Strategies and methodologies for adaptation to climate change

V. Sudha Rani and Shivakrishna Kota*

Department of Agricultural Extension, College of Agriculture, AcharyaN. G. Ranga Agricultural University, Hyderabad, A.P., India

*E-mail: kotashivakrishna@gmail.com

ABSTRACT

Agriculture is the back bone of India. It has a prominent share in world agricultural production. India, being the second largest developing and populous country in the world, has significant role to play both as a source of climatic change and as a sink for its consequences/impacts. With a large and growing population, emissions of greenhouse gases are increasing. At the same time, potential climate impacts in India are severe; they include sea level rise, changes in the monsoon, increased severe storms and flooding, and severe drought. All these lead to great set back in general socio-economic development. Continued dependence upon agriculture for food and livelihood (25% of GDP and 60% of the labor force, 2002 and 1999 estimates) makes the Indian people particularly vulnerable to climate variability and change. Since the Indian economy is intrinsically linked with the climate change. A better understanding of the future behavior of the climate changes and its variability is warranted for disaster preparedness, mitigation and for developing adaptation strategies and methodologies to cope and adapt to climate change. Since, past one decade, the impact of climate change is more rampant on Indian agricultural economy. The article briefly discusses about the challenges involved and potential opportunities for development and implementation of strategies and methodologies for proactive adaptation and mitigation to combat climatic change.

KEY WORDS: Agriculture, climate change, effects, mitigation strategies

Worldwide agriculture in general is highly sensitive to variations in climate and in India in particular. The Indian climate is already changing and these changes have a measurable impact on Indian agricultural economy. As we know, agriculture is the backbone of India which is the second largest developing and populous country in the world. It has a prominent share in world agricultural production. India is a land of small cultivators and 80 per cent of its farmers owning less than 2 ha of land. In other words, the land provides livelihood security for 65 per cent of the people, and the small farmers provide food security for 1 billion people. Agriculture and allied sectors like forestry, logging and fishing accounted for 16.6% of the GDP in 2007, employed 60% of the total workforce (CIA Fact book, 2008) and O'Brien et al., (2004) revealed that despite a steady decline of its share in the GDP, it is still the largest economic sector. More than one billion people in India, directly or indirectly are involved in the agricultural sector. Moreover, India acts both as source of climate change and as a
sink for its consequences/impacts. With large and growing population, emissions of greenhouse gases are increasing. There is a national imperative to equip Indian agriculture to be prepared to adapt to climate change.

Projections of future climate are based on climate models, complicated computer programs that attempt to describe how the atmosphere will behave through time in response to the forces that act upon it. Stern, (2006) revealed that climatic model results have shown that compared to the pre-Industrial era, the world temperature has warmed by half a degree centigrade. The major causes for this warming have been attributed to the rising stocks of greenhouse gases in the atmosphere including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), chloro-and fluoro-carbons and a number of other gases that arise from industrial processes. The current level or stock of greenhouse gases in the atmosphere is estimated to be equivalent to 430 parts per million (ppm) of carbon dioxide compared to 280 ppm before the industrial revolution. If we continue with business as usual, it is predicted that by the end of 2035, there would be a 2°C increase in temperature. It is clear that climate change will impact heavily on agriculture and renewable natural resources.

**Global warming and implications on livelihoods**

Saka, (2008) observed that climate change across the globe is real. The causes have now been documented and each day, the body of knowledge on the causes and consequences of climate change is being expanded. It is known that global warming which is the major cause of climate change is caused by the accumulation of greenhouse gases in the atmosphere. Figure 1 shows worldwide total emissions by industry in 2000.

With the current accelerating levels of emissions with fast-growing economies investing in high carbon infrastructure and as the demand for energy and transport increase, it is envisaged that there is between a 77-99 per cent chances that by about 2035, the world would have warmed by greater than 2°C (Stern, 2006). These changes are likely going to impact negatively on food production, health and the environment.

Saka, (2008) observed that with increasing human activities, it is projected that greenhouse gas emissions will increase considerably over the coming years and by the year 2035, out of an estimated 11.7 billion tonnes of carbon that will be emitted; developed countries will contribute 50% and developing countries the other 50%. This significant shift in greenhouse gas (GHG) emissions has important implications for Africa and the world at large.

