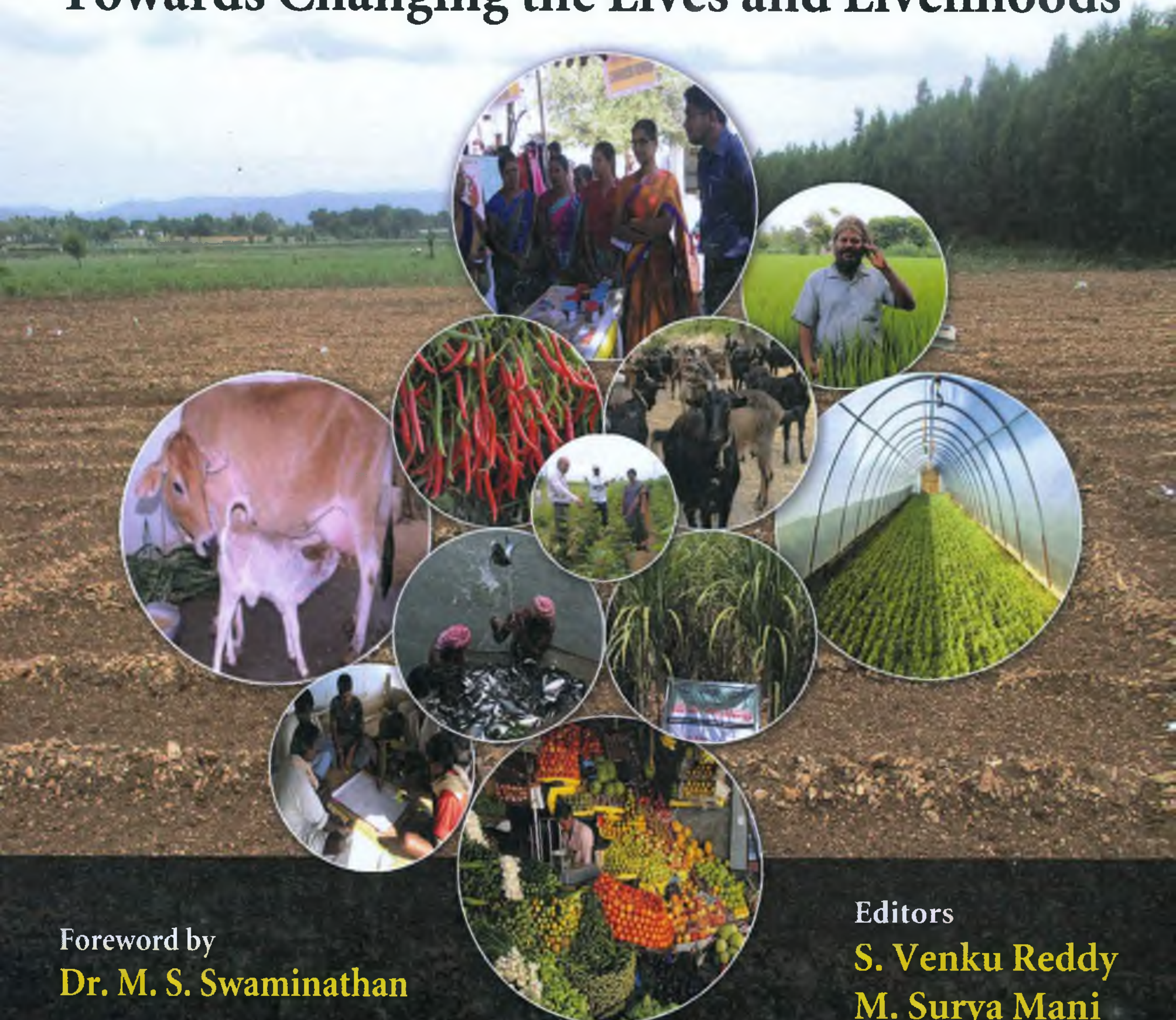
Advances in Agricultural Extension

Towards Changing the Lives and Livelihoods



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BS Publications

33 Climate Change Adaption and Mitigation – Role of Extension

- AVR Kesava Rao, Suhas P Wani and Mukund D Patil

Introduction

Evidences over the past few decades show that significant changes in climate are taking place all over the world as a result of enhanced human activities in deforestation, emission of various greenhouse gases, and indiscriminate use of fossil fuels. Global atmospheric concentration of CO_2 has increased from pre-industrial level of 280 parts per million (ppm) to 400 ppm in 2014. Global projections indicate higher temperature of 1.5 to 4.5°C by the year 2050, as a result of enhanced greenhouse gases. Climate change predictions for India indicate that warming is likely to be above the global mean and fewer very cold days are very likely. Frequency of intense rainfall events and winds associated with tropical cyclones are likely to increase.

