POLICY PAPER 65

Climate Resilient Agriculture in India

NAAS

NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI

December 2013

Climate Resilient Agriculture in India

N A A S

NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI

December 2013

CONVENER : Dr A.K. Singh, Vice-Chancellor, Rajmata Vijayaraje Sciendia Krishi Vishwa Vidyalaya, Gwalior, the then Deputy Director General (NRM), ICAR

Dr B.Venkateswarlu, Director, CRIDA, Hyderabad

EDITORS : Dr C. Devakumar
: Dr P.K. Chhonkar

REVIEWERS : Dr C.L. Acharya, Dr Rajendra Prasad, Dr A.R. Sharma, and Dr S.M. Virmani

CITATION : NAAS 2013. Climate Resilient Agriculture in India. Policy Paper No. 65, National Academy of Agricultural Sciences, New Delhi: 20 p.

Published by Mr H.C. Pathak, Executive Secretary on behalf of
NATIONAL ACADEMY OF AGRICULTURAL SCIENCES
NASC, Dev Prakash Shastry Marg, New Delhi - 110 012
Tel: (011) 25846051-52; Fax: (011) 25846054
Email: naas@vsnl.com; Web site: http://www.naasindia.org

Preface

World Meteorological Organization (WMO) defines climate change as a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Climate change and climate variability are emerging as major challenges to sustainable agriculture. The high inter- and intra-seasonal variability in rainfall distribution, extreme temperature and rainfall events are causing crop damages and thus, farmers face huge losses each year. One or the other part in India is affected every year by droughts, floods, cyclones, hailstorms, frost and other climatic events caused by climate change.

The Fourth IPCC Report clearly brought out the global and regional impacts of climate change on agriculture, water resources, natural eco-systems and food security. Among the several highly populated regions of the world, South Asia has been categorized as one of the most vulnerable areas. Although climate change impacts are being witnessed all over the world, the countries like India are intensely affected because of the huge population which is primarily dependent on agriculture for livelihood. In order to discuss the important issue of climate change and its impact on India's food security, a select group of experts met on the 25 April, 2012 at the National Academy of Agricultural Sciences, NASC Complex, New Delhi. Based on their discussions, this policy document has been prepared.

Currently, India is facing a challenge of producing adequate food from shrinking natural resource base for the ever-increasing population. Intensification of agricultural activities through enhanced productivity and efficient resource use is the only option available as competition for land and water is increasing from non-farm sectors. In other words, more production is needed with reduced natural resources under a variable climate. India also needs to take steps towards a carbon and energy efficient economy. All this calls for a Climate Resilient Agriculture (CRA) leading to sustainable food security through integrating innovations, technologies, efficient resource use, sound public policies, establishment of new institutions, and development of infrastructure.

It is hoped that the policy options and actions (recommendations) enunciated in this policy paper shall help mainstream CRA in the national policy on comprehensive food and livelihood security.

Grateful thanks are due to the Conveners Dr. A.K. Singh, VC, RVSKVV, Gwalior and Ex-DDG (NRM), ICAR and Dr. B. Venkateswarlu, Director, CRIDA, ICAR for their initiative in organizing the Brainstorming Session.

(R.B. Singh)
President, NAAS

Climate Resilient Agriculture in India

1.0 INTRODUCTION

Climate change and its variability are emerging as the major challenges influencing the performance of Indian agriculture. Long-term changes in shifting weather patterns result in changing climate, which threaten agricultural productivity through high and low temperature regimes, increased rainfall variability, and rising sea levels that potentially deteriorate coastal freshwater reserves and increase risk of flooding. Climate change (and global warming) impacts all sectors of human life. Agriculture is particularly vulnerable to it. Higher temperatures tend to reduce yields of many crops; and encourage proliferation of weeds and pests. Although yield increases in some crops and other positive benefits have been noted in some regions of the world, the overall impact of climate change on agriculture is likely to be negative. Climate change will have a negative effect on yields of irrigated crops across regions, both due to increase in temperature and changes in availability of water. Rainfed agriculture will be primarily impacted due to rainfall variability and reduction in number of rainy days (Venkateswarlu and Shanker, 2012). Climate change might result in price hike of agricultural commodities, feed supplies and consequently livestock products like meat and milk.