Kandji et al., (2006) observed that most countries are already experiencing a number of adverse climatic hazards including dry spells, seasonal droughts, intense rainfall, riverine floods and flush floods. Some of these, especially droughts and floods have increased in frequency, intensity and magnitude over the last two decades, and have adversely impacted on food, water security, quality, energy and the sustainable livelihoods of rural communities.
Fig. 1: Greenhouse gas emissions in 2000, by source - Data adapted from Stern (2006)

Over the 1900-1999 period, the emissions of anthropogenic CO2 from fossil fuel combustion show that Europe and the United States were the greatest contributors (Figure 2).

Fig. 2: Anthropogenic CO2 emissions by different countries/continents from 1900-1999. (Data Source: Saka, 2008)
In addition to the effects on food production, ecosystems and biodiversity will be particularly vulnerable to climate change, with around 15-40% of the species potentially facing extinction after only 2°C of warming. Ocean acidification, a direct result of the rise in CO2 will have major effects on marine ecosystems, with possible adverse effects on fish stocks. We cannot continue with business as usual approach if we want to stabilise the GHGs. Stabilisation at whatever level requires that annual emissions be brought down to the level that balances the earth’s natural capacity to remove greenhouse gases from the atmosphere. In the long term, annual global emissions will need to be reduced to below 5 GtCO2e (gigatonnes of carbon dioxide equivalent emission), the level that the earth can absorb without adding to the concentration of the GHGs in the atmosphere.

Reversing the historical trend in emissions growth is a major challenge. Greenhouse-gas emissions can be cut in four ways:

- Reducing demand for emissions-intensive goods and services
- Increased efficiency which can save both money and emissions
- Action on non-energy emissions, such as avoiding deforestation and ecosystem degradation
- Switching to lower carbon technologies for power, heat and transport

**Impact of Climate change on Indian agriculture**

Potential impact of increased greenhouse gases on Indian agricultural activity depends on the magnitude of climate change locally (e.g. shifts in local temperature, rainfall patterns, and extreme events), how strongly each amount of change in the climate affects farm productivity, and lastly the actions taken in response to the climate changes. The ultimate effect of climate change on farm enterprises and the rural economy therefore depends not only on how the climate affects farm production directly, but also on the way that individual farmers, communities, and whole industries respond to the changes. Scientific evidence about the seriousness of the climate threat to agriculture is now unambiguous, although the exact magnitude is uncertain because of the complex interactions and feedback processes in the ecosystem and in the economy. The Fourth Assessment Report by the Inter-Governmental Panel on Climate Change (IPCC) in (2007), projects for India an acceleration of warming above that observed in the 20th century, a decrease in precipitation, and an increase in the occurrence of extreme weather events. Climate change is expected to have adverse effects on agriculture, the eradication of poverty, food security, and the water supply (IPCC, 2007).

Climate change is likely to affect all the natural ecosystems as well as socio-economic systems as shown by the National Communications Report of India to the UNFCCC (INC, 2004). Various studies have indicated a probability of 10 to 40 per cent loss in crop production in the country due to the anticipated rise in temperature by 2080. Studies conducted by Indian Agricultural Research Institute (IARI) have pointed to a
possible loss of 4 to 5 million tonnes in the overall wheat production with every 1 degree centigrade increase in temperature throughout the growing period of the crop.

Lal et al., (1998); Kumar and Parikh, (2001); TERI, (2008); Mali et al., (2006) observed that with the growing evidence of climate change over the last few years, an increasing emphasis was put on studying the impact of climate change on Indian agriculture A number of crop simulation modeling studies, based on future climate change scenarios, with a focus on the vulnerability of rice and wheat yields has been carried out. Lal, (2007) cited in IPCC, (2007) observed that according to the latest results of the crop simulation modeling studies published in the AR4, the drop in yields of non-irrigated wheat and rice in India will be significant: a temperature increase beyond 2.5 °C would incur a loss in farm-level net revenue between 9 and 25 percent. (Lal, 2007 cited in IPCC, 2007) concluded that net cereal production in India is projected to decline at least between 4 and 10 percent by the end of this century under the most conservative climate change scenario

Mali et al. (2006) provide an excellent review of climate change impact studies on Indian agriculture, mainly from the perspective of physical impact. While yields of important cereal crops like rice and wheat are expected to drop significantly with impacts of projected climate change, biophysical impacts on some of the important crops like sugarcane, cotton and sunflower are yet to be studied adequately.