The global average surface temperature in 2015 broke all previous records by a strikingly wide margin, at 0.76 ± 0.1°C above the 1961-1990 average. For the first time on record, temperatures in 2015 were about 1°C above the pre-industrial era, according to a consolidated analysis from the World Meteorological Organization (WMO, 2016).

Under the threat of increased greenhouse gases and resultant higher temperatures and uncertainty in rainfall regimes, there is a critical need to communicate climate change scenarios, adaptation and mitigation strategies to all stakeholders particularly farmers and agricultural extension personnel to enhance resilience and also to reduce greenhouse gas emissions.

Climate Variability and Change in India

Various studies show that climate change in India is real and it is one of the major challenges faced by Indian Agriculture, more so in the semi-arid tropics (SAT) of the country. India ranks first among the countries that practice rainfed agriculture in terms of both extent and value of production. Rainfed agriculture is practiced under a wide variety of soil types, agro-climatic and rainfall conditions. Rainfed agriculture supports nearly

40% of India's estimated population of 1.21 billion in 2011 (Sharma, 2011). The rainfed agro-ecologies cover about 60 per cent of the net sown area of 141 million ha and are widely distributed in the country (DOAC, 2011). Even after achieving the full irrigation potential, nearly 50% of the net cultivated area may remain dependent on rainfall. Changes in climate would affect agriculture directly through abiotic stresses and indirectly through biotic stresses.

Climate change is seen as changes in temperature, increased variability in rainfall, enhanced carbon dioxide concentrations. Climate change is likely to make changes in the length of the rainfed crop-growing period. Rainfed agriculture in India plays a crucial role in ensuring food security for the larger and poorer segment of the population but often it coincides with a high incidence of poverty and malnutrition. Reduction in yields due to climate change is likely to be more prominent in rainfed agriculture and under limited water supply situations. Crop yields in dryland areas of the country are quite low (1-1.5 t ha^{-1}) which are lower by two to five folds of the yields from researchers' managed plots (Bhatia et al., 2006). Current rainwater use efficiency in dryland agriculture varies between 35-45% and vast potential of rainfed agriculture could be unlocked by using available scientific technologies including improved cultivars.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is one of the 15 Future Harvest Centers of the Consultative Group on International Agricultural Research (CGIAR). It recognizes that opportunities for sustainable productivity increases in the SAT will be firmly anchored on Integrated Genetic and Natural Resource Management (IGNRM) strategies, improved input-output market delivery systems for agricultural produce, and knowledge dissemination through capacity building.

Due to anthropogenic activities, a steady increase in atmospheric turbidity is observed in India. Indian annual mean (average of maximum and minimum), maximum and minimum temperatures showed significant warming trends of 0.51, 0.72 and 0.27 °C 100 y^{-1}, respectively, during the period 1901–2007 (Kothawale et al., 2010). However, accelerated warming was observed in the period 1971–2007, mainly due to intense warming in the recent decade 1998–2007. Mean annual temperature of India in 2010 was + 0.93°C above the 1961-1990 average and the India Meteorological Department (IMD) declared that 2010 was the warmest year on record since 1901. Mean temperature in the pre-monsoon season (March-May) was 1.8°C above normal during the year 2010.

At the country scale, no long-term trend in the southwest monsoon rainfall was observed, although an increasing trend in intense rainfall events was reported. Goswami et al., (2006) analysed gridded rainfall data for the period 1951-2000 and found significant rising trends in the frequency and the magnitude of extreme rain events, and a significant decreasing trend in the frequency of moderate events over central India during the monsoon seasons. The seasonal mean rainfall does not show a significant trend, because the contribution from increasing heavy events is offset by decreasing moderate events. They concluded that a substantial increase in hazards related to heavy rain is expected over central India in the future. Increased frequency and intensity of extreme weather events in the past 15 years were reported (Samra et al., 2003 and 2006).

