Developing countries will not agree to control greenhouse gas emissions, however, unless the costs are low enough to be acceptable given the seriousness and urgency of the other problems such countries face. The only net cost likely to be acceptable is close to zero. The inescapable conclusion is that effective controls over emissions will only be implemented at enormous cost to the taxpayers of the developed countries.

3

Impact of Climate Change on Agricultural Production at Global Level and in India

Dr. S. Candhimathi

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of climate change on agriculture will depend on the balance of these effects. Assessment of the effects of global climate changes on agriculture might help to properly anticipate and adapt farming to maximize agricultural production. At the same time, agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide, but also by altering the Earth's land cover, which can change its ability to absorb or reflect heat and light, thus contributing to radioactive forcing. Land use change such

Assistant Professor of Economics (SG/Reader), Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore - 641 043.

as deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide: agriculture itself is the major contributor to increasing methane and nitrous oxide concentrations in earth's atmosphere. In this backdrop, an attempt was made to analyse the impact of climate change on agricultural production at global level and also in India.

Due to climate change, "southern Africa could lose more than 30 per cent of its main crop, maize, by 2030. In South Asia losses of many regional staples, such as rice, millet and maize could top 10 per cent". In India, it was found that increases in temperature (by about 2°C) reduced potential grain yields in most places. Regions with higher potential productivity (such as northern India) were relatively less impacted by climate change than areas with lower potential productivity (the reduction in yields was much smaller); Overall, temperature increases are predicted to reduce rice yields. An increase of 2-4°C is predicted to result in a reduction in yields.

Climate change is a long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years. It may be a change in the average weather conditions or a change in the distribution of weather events with respect to an average, for example, greater or fewer extreme weather events. Climate change may be limited to a specific region, or may occur across the whole Earth. In recent usage, especially in the context of environmental policy, climate change usually refers to changes in modern climate. It may be qualified as anthropogenic climate change, more generally known as global warming or anthropogenic global warming.

Factors that can shape climate are climate forcing. These include such processes as variations in solar radiation, deviations in the Earth's orbit, mountain-building and continental drift, and changes in greenhouse gas concentrations. There are a variety of climate change feedbacks that can either amplify or diminish the initial forcing. Some parts of the

climate system, such as the oceans and ice caps, respond slowly in reaction to climate forcing because of their large mass. Therefore, the climate system can take centuries or longer to fully respond to new external forcing.

Climate Change and Agricultural Production at Global Level

Despite technological advances, such as improved varieties, genetically modified organisms, and irrigation systems, weather is still a key factor in agricultural productivity, as well as soil properties and natural communities. The effect of climate on agriculture is related to variability in local climates rather than in global climate patterns. The Earth's average surface temperature has increased by 1 degree F in just over the last century. Consequently, agronomists consider any assessment has to be individually consider each local area. On the other hand, agricultural trade has grown in recent years, and now provides significant amounts of food, on a national level to major importing countries, as well as comfortable income to exporting ones. The international aspect of trade and security in terms of food implies the need to also consider the effects of climate change on a global scale.

A study published in *Science* suggests that, due to climate change, "southern Africa could lose more than 30 per cent of its main crop, maize, by 2030. In South Asia losses of many regional staples, such as rice, millet and maize could top 10 per cent". 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. In Africa and Latin America many rain-fed crops are near their maximum temperature tolerance, so that yields are likely to fall sharply for even small climate changes; falls in agricultural productivity of up to 30 per cent over the 21st century are projected. Marine life and the fishing industry will also be severely affected in some places.

Climate change induced by increasing greenhouse gases is likely to affect crops differently from region to region. For

example, average crop yield is expected to drop down to 50 per cent in Pakistan according to the UKMO scenario whereas corn production in Europe is expected to grow up to 25 per cent in optimum hydrologic conditions.

More favourable effects on yield tend to depend to a large extent on realisation of the potentially beneficial effects of carbon dioxide on crop growth and increase of efficiency in water use. Decrease in potential yields is likely to be caused by shortening of the growing period, decrease in water availability and poor verbalization.