Adapting Indian agriculture

Some agricultural communities, industries or regions will have a greater capacity to adapt than others: understanding their constraints and incentives is important in ensuring that they do so successfully. An early part of adapting agriculture to climate change involves helping communities to understand why adaptation is a needed part of today’s vision of the future and therefore of their management strategies. The first step towards developing an adaption strategy to climate change should be to undertake initial or ex ante assessment to understand farmers' perceptions, attitudes, long-term goals, and other cognitive and decision-making information through participatory methods. Once enough data has been elicited and analyzed, we may start to develop Extension strategies for adaptation and mitigation to climate change to targeting end-goal of economic and ecological sustainability.

Lybbert and Sumner, (2010); Kandjiet al, (2007) stated that the core challenge of climate change adaptation in agriculture is to provide (i) more efficient food, (ii) under more volatile production conditions, and (iv) with net reductions in GHG emissions from food production. The following adaptation strategies could be part of a climate variability/change.

- Changing planting or harvest dates are effective, low-cost options. The major risk could be shifting to a different market window with lower prices;
- Changing varieties is another low-cost option, although some varieties can be more expensive or require investments
in new planting equipment. Examples are the increased adoption of genetically modified cotton varieties resistant to certain types of herbicides and pests;

- Increased use of irrigation, fertilizer, herbicide, and pesticide may be necessary to achieve maximum benefits from increased atmospheric CO$_2$. Climate change is also likely to increase weed and pest pressure in most cases as discussed above;

- Changing crop species or livestock produced could bring new profits, but is a risky and more expensive option because the necessary infrastructure or marketing mechanisms may not exist locally;

- Investments in new irrigation or drainage systems or other capital items are likely to be essential if climate change increases climate variability.

- Changes in tillage practices, selection of varieties with greater drought and heat tolerance, and development and implementation of improved Integrated Pest Management (IPM) programs. The extent of adaptation will depend mostly on the affordability of proposed strategies, the rate of climate change, and access to knowhow and technology.

- Soil carbon sequestration has additional appeal because practices that enhance soil carbon also improve soil quality and fertility. Irrigation can enhance carbon sequestration over native soil levels by overcoming the moisture limitation to increased plant biomass production. Examples of management practices with the potential to increase soil organic carbon include:

  - Adoption of conservation and no-tillage practices;
  - Optimize crop rotations by using legumes, rotations crop-pasture, green manures;
  - Improved fertilization to stimulate biomass production and root growth;
  - Optimize manure management;
  - Promotion of land use shifts that enhance soil organic matter (e.g., forest, wetlands), mixed cropping systems that combine annual and perennial crops (e.g., agroforestry).

**Adaptation priorities and opportunities:**
Some adaptation priorities apply broadly across the whole agricultural sector. Among these is the need to improve and promote existing management strategies for dealing with climate variability. This will enhance farmers’ capacity to plan for, and deal with, extreme events (droughts, floods, fire, hail, etc.) in the medium and longer term. Using climate forecasts at a range of time scales to make pre-emptive, tactical management adjustments will help to track the early stages of climate change, until the longer term trends and necessary adaptations in particular regions become clearer.

**However there is an urgent need for successful adaptation by stake holders**

(1) confidence among farmers and others that the climate really is changing and that inaction is not an option
(2) the motivation to change, to avoid negative impacts, or seize opportunities
(3) wide communication and demonstration of the benefits of new climate adaptations
(4) support for farmers as they make the transition to new systems, new land uses, or new forms of livelihood

(5) building capacity in farming communities to take up and implement adaptation strategies

(6) a rapidly evolving transport, market, and financial infrastructure to support the most climate-efficient forms of agriculture

(7) an effective system for monitoring climate change impacts and human adaptive responses, so that policy and management can develop ‘ahead of the game’.