A study carried out by ICRISAT under the National Initiative on Climate Resilient Agriculture (NICRA) project described a net reduction in the dry sub-humid area (10.7 m ha) in the country, of which about 5.1 Million ha (47%) shifted towards the drier side and about 5.6 Million ha (53%) became wetter, comparing the periods 1971-1990 and 1991-2004 (Kesava Rao et al., 2013a). Results for Madhya Pradesh have shown the largest increase in semi-arid area (about 3.82 Million ha) followed by Bihar (2.66 Million ha) and Uttar Pradesh (1.57 Million ha). Relatively little changes occurred in AP; semi-arid areas decreased by 0.24 Million ha, which were shifted to both towards drier side (0.13 Million ha under arid type) and wetter side (0.11 Million ha under dry sub-humid type). Results indicated that dryness and wetness are increasing in different parts of the country in the place of moderate climates existing earlier in these regions.

Climate Change Impacts on Agriculture

Due to global warming, length of the growing period (LGP) is likely to increase, however due to increase in day and night temperatures, physiological development is accelerated resulting in hastened maturation and reduced yields. Increased nighttime respiration may also reduce potential yields. With global climate change, rainfall variability is expected to further increase. When decrease in rainfall coupled with higher atmospheric requirements due to elevated temperatures, the LGP is likely to shorten. At Nemmikal watershed in the Nalgonda district of Telangana, the LGP has decreased by about 15 days since 1978 and the climate has shifted to more aridity from semi-arid (Wani et al., 2012). Shift in the length of growing period, if not understood by the farmers, generally results in more crop failures due to late season drought (Fig. 33.1). Present popular varieties of maize and pigeonpea are likely to produce lower yields more often in future.

In the Eastern Dry Agroclimatic Zone of Karnataka (consisting of Bangalore and Kolar districts and parts of Tumkur district), there is a perceptible shift in rainfall pattern from July to August and also from September to October (Rajegowda *et al.,* 2000). If sowing is done in July, crops would suffer from moisture stress due to the reduction in rainfall during September and also the crop grown would be caught in October rains causing considerable loss in the grain yield. Thus, sowing of crops (long duration variety crops of about 115 days) could be done during August preparing the land using June and July rains. In the years of early onset of southwest monsoon, sowing can be recommended during last week of July also. Crops sown during August would reach the grand growth period during October. As October receives higher rainfall the crop in its grand-growth period would not suffer for want of moisture and higher crop yields are expected.

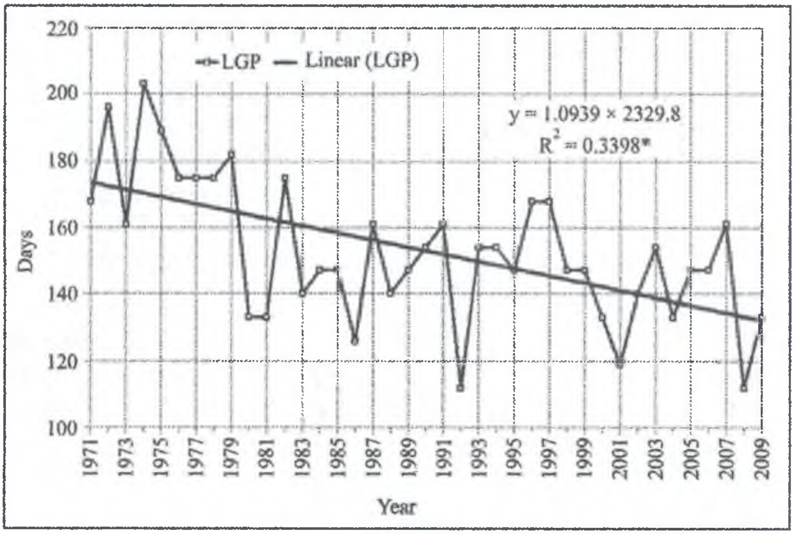

Fig. 33.1 Shift in Length of Rainfed Growing Period at Nemmikal, Nalgonda district

Rise in the mean temperature above a threshold level will cause a reduction in agricultural yields. A change in the minimum temperature is more crucial than a change in the maximum temperature. Grain yield of rice, for example, declined by 10% for each 1 °C increase in the growing season minimum temperature above 32 °C (Pathak et al., 2003). Climate change impact on the productivity of rice in Punjab (India) has shown that with all other climatic variables remaining constant, temperature increases of 1 °C, 2 °C and 3 °C, would reduce the rice grain yields by 5.4%, 7.4% and 25.1%, respectively (Aggarwal et al., 2009).