In the long-run, the climatic change could affect agriculture in several ways:

- *Productivity*, in terms of quantity and quality of crops.
- *Agricultural practices*, through changes of water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers.
- *Environmental effects*, in particular in relation of frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion reduction of crop diversity.
- *Rural space*, through the loss and gain of cultivated lands, land speculation, land renunciation, and hydraulic amenities.
- *Adaptation*, organisms may become more or less competitive, as well as humans may develop urgency to develop more competitive organisms, such as flood resistant or salt resistant varieties of rice.

They are large uncertainties to uncover, particularly because there is lack of information on many specific local regions, and include the uncertainties on magnitude of climate change, the effects of technological changes on productivity, global food demands, and the numerous possibilities of adaptation.

Most agronomists believe that agricultural production will be mostly affected by the severity and pace of climate change, not so much by gradual trends in climate. If change is gradual, there may be enough time for biota adjustment. Rapid

climate change, however, could harm agriculture in many countries, especially those that are already suffering from rather poor soil and climate conditions, because there is less time for optimum natural selection and adaption.

Climate Change and Agricultural Production in India

In India, the agricultural sector represents 35 per cent of India's Gross National Product (GNP) and as such plays a crucial role in the country's development. Food grain production quadrupled during the post-independence era; this growth is projected to continue. The impact of climate change on agriculture could result in problems with food security and may threaten the livelihood activities upon which much of the population depends. Climate change can affect crop yields (both positively and negatively), as well as the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests. Hence an attempt was made to analyse the vulnerability of agricultural production to climate change, with the objective of determining differences in climate change impacts on agriculture by region and by crop.

Models used to Predict Climate Change by the Indian Agricultural Research Institute (IARI)

The following models were developed by the agricultural research institute, to evaluate the impacts of changes in temperature and carbon dioxide on crops: INFOCROP, a generic growth model for various crops, was developed by IARI for optimal resource and agronomic management options. INFOCANE, a simple sugarcane growth model, was developed by IARI to measure effects on cane yield. Simple tea and coconut models were developed for tropical India and Sri Lanka. Pest damage mechanisms were coupled with INFOCROP for simulating the effect of pests. The use of this model meant that assessments could be made of the impact of climate change and its variability on incidence of pests for various crops. Interaction effects of climate changes (temperature rise, rainfall and radiation changes), with irrigation and nitrogen amounts,

and agronomic management practices were established for various agro-ecologies. These were used to calculate the actual impact of climate change on agricultural production as well for suggesting agro-and resource management options for sustaining production in India.

Predicted Climate Change Effects on Agriculture

The predicted changes to agriculture vary greatly by region and crop. Findings for wheat and rice are reported here:

Wheat Production

- The study found that increases in temperature (by about 2°C) reduced potential grain yields in most places. Regions with higher potential productivity (such as northern India) were relatively less impacted by climate change than areas with lower potential productivity (the reduction in yields was much smaller).
- Climate change is also predicted to lead to boundary changes in areas suitable for growing certain crops.
- Reductions in yields as a result of climate change are predicted to be more pronounced for rain fed crops (as opposed to irrigated crops) and under limited water supply situations because there are no coping mechanisms for rainfall variability.
- The difference in yield is influenced by baseline climate. In sub tropical environments the decrease in potential wheat yields ranged from 1.5 to 5.8 per cent, while in tropical areas the decrease was relatively higher, suggesting that warmer regions can expect greater crop losses.

Rice Production

- Overall, temperature increases are predicted to reduce rice yields. An increase of 2-4°C is predicted to result in a reduction in yields.
- Eastern regions are predicted to be most impacted by increased temperatures and decreased radiation, resulting in relatively fewer grains and shorter grain filling durations.

- By contrast, potential reductions in yields due to increased temperatures in Northern India are predicted to be offset by higher radiation, lessening the impacts of climate change.
- Although additional CO_2 can benefit crops, this effect was nullified by an increase of temperature.