(8) inculcating “Go green” concept in the minds of the farmers.

It is important to note that many climate adaptation options are similar to existing ‘best practice’ and good natural resource management, and do not require farmers to make radical changes to their operations and industries in the near term. These options can, and should, be prioritised as part of a ‘no regrets’ or win–win strategy for agriculture because they will provide immediate and ongoing benefits, as well as preparing the sector for climate change. (Howden et al., 2007)

Mitigation strategies

Since it has been demonstrated that GHG emissions resulting from man’s activities are responsible for global warming and subsequent changes in the climate system, there is a need to identify measures for limiting greenhouse gas emissions into the atmosphere. There is a need to use cleaner technologies that do not emit a lot of GHGs or provide sinks for the emitted GHGs. Most of the mitigation measures will be in the energy sector through use of cleaner technologies, forestry sector through reforestation and the agriculture sector through improved fertilizer application, crop and livestock management.

1. Extension strategies are to reduce risks associated with climate variability. Adding the perspective of climate change is an attractive option given the existing focus on developing adaptation strategies and training of stakeholders to add seasonal climate variability as part of their decision making process. Dissemination and promotion of mitigation strategies should also be included, especially strategies that increase the efficiency of inputs, improve soil quality, and may allow the participation of producers in the carbon trading market. Changing the mindset of the farmer. Changing the knowledge base.

2. In the forestry sector strategies include planting of tree species in woodlots, forestry plantations, onfarm boundary planting and other agroforestry systems. Agroforestry can enhance adaptation to climate change through provision of diversified tree products and services.

3. In the energy sector, strategies would include biomass-based technologies such as use of i) wood fuel in improved mud stoves and ceramics, ii) biogas fuel from bio-wastes to produce biogas for cooking and heating, and iii) briquettes for cooking instead of wood.

4. The non-biomass based strategies would include i) rural electrification through grid extension, ii) mini-hydropower, iii)
compact fluorescent lamps for lighting, iv) renewable energy sources (solar cookers and heaters) and v) wind power for pumping water.

5. The agriculture sector, strategies to reduce the GHG emissions include: i) incorporation of crop residues into the soil instead of burning, ii) good management of livestock manure to reduce methane emissions and proper management of nitrogenous fertilizers in rice and upland agricultural soils to reduce nitrous oxide emissions.

Schneider, (2008) stated that some scientists think mitigation of climate change needs a more radical approach. The Royal Society Academy in England has written a series of papers in “Philosophical Transactions” proposing “geoengineering” as a way of buying time for the transition to a low-carbon economy to take place in an orderly manner. Broadly the ideas fall into two categories: one is to remove excess CO2 from the atmosphere while the other is to compensate for climate-warming greenhouse effects the CO2 and other gases cause, by reducing the amount of sunlight reaching the ground. The strategies include increasing photosynthesis to wipe out excess CO2 through planting more trees and also through encouraging increased phytoplankton growth which eventually will sink to the bottom of the ocean and not release the carbon. The CO2 can also be recycled into fuel through a reaction with H2 or it can be ejected from the atmosphere using the planet’s magnetic field. The stratosphere can also be deliberately polluted with sulphate in order to reflect solar heat into space. These ideas are all being tested and if they can be proven to be satisfactory, with predictable long-term effects, they could offer mankind the space and opportunity to think through more sustainable mitigation strategies to the challenges posed by climate change. It will be important that students in tertiary agricultural institutions have a good understanding of the issues surrounding climate change mitigation and the new concept of geoengineering.

Extension strategies for adaptation:

**Information delivery** to farmers from climate analyses can be enhanced by providing projections of management- and policy-relevant weather metrics (e.g. cold indices for stone fruit), providing climate information at scales relevant to the decisions being made, and combining information on both climate variability and trends in seasonal and medium-term (decadal) forecasts.

**Better models of agricultural systems** can assess climate change impacts and more reliably explore and improve adaptation options.

**Monitoring and evaluation systems** are needed to track changes in climate, impacts on agriculture, and the effectiveness of adaptation measures, to help decide when to implement particular options and to refine them over time.