Field experiments and lab analyses were conducted at IARI, New Delhi in 2005, with five high-yielding rice varieties including aromatic and non-aromatic types, exposed to twelve different diurnal temperature (day/night) and radiation regimes to ascertain the impact of diurnal temperature and radiation changes on yield and yield components of aromatic and non-aromatic rice varieties in the field conditions and to document their effect on the grain and seed quality. Salient results indicate that the grain yield of all the five varieties was most significantly influenced by MNT ($P < 0.001$), followed by radiation ($P < 0.001$), explaining 87% and 77% of the yield variation respectively (Anand et al., 2015). Highest yields were recorded around a very narrow optimum temperature of 23°C to 24°C, with subsequent increase in temperature even by 1°C or 2°C, significantly reducing the grain yield.

Surface air temperature and diurnal temperature ranges are likely to increase along the high-ranges of the Western Ghats region of India and under such conditions; there is a threat to thermo-sensitive crops like black pepper, cardamom, tea, coffee, cashew and other plantation crops.

ICRISAT studied the effects of climate change on crop growth, development and productivity using crop models (DSSAT and APSIM) under different climate change scenarios. The simulation outputs indicate that climate change in the dryland regions characterized by existing high temperature will reduce crop sorghum crop duration by 15 days in Maharashtra. Increase in temperature causes reduced radiation interception, harvest index, biomass accumulation and increasing water stress in plants as a result of increased evapotranspiration demand. Temperature increase of 3.3°C, which is expected to take place by the end of this century, is likely to reduce sorghum crop yields by 27% at Parbhani, Maharashtra.

Groundnut modelling results at ICRISAT, Patancheru have shown that in SAT Alfisols, if a dry spell occurs for more than 15 consecutive days, during the 25-day period between 35 and 60 days after sowing, groundnut yields could be reduced by 35-38 per cent of the potential yield. Crop-growth simulation studies at ICRISAT have shown that groundnut pod yield would reduce by 9 to 13 per cent under projected climate scenarios (Table 33.1). Crop growth simulations using Agricultural Production Systems Simulator (APSIM) showed that in Gulbarga, Karnataka increase in temperature by 2°C could reduce pigeonpea yields by about 16% (Kesava Rao et al., 2013b). Rainfall decrease of 10% from present coupled with 2°C increase in temperature could reduce yields further by 4%, making the total reduction to be at 20%. Crop-growth simulationhas shown that pigeonpea yields would reduce by about 11 per cent under projected climate scenarios. In both crops, more runoff is likely which will lead to more soil erosion and nutrient loss.

Table 33.1 Impacts of projected climate on groundnut yields at ICRISAT

CC Scenario	Pod / Seed yield (kg ha^{-1})	Change in Pod / Seed yield (%)	Total Dry Matter production (kg ha^{-1})
Groundnut on Alfisols			
Current	2000	–	5430
HadGEM2-ES	1820	– 9	5410
GFDL-CM3	1830	– 9	5350
CNRM-CM5	1750	– 13	5250

At Guna, Madhya Pradesh, grain yield of soybean would reduce by 14% with increase in temperature by 2 °C and further reduce by 5% when coupled with reduced rainfall of 20%. At Guna, wheat crop duration would reduce by 10 days with increase in temperature of 2 °C. The increase in temperature by 2 °C would reduce the grain yield by 29%.

Climate change affects dynamics and interaction among species and it will affect and change the pattern of pest damage and pest control strategies. Increase in temperature may increase the need for application of pesticides and may reduce pesticide effectiveness and increase residues. Using the 'Rice FACE' facility in northern Japan, Kobayashi et al., (2006) studied the effect of 200–280 ppm above-ambient CO_2 on rice blast and sheath blight disease for three seasons. Severity of leaf blast (*Magnaportheoryzae*) was consistently higher at the elevated CO_2 levels in all the three years assessed at two different stages of rice growth. Global warming will lead to earlier infestation by *Helicoverpa armigera* (Hub.) in North India (Sharma, 2010), resulting in increased crop loss. Rising temperatures are likely to result in availability of new niches for insect pests. Climate change is likely to make sleeper weeds to become invasive and favours expansion of weeds into higher latitudes and altitudes.