Each year one or the other part in the country is affected by droughts, floods, cyclones, hailstorm, frost and other climatic events. The fourth IPCC report clearly brought out the global and regional impacts of projected climate change on agriculture, water resources, natural eco-systems and food security. Among the several highly populated regions of the world, South Asia is categorized as one of the most vulnerable. Although climate change impacts are being witnessed all over the world, countries like India are more vulnerable in view of the huge population dependent on agriculture, excessive pressure on natural resources and poor coping mechanisms.

Significant decline in production is likely to be caused by shortening of growing period, which will have negative impact on reproduction and grain filling particularly due to terminal heat stress and decreased water availability. Biodiversity will be also adversely affected, which in turn, will affect agricultural production. Poor people, especially those living in marginal areas of low agricultural productivity, depend on the genetic diversity. Climate resilient agriculture (CRA), encompassing adaptation and mitigation strategies and the effective use of biodiversity at all levels - genes, species and ecosystems - is thus an essential pre-requisite for sustainable development in the face of changing climate (Box 1).

BOX 1. CLIMATE RESILIENT AGRICULTURE (CRA) DEFINED

CRA means the incorporation of adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting damage and recovering quickly. Such perturbations and disturbances can include events such as drought, flooding, heat/cold wave, erratic rainfall pattern, long dry spells, insect or pest population explosions and other perceived threats caused by changing climate. In short it is the ability of the system to bounce back. Climate resilient agriculture includes an in-built property in the system for the recognition of a threat that needs to be responded to, and also the degree of effectiveness of the response. CRA will essentially involve judicious and improved management of natural resources viz., land, water, soil and genetic resources through adoption of best bet practices.

The Indian agricultural production system faces the daunting task of having to feed 17.5 percent of the global population with only 2.4 per cent of land and 4 per cent of the water resources at its disposal. With the continuously degrading natural resource base compounded further by global warming and associated climate changes resulting in increased frequency and intensity of extreme weather events, "business as usual" approach will not be able to ensure food and nutrition security to the vast population as well as environmental security (the need of the hour). The challenge is formidable because more has to be produced with reduced carbon and water footprints. To achieve this task of paving the way for climate smart agriculture we need to take several measures that will have enabling policies, institutions and infrastructure in place and the farming community be better informed and empowered with necessary resources.

With the above backdrop, the issues and challenges of climate change and mechanisms of agricultural resilience to its impact and possible policy options and actions were discussed at a Brainstorming Session amongst select group of experts on the 25th of April 2012 at NAAS, based on which this policy document has been elucidated.

2.0 IMPACT OF CLIMATE CHANGE ON INDIAN AGRICULTURE

Climate change impacts agriculture both directly and indirectly. The type and magnitude of impact will vary depending on the degree of change in climate, geographical region and type of production system. Assessment of impact of climate change is carried out through controlled experimentation and simulation modelling. Experimental results obtained are extrapolated on regional basis in relation to the projected climate change under different scenarios. The key influences are:

- Change in productivity, with reference to quantity and quality of crops.
- Change in agricultural practices like water use and application of fertilizers, insecticides, and herbicides etc.
- Environmental influences, particularly in relation to the frequency and intensity of soil drainage which may lead to loss of nitrogen through leaching, soil erosion and reduction of crop diversity.

2.1 Effects on agricultural crops

The major effect on crop is due to shortening of crop duration which is related to the thermal environment. Increase in temperature will hasten crop maturity. In annual crops, the shortening of crop duration may vary from 2-3 weeks, thus, adversely impacting productivity. Another direct effect in crops such as rice, wheat, sunflower etc., is on reproduction, pollination and fertilization processes, which are highly sensitive to temperature. The indirect influences operate through changes in water availability due to inadequate or excess rainfall and effect of increase in temperatures on pest and disease incidence.