**Policy and management decisions** require timely inclusion of climate information as it becomes available, as well as closer collaboration between policy makers.
makers, managers, researchers, extension agencies, and farmers.

In addition to above strategies few other strategies are:

Technological strategies for adaptation:

**Biotechnology** and traditional plant and animal breeding have the potential to develop new ‘climate-ready’ varieties and new crops or pastures pre-adapted to future climates.

**Plant nutrition** can be adjusted by measures such as precision fertiliser use, legume rotations, and varietal selection to maintain the quality of grain, fruit, fibre, and forage sources.

**Irrigation efficiency** will become critical as water resources become more constrained, particularly in southern Australia. This can be assisted by identifying less water intensive production options, by developing better water delivery technologies, and by implementing water markets and water-sharing arrangements.

**Soil and water conservation methods** and new systems become even more important as climates fluctuate more and extreme events become more frequent.

**Biosecurity,** quarantine, monitoring, and control measures can be strengthened to control the spread of pests, weeds, and diseases under a warming climate.

India’s proactive preparedness to climate change:

Observed changes in climate reported by India Meteorological Department (IMD) for the past 130 years are as follows:

- Monsoon rainfall at all India level does not show any trend but there are some regional patterns. Areas of increasing trend in monsoon rainfall are found along the west coast, north Andhra Pradesh and north-west India, and those of decreasing trend over east Madhya Pradesh and adjoining areas, north-east India and parts of Gujarat and Kerala (-6 to -8% of normal over 100 years).
- A recent study indicates that the intensity and frequency of heavy to very heavy rainfall events is showing an increasing trend during the past 50 years over the region covering parts of Andhra Pradesh, Orissa and Chhattisgarh and Madhya Pradesh.
- Mean annual surface air temperatures show a significant warming of about 0.5°C/100 year during the last century and recent data indicates a substantial acceleration of this warming after the 1990’s. This is comparable to the global warming trends reported.

Specific Climate Change Projections for India are:

- Various studies conducted in the country have shown that the surface air temperature in India is rising at the rate of 0.4°C per hundred years, particularly during the post-monsoon and winter season. Models project that mean winter temperatures will increase by as much as 3.2°C in the 2050s and 4.5°C by 2080s. Summer temperatures will increase by
Extreme temperatures and heat spells have already become common over Northern India, often causing loss of human life. In 1998 alone, 650 deaths occurred in Orissa due to heat waves.

An annual mean surface temperature rise by the end of the century, ranging from 3 to 5°C under A2 scenario and 2.5 to 4°C under B2 scenario, with warming more pronounced in the northern parts of India. A 20% rise in all India summer monsoon rainfall and further rise in rainfall is projected over all states except Punjab, Rajasthan and Tamil Nadu, which show a slight decrease. *(Predictions based on Regional Climate Modeling (RCM) system, known as PRECIS developed by Hadley Center and applied for India using IPCC scenarios A2 and B212 changes in tillage)*

Now-a-days awareness of farmers in climate change has recently increased in response to intense media coverage of climate change, recent weather extremes in India such as drought, floods and additional revenue possibilities in the carbon market. The question this article addresses is whether and how research and extension efforts to develop adaptation strategies aimed at helping farmers cope with seasonal climate variability can be extended to address longer-term climate change. In this context vulnerability, defined as the degree of sensitivity and ability to cope with climate variability. Adaptation defined as adjustments to environmental stresses caused by climate variability, can also be applied to climate change.

First, we should develop information system with decision support system and expert system made accessible at grass root level for the use by extension functionaries, farmers, water use managers and community organizers in drought and effected area to enable adequate preparedness and reduce risk associated with climate variability. Secondly, information development and dissemination of management practices for mitigation and combating consequences of seasonal climatic variability. These approaches help to mitigate risks associated with seasonal climatic variability focusing primarily on techniques such as shifting cultivation, mulching, planting dates, changing crop varieties and cultural practices. Adaptation strategies could also include practices, selection of varieties with greater drought and heat tolerance, and development and implementation of improved Integrated Pest Management (IPM) programs.