Pest-warning systems are key elements of Integrated Pest Management (IPM) efforts to reduce excessive use of chemical pesticides. The five components of an IPM program are prevention, monitoring, correct disease and pest diagnosis, development and use of acceptable thresholds, and optimum selection of management tools (Das et al., 2011). The management strategies available include genetic control, cultural control, biological control, and chemical control. Weather based pest and disease forewarning systems help farmers to avoid the risk of outbreaks of economically damaging crop pests and diseases by applying pesticides and fungicides, only when it is absolutely essential.

Climate-smart Agriculture (CSA)

Climate-smart agriculture (CSA), as defined and presented by the FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, contributes to the achievement of sustainable development goals. Climate-smart agriculture is a way to achieve short-and-long-term agricultural development priorities in the face of climate change and serves as a bridge to other development priorities. It seeks to support countries and other actors in securing the necessary policy, technical and financial conditions to enable them to:

1. Sustainably increase agricultural productivity and incomes in order to meet national food security and development goals.
2. Build resilience and the capacity of agricultural and food systems to adapt to climate change.
3. Seek opportunities to mitigate emissions of greenhouse gases and increase carbon sequestration.

These three conditions (food security, adaptation and mitigation) are referred to as the "triple win" of climate-smart agriculture. Climate-smart agriculture includes practices and technologies that sustainably increase productivity, support farmers' adaptation to climate change, and reduce levels of greenhouse gases. Climate-smart approaches can include many diverse components from farm-level techniques to policy and finance mechanisms.

Climate adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Climate Adaptation

Adaptation strategies need to be identified properly for increasing resilience of agricultural production to climate change. Several improved agricultural practices are evolved over time in various regions of the country. Management practices that are being followed under conditions of weather aberrations could also become potential adaptation strategies for climate change.

Resilience to climate change requires identifying climate smart crops and management practices and degree of awareness of community. Intercropping with grain legumes is one of the key strategies to improve productivity and sustainability of rainfed agriculture. Productive intercropping options identified to intensify and diversify rainfed cropping systems are:

- Groundnut with maize
- Pigeonpea with maize
- Pigeonpea with soybean

Some of the other initiatives are ridge planting systems; seed treatment; Integrated Pest Management (IPM); adoption of improved crop varieties and production technologies; promoting community-based seed production groups and market linkages. Farmers need to be encouraged to practice seed treatment with Trichoderma spp. and fungicides for managing seedling diseases and IPM options for controlling pod borer in chickpea and pigeonpea. Improved water use efficiency through IWM is the key in rainfed agriculture. Alternative sources of irrigation water are the carefully planned reuse of municipal wastewater and drainage water.

Climate Mitigation

Strategies for mitigating methane emission from rice cultivation could be alteration in water management, particularly promoting mid-season aeration by short-term drainage; improving organic matter management by promoting aerobic degradation through composting or incorporating it into soil during off-season drained period; use of rice cultivars with few unproductive tillers, high root oxidative activity and high harvest index; and application of fermented manures like biogas slurry in place of unfermented farmyard manure.

Methane emission from ruminants can be reduced by altering the feed composition, either to reduce the percentage which is converted into methane or to improve the milk and meat yield. The most efficient management practice to reduce nitrous oxide emission is site-specific, efficient nutrient management. The emission could also be reduced by nitrification inhibitors such as nitrapyrin and dicyandiamide (DCD).

Direct Seeded Rice (DSR) is an alternative method that can reduce the labour and irrigation water requirements. In the face of increasing population and growing demand for food, the upgrading of rainfed areas through DSR can help in soil and water conservation and deal with risks arising from climate change. Conservation agriculture technology helps to cope up with climate change impacts.

Legume-based systems are more sustainable than cereal only systems on Vertisols. Several soil and crop management practices affect C sequestration in the soil. Among them, conservation tillage, regular application of organic matter at high rates, integrated nutrient management, restoration of eroded soils, and soil and water conservation practices have a relatively high potential for sequestering C and enhancing and restoring soil fertility in the longer-term.