Modelling studies have indicated that changing climate will decrease yields in major crops like wheat, rice and maize. On the other hand the impacts could be neutral to positive in groundnut, soybean and chickpea. The crop-wise impacts are described below:

2.1.1 Rice

Monsoon in India has become increasingly unpredictive and erratic in recent times. The number of intense rainfall events together with reduced number of rainy days has been noted during the latter half of last 50 years. Thus, risks of drought and floods have increased to the country's wet-season (kharif) rice crop. Statistical analyses of state-level data confirm that drought and extreme rainfall adversely affected rice yield in predominantly rainfed areas during 1966–2002. The drought has been found to have much greater impact than extreme rainfall events (Auffhammer *et al.*, 2012). On an aggregated scale, the mean of all emission scenarios indicate that climate change is likely to reduce irrigated rice yields by ~4% in 2020 (2010–2039), ~7% in 2050 (2040–2069), and by ~10% in 2080 (2070–2099) climate scenarios. On the other hand, rainfed rice yields in India are likely to be reduced by ~6% in the 2020 scenario, while under the 2050 and 2080 scenarios, the yields are projected to decrease only marginally (<2.5%), (Soora *et al.*, 2013).

2.1.2 Wheat

Early modelling studies on wheat indicated that with every rise of 1°C in mean temperature, India could loose 4-5 million tonnes of wheat (Aggarwal, 2008). Under the current predicted changing pattern of climate by 2050, Indo-Gangetic Plains (IGPs) account for 15% of global wheat production. Here, as much as 51% of it's area has to be reclassified as a heat-stressed, irrigated, short-season production mega-environment (Ortiz *et al.*, 2008). This shift would also result a significant reduction in wheat yields, unless appropriate cultivars and crop management practices are innovated and adopted by farmers. Acceleration in senescence due to extreme heat, in addition to the effects of increased temperatures has been noticed in wheat in India. Simulation studies with two commonly used process-based crop models indicate that existing models under-estimate the effects of heat on wheat, with several models underestimating yield losses for +2°C by as much as 50% for some planting dates. These results imply that global warming presents an even greater challenge to wheat than shown by previous modelling studies, and that the effectiveness of adaptations will depend on how well they reduce crop sensitivity to very hot days (Lobell *et al.*, 2012). Model simulations predict reduction in crop yields associated with shortening of growth period due to increased temperature. Yield reduction was more with increase in maximum temperature than minimum (Jalota *et al.*, 2013). Differential response of wheat cultivars has also been noted under diverse environmental conditions. Simulation experiments to evaluate growth and yield attributes of wheat genotypes under timely and late-sown conditions in different regions of India using DSSAT v4 showed that the anthesis, maturity period, grain number and yield exhibited high variation among genotypes (Attri *et al.*, 2011).

2.1.3 Maize

Winter (Rabi) maize grain yield in India is projected to reduce with increase in temperature in Mid Indo-Gangetic Plains (MIGP), and Southern Plateau (SP). Spatio-temporal variations in projected changes in temperature and rainfall are likely to lead to differential impacts in different regions (Byjesh et al., 2010). In particular, monsoon season yield can reduce mostly in SP (up to 35%) and winter yield will reduce in MIGP (up to 55%), while upper IGP yields will be relatively unaffected. Developing new cultivars with growth pattern in changed climate scenarios similar to that of current varieties in present conditions could be an advantageous adaptation strategy for minimizing the vulnerability of maize production in India (Byjesh *et al.*, 2010). Using field experiments and simulation models Singh *et al.* (2010) reported that growth and yield of maize was greatly affected by temperature changes associated with sowing dates. Yield was reduced in late-sown crops due to the harmful effect of chilling temperature. Irrigated wet- maize is projected to reduce yields by upto 18% in 2020 and 2050 scenarios. This adverse effect of climate change is projected to be about 23% in 2080 scenarios. Adaptation strategies such as improved and tolerant cultivar(s) managed under improved inputs with additional nitrogen fertilizer can enhance the irrigated maize net production by about 21% in 2020, 10% in 2050 and 4% in 2080 scenarios (Soora *et al.*, 2012).

