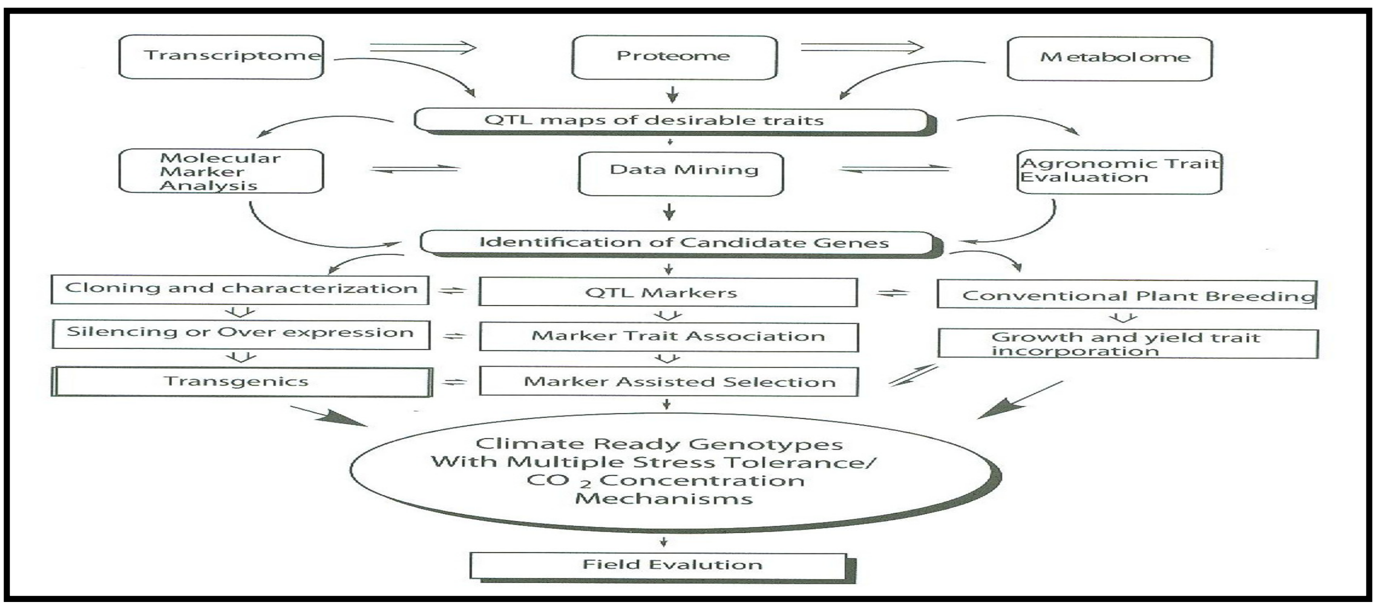

Figure-4
Process network in development of climate ready cultivars

Table-2
Farmer's adaptation measures towards climate change in Anantapur

Adaptation Measure	Frequency*	%	Rank
Buy insurance	56	93	I
Plant contingency crops	55	92	II
Change in planting dates of groundnut	48	80	III
Increased water availability through increased storage	47	78	IV
Construct water harvesting structures	45	75	V
Improved drought forecasting	44	73	VI
Work as labour	43	72	VII