Leaf Colour Chart (LCC) is an easy-to-use and inexpensive tool for determining nitrogen status in plants. Use of the LCC promotes timely and efficient use of N fertilizer in rice and wheat to save costly fertilizer and minimize the fertilizer related pollution of surface water and groundwater. It is a promising eco-friendly and inexpensive tool in the hands of the farmers.

Renewable energy and farming are a winning combination. Wind, solar, and biomass energy can be harvested forever. Among various renewable sources of energy, biomass, which is produced right in the villages, offers ample scope for its efficient use to carry out domestic, production agriculture, livestock rising and agro-processing activities through thermal and bio-conversion routes. Usage of solar energy is slowly increasing in rural India for solar cookers for cooking, solar drier for drying agriculture produce, solar water heaters and solar photovoltaic systems for pumping devices which are used for irrigation and drinking water.Farmers can lease land to wind developers, use the wind to generate power for their farms, or become wind power producers themselves.

ICRISAT's Hypothesis of Hope to Address Climate Variability and Change

ICRISAT's research findings showed that Integrated Genetic and Natural Resources Management (IGNRM) through participatory watershed management is the key for improving rural livelihoods in the SAT (Wani et al., 2002, 2003 and 2011). Even under a climate change regime, crop yield gaps can still be significantly narrowed down with improved management practices and using Germplasm adapted for warmer temperatures (Wani et al., 2003, 2009 and Cooper et al., 2009). Some of the climate resilient crops are short-duration chickpea cultivars ICC 96029 (Super early), ICCV 2 (Extra-early) and KAK 2 (Early maturing); wilt resistant pigeonpea hybrid (ICPH 2671) with a potential to give 80% higher yields than traditional varieties and short-duration groundnut cultivar ICGV 91114 that escapes terminal drought.

Integrated Watershed Management (IWM) comprises improvement of land and water management, integrated nutrient management including application of micronutrients, improved varieties and integrated ·pest and disease management for substantial productivity gains and economic returns by farmers. The goal of watershed management is to improve livelihood security by mitigating the negative effects of climatic variability while protecting or enhancing the sustainability of the environment and the agricultural resource base. Greater resilience of crop income in Kothapally, Ranga Reddy district (Telangana) during the drought year 2002 was indeed due to watershed interventions. While the share of crops in household income declined from 44% to 12% in the non-watershed project villages, crop income remained largely unchanged from 36% to 37% in the watershed village (Wani et al., 2009).

Agroclimatic analysis at watershed level (Rao AVRK et al., 2008) coupled with crop-simulation models, and better seasonal and medium duration weather forecasts, help build resilience to climate variability / change. Farmers need to be encouraged to enhance soil quality and fertility through composting of organic wastes; and to promote cultivation of Leucaena, *Hardwickiabianta* and Glyricidia on farm bunds. Governments may also consider promoting and incentivizing the soil and water conservation measures taken by farmers. An improved agromet advisory service at the local level along with associated weather insurance packages is a sure way to enhance the resilience of poor farmers in the context of climate change. Policy interventions are needed to mitigate the climate change effects and Governments have to be proactive in developing adaptation strategies for those sectors like agriculture, water resources, forestry and biodiversity which are highly exposed to the future climate changes and have a significant impact on livelihoods.

ICRISAT's principle to improve the livelihoods of small-holder farmers even under future climate change scenario is built on the concept of Inclusive Market Oriented Development (IMDO), which is a Dynamic Development Pathway consisting of innovative environment, inclusive and market oriented.

Innovative Extension Systems for Climate Resilient Agriculture

Climate change adaptation involves adjustments to decrease the vulnerability of agriculture to current climate variability and to future changes. Farmers have traditional knowledge on sowing and harvest times and crop management practices. Farmers may not have the necessary information of possible climate adaptation options without an effective network of extension services that can filter knowledge gained through science to grass roots. In addition, it is necessary that farmers possess the necessary skills to implement an alternative production technique. Under the climate change scenario, due to uncertainty in rainfall conditions and occurrence of extreme weather, farmers need to be supported with both climate and weather information for sustainable crop production.