The Government has been trying to mainstream climate change concerns into the relevant sector policies. Several ongoing efforts to promote sustainable agriculture, forestry and coastal zone development, address some of these vulnerability concerns, although they are primarily driven by the objective of sustainable livelihood and poverty alleviation. The Government of India recognized the need for a national strategy to firstly, adapt to climate change and secondly, to further enhance the ecological sustainability of India's development path. Currently, India spends around 2.6% of its GDP on adaptation activities.
National Action Plan on Climate Change (NAPCC)


The National Mission for Sustainable Agriculture, supervised by the Ministry of Agriculture, has put special thrust on the following key aspects:

- Strategic Research on varietal improvement (through biotechnology).
- Sustained Increase in food-grain production (through environment friendly, organic, conserving farming practices)
- Improvement in water-use efficiency.
- Strengthening Risk Management Systems (through efficient early warning systems and easy insurance schemes)
- Measures for Capacity Building for farmers and Information Management at block levels.

National Farmers Policy 2007

The Ministry of Agriculture has brought out a comprehensive National Policy for Farmers in 2007, so far the only policy, which explicitly spells out the vulnerability of farmers to climate change. It has a full section devoted to Climate Change where it mentions forming “Climate Managers” to be trained to face floods, droughts and monsoon aberrations. The policy recommends “Proactive measures based on simulation models, contingency plans and alternative land-use and water-use strategies for each major agro-climatic zone, to reduce the vulnerability to climate change”.

The National Agriculture Policy, 2002, seeks to achieve growth in a sustainable manner and with equity. Price fluctuation and natural calamities are recognized as main factor for imparting instability to condition of farmers. The NAP suggests putting emphasis on following aspects: (1) enhancing flood proofing and drought proofing (2) ensuring remunerative prices through announcement of Minimum Support Prices (MSP) and (3) future trading in agriculture products. Risk proofing in agriculture through insurance is a very complicated process. Covering all crops and all farmers through this seems to be gigantic, rather ambitious task.

Sustainable development issues are of core concern to the country providing the best mechanism to address most of these issues. Commitment to the United Nations Framework Convention on Climate Change (UNFCCC) as well as many other Multilateral Environmental Agreements highlights India’s concerns related to these
issues besides other steps that have been taken to address to push socio-economic development and eradicate poverty. The challenges lie in identifying opportunities that would facilitate sustainable development by making use of existing technologies and development policies that make climate-sensitive sectors resilient to climatic variability. This strategy will require developing countries to have access to appropriate technologies, information, and adequate financing.

CONCLUSION

As climate change unfolds through the early decades of the 21st century, extension strategies for adaptation and mitigation will play a pivotal role in maintaining food security and self-sufficiency to retain vibrant rural communities and to sustain globally important agricultural exports. Research must play a proactive role to generate necessary responses and technologies that farmers will need to handle such future challenges. Linkage between the Researcher- Extension worker - Farmer should be strengthen in order cope up with climate change for sustainable agriculture. Proactive extension activities will help in capacity building and strengthening/changing the mindset of farmers and identify stakeholders which can realize, identify and generate effective adaptation to climate change.

Firstly, we should develop information system with decision support system and expert system made accessible at grass root level for the use by extension functionaries, farmers, water use managers and community organizers in drought and effected area to enable adequate preparedness and reduce risk associated with climate variability. Secondly, information development and dissemination of management practices for mitigation and combating consequences of seasonal climatic variability. These approaches help to mitigate risks associated with seasonal climatic variability focusing primarily on techniques such as shifting cultivation, mulching, planting dates, changing crop varieties and cultural practices. Adaptation strategies could also include changes in tillage practices, selection of varieties with greater drought and heat tolerance, and development and implementation of improved Integrated Pest Management (IPM) programs. Hence, it is need of the hour to develop and establish information and communication in empowering the farmers for effective preparedness to face disasters and to combat the ill effects of climate change.

REFERENCES


[MS received 06 February 2013; MS accepted 14 March 2013]

Disclaimer: Statements, information, scientific names, spellings, inferences, products, style, etc. mentioned in Current Biotica are attributed to the authors and do in no way imply endorsement/concurrence by Current Biotica. Queries related to articles should be directed to authors and not to editorial board.