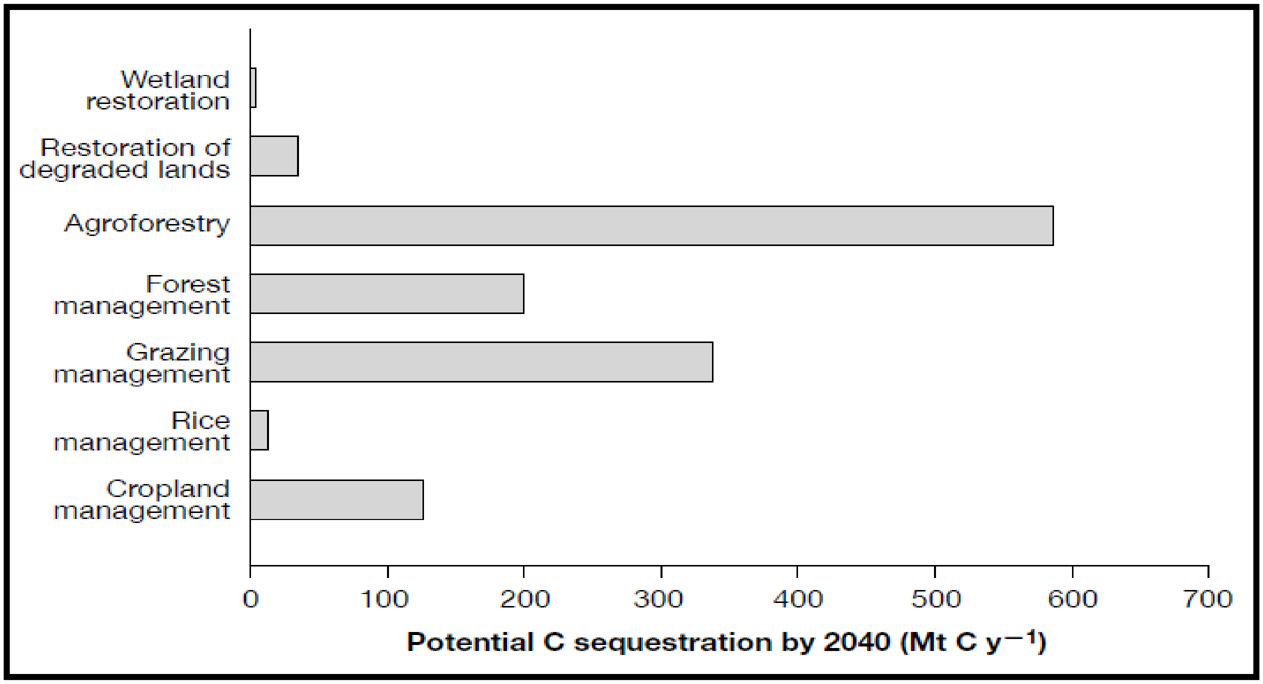

Figure-5
Global warming potential of rice cultivated under water logged and unsaturated conditions (kg CO_2/ha)

Table-3
Agricultural practices for enhancing productivity and increasing the amount of carbon in soils

Conventional practice	Recommended practice
Plough tilling	Conservation tilling/ zero tillage
Residue removal/burning	Residue return as mulch
Summer fallow	Growing cover crops
Low off-farm inputs	Judicious use of fertilizers and INM
Regular fertilizer use	Site-specific soil management
No water control	Water management/conservation, irrigation,
Fence-to-fence utilization	Conversion of marginal lands to nature conservation
Monoculture	Improved farming systems with several crop rotations
Drainage of wetlands	Restoring wetlands

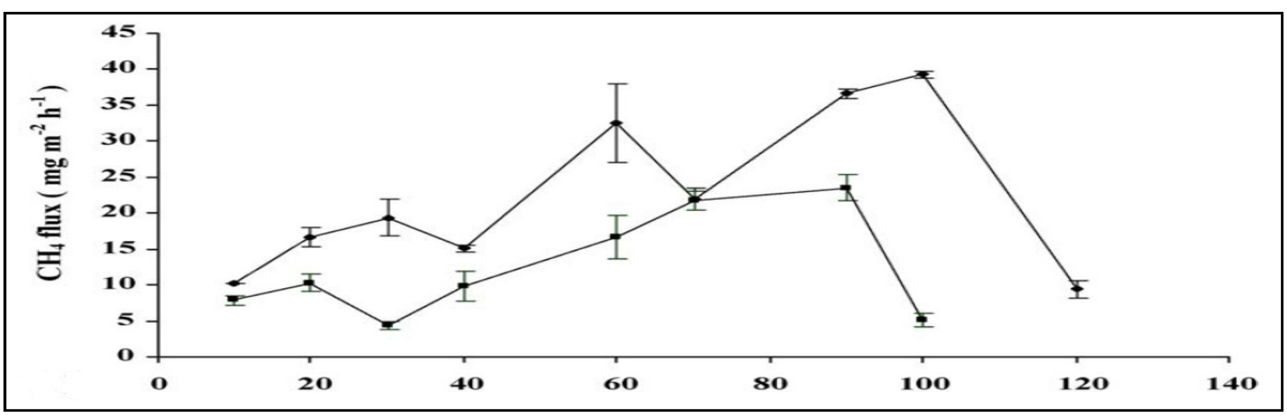

Figure-6
Effect of staggered transplantation on (A) CH_4 efflux from a flooded field planted to rice (cv. Gayatri)
(●early 35 days; & ■late 45 days)

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