Agriculture extension system plays very important role in enhancing the knowledge and skills of farmers for improving agricultural productivity as lack of awareness among farmers about good agricultural practices is always been a key limiting factor for improving productivity levels. Thus, there is a clear and distinct role for strengthening extension services in agriculture to enhance farmer awareness of potential adaptation response options. Agricultural extension personnel are the main stakeholders to communicate with the farmers on how to cope with climate change through adaptation strategies. There is a need to develop appropriate training modules for the agricultural extension staff on the science of climate change and the various adaptation and mitigation strategies available in the universities, research institutes and the government departments. In this way, extension personnel will be acquainted with knowledge on climate change. Seminars / Workshops need to be organized frequently on climate change and extension personnel should be given the privilege to attend so that they can acquire required skills to help farmers.

The other dimension of extension system is knowledge delivery pathways (KDP). The tradition ways to delivery information are through announcements, info-graphics (wall writing or banners), and scheduled programs on television and radio, which still are effective option for mass communication. Often, farmers require information about weather, good agricultural practices, insect/pest identification and their control, where to purchase the input and where to sell the produce. But, this information should come at the time when it is actually needed, for which the traditional KDP are inadequate to provide this solution. Therefore, it is important to rejuvenate the existing Agricultural Extension Systems with innovative ICT models for knowledge generation and dissemination to make them truly innovative.

Information communication tools have provided the wide range of options to assist extension agents as well as farmer for getting up-to-date knowledge. Government of India and private companies are transforming the AES. There are several technologies are being used for information dissemination. For example, Government of India has Kisan Call Center (KCC) facility to satisfy information request as per farmers demand in 22 local languages. Karnataka State Natural Disaster Management Center is provider service to its subscribers in state to receive daily weather update including alert about abnormalities in weather. In addition to Government, private companies are also providing innovative solutions for agriculture extension. For example, IFFCO Kisan Sanchar Limited has introduced voice messages for agro-advisory system and Thomson Reuters introduced mobile based integrated agro-advisory system 'Reuters Market Light'. Information updates obtained from such advisory system allow farmers to take decision regarding various farm operations, which eventually help farmers to cope to climate variability and change.

Thus, the key strategies required for climate smart agriculture include training of extension staff to acquire the new knowledge and skills in climate risk management, setting up of emergency management unit by extension agencies, dissemination of innovations strategic research on best practices and building resilience capacities of vulnerable people in climate risk management, providing feedback to government and interested agencies with situation reports on various causes of climate change and its effects (Iqbal Singh and Jagdish Grover, 2013). Adaptation to climate variability and change must become an important policy priority to the Government and effectively be mainstreamed into national, provincial, local and sectoral development agendas (IPCC, 2011). There is a clear and distinct role for strengthening extension services in agriculture to enhance farmer awareness of potential adaptation response options. For an effective extension system a combination of on-field demonstration through farmers' participation, dissemination of results through conventional delivery pathways, and advance ICT for faster and interactive service is required so that gap between available information on climate change mitigation option and farmer impacted by climate change will be reduced. Enabling the farmers on the options to adapt also requires that other factors first be in place. In particular, investment in institutional support to promote the dissemination of knowledge through extension is important (Kurukulasuriya and Rosenthal, 2013).

Paris Agreement to Combat Climate Change

The United Nations Framework Convention on Climate Change came to a landmark agreement on December 12, 2015 in Paris. The Paris Agreement was signed by 196 nations and is the first comprehensive global treaty to combat climate change, and will follow on from the Kyoto Protocol when it ends in 2020. It will enter into force once it is ratified by at least 55 countries, covering at least 55% of global greenhouse gas emissions.

The agreement commits nations to keep temperatures well below 2 °C above the pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C. The French foreign minister Laurent Fabius, President of the COP21 summit has stated that "This agreement is differentiated, fair, durable, dynamic, balanced, and legally binding".

In order to create more vibrant and resilient communities and natural resources-dependent economic sectors able to mitigate and adapt to the risks associated with climate variability and change, there is a critical need to develop a "climate-literate society." People must gain a better appreciation of how a changing climate is likely to impact their own lives, local ecosystems, regional industries and society at large (Sea Grant Climate Extension Summit Report, 2013).

Let us join together to strengthen the Extension System to help manage the risks posed by climate variability and change for achieving sustainable agricultural production and better livelihoods.

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