What are the Policy Implications of these Predictions

The policy implications for climate change impacts in agriculture are multi-disciplinary, and include possible adaptations to:

- *Food Security Policy*: To account for changing crop yields (increasing in some areas and decreasing in others) as well as shifting boundaries for crops, and the impact that this can have on food supply.
- *Trade Policy*: Changes in certain crops can affect imports/exports, depending on the crop (this is particularly relevant for cash crops such as chilies).
- *Livelihoods*: With agriculture contributing significantly to GNP, it is critical that policy addresses issues of loss of livelihood with changes in crops, as well as the need to shift some regions to new crops, and the associated skills training required.
- *Water Policy*: Because impacts vary significantly according to whether crops are rain fed or irrigated, water policy will need to consider the implications for water demand of agricultural change due to climate change.
- *Adaptive Measures*: Policy-makers will also need to consider adaptive measures to cope with changing agricultural patterns. Measures may include the introduction of the use of alternative crops, changes to cropping patterns, and promotion of water conservation and irrigation techniques.

A Case Study on the Effect of Climate Change on Agricultural Production in India

Sushila Kau (2008), analysed the impact of climate change on agricultural production in India.

In order to study the impact of climate change on productivity, regression equations were estimated.

The results indicate that the variables of fertilizer used, human labour, actual rainfall, mean maximum temperature and mean minimum temperature, explained 73 per cent of variation in the productivity of Rice. This implies that productivity of Rice on per hectare basis is influenced by these variables. Moreover, the fertilizer use variable had a highly significant co-efficient, suggesting a significant impact of fertilizer use on productivity.

Surprisingly, the variables pertaining to actual rainfall and maximum temperature, during the growing period of the crop, had negative co-efficient, implying that these two variables had negative impact on productivity. The mean minimum temperature had a statistically significant and positive co-efficient, implying that this variable would affect the productivity of rice positively.

He also estimated regression equations for Rice crop and climate related variables, using data from various districts of Orissa state.. The results indicated that the use of fertilizer variable has a negative impact on Jowar productivity, which is not correct on theoretical grounds. However, the human labour variable has a positive and statistically significant impact on Jowar productivity. The deviation from normal rainfall had negative impact on productivity. This implies that rainfall contributes significantly in raising productivity of Jowar, which is normally a rain-fed crop. The mean maximum temperature, during the growing season of the crop had a negative implication for the crop, while the minimum temperature, during the same period, would affect the crop productivity positively. The model had better fit. In the state of Karnataka, the use of fertilizer has negative impact on the crop productivity, which is theoretically inconsistent.

The rainfall during the crop growth period has also negative co-efficient. Whereas mean maximum temperature will effect the crop positively. The results indicate that the effect of climate related variables have mixed effects on

productivity of Jowar, as rainfall shows negative impact, while maximum temperature has a positive effect. However, for understanding the real effect of these variables on productivity of Jowar crop, a detailed study is required.

Need for Further Research

Due to the complex interaction of climate impacts, combined with varying irrigation techniques, regional factors, and differences in crops, the detailed impacts of these factors need to be investigated further.

Specific recommendations for further research include:

- Precision in climate change prediction with higher resolution on spatial and temporal scales.
- Linking of predictions with agricultural production systems to suggest suitable options for sustaining agricultural production.
- Preparation of a database on climate change impacts on agriculture.
- Evaluation of the impacts of climate change in selected locations.
- Development of models for pest population dynamics.

References

1. Climate Change, (2011)., http://en.wikipedia.org/wiki/Climate_change#Terminology
2. Kavi Kumar, K.S. and Jyoti Parikh (2001). "Indian Agriculture and Climate Sensitivity" Global Environmental Change, Vol. 11 (2).
3. Kaul and Sushila (2006). "Economic Analysis of Productivity of Rice Production-State-wise Analysis" presented at the 14th Annual Conference of Agricultural Economics Research Association, held during Sept. 27-28,2006 at G.B. Pant University of Agri. and Tech., Pant Nagar, Uttaranchal.
4. Sushila Kaul (2008). Bio-economic Modelling of Climate Change on Crop Production in India, Research paper, Division of Econometrics, Indian Agricultural Statistics Research Institute, New Delhi, India.