2.1.4 Other crops

General circulation models (GCMs) projected an increase of 3.95, 3.20 and 1.85°C in mean temperature in cotton-growing regions of India for the A2, B2 and A1B scenarios which describe a future world of dynamic levels of economic growth and global population. Simulation results using the INFOCROP-cotton model indicated that seed cotton yield declined by 477 kg ha^{-1} for the A2 scenario and by 268 kg ha^{-1} for the B2 scenario (Hebbar *et al.*, 2013). Climate change is projected to intensify drought and heat stress in groundnut production areas. Different combinations of adaptation strategies will be needed to increase and sustain the productivity of groundnut under climate change (Singh *et al.*, 2013b). Area under groundnut is projected to decrease by 5% and 4% respectively, in medium and long-term, while groundnut yields are projected to decline by 7% in medium-term and by 5% in long-term (Soora *et al.*, 2012).

2.2 Effect on Horticulture

Climate change may increase production of potatoes in Punjab, Haryana and western and central Uttar Pradesh by 3% to 7% in A1B 2030 scenario, but in the rest of India, particularly West Bengal and Southern Plateau region, the production may decline by 4-16%. It is primarily attributed to the rise in mean minimum temperature during tuber development stages which affects potato yield. The increase in temperature due to climate change may decrease harvest index (HI) of this crop grown in large parts of Maharashtra, parts of Karnataka and Andhra Pradesh. Even though, in the traditional potato growing belt in the IGP, the HI may remain more or less stable but pockets of high HI are likely to diminish (Soora *et al.*, 2012; Singh *et al.*, 2013a). Adaptation to climate change can increase the yields by 13-19% in different scenarios, thereby increasing the overall production by about 20%. Potato and vegetables mature early, and heavy crop losses will be noted when crops are exposed to abnormal increases in temperature (heat wave). The prolonged droughts during summer generally affected the crops like cocoa, black pepper, coconut, coffee, tea and cardamom along the west coast adversely in 1982–83 and 2003–04. Increase in night temperature in several parts of the country during winter 2010 adversely affected mango flowering

(Rao *et al.*, 2013). Grapes and its value-added products have also been affected by variable climate. The grape yields are expected to be reduced with the likelihood of change in the incidence and pattern of attack of insect-pests like mealy bug, thrips and mites. Similarly, the disease incidence pattern is also likely to be affected with a change in climate. This is evidenced by decrease in productivity during recent years from > 25 t/ha to 8 t/ha during 2009–10 and 12 t/ha in 2010–11 due to unseasonal rains which led to a serious infection of downy mildew (Sharma *et al.*, 2013). Cashew nut, an important export-oriented horticultural crop is also likely to be affected by changing climate thereby affecting the export revenues. Climate change would pose problem for cashew cultivation since cashew is grown in ecologically sensitive regions such as coastal belts, hilly areas, and areas with high rainfall and humidity. The flowering, fruiting, insect-pest incidence, yield and quality of cashew nut and kernels are more vulnerable to climate variability. Unseasonal rains and heavy dew during flowering and fruiting periods are the major factors which adversely affect the yield and quality of cashew nut. Cloudy conditions, high relative humidity and heavy dew are favourable for outbreak of insect-pests and diseases. Drought conditions also drastically reduce cashew production (Rupa *et al.*, 2013). Oil palm is grown as an irrigated crop in India. It is likely to be more vulnerable to climate change due to excessive dependence on ground water with poor adaptation mechanisms. The water requirement is estimated to increase by 10% for every 1°C rise in temperature. Under such situations, when oil palm yield decreases, small and marginal palm growers would be affected the most (Suresh *et al.*, 2013).

2.3 Effect on Livestock

Climate changes could impact the economic viability and livestock production. Changes in crop biomass availability and quality affect animal production through changes in feed supplies. Dairy cattle will be affected by climate change more adversely than others. Heat stress to animals is of primary concern in India. Numerous changes can occur in the animal health as a result of heat stress. These include: elevated body temperature, increased respiration rates and increased maintenance energy requirement. The maintenance energy needed may increase by 20-30% under heat stress. This decreases the energy available for productive functions such as milk yield. Blood flow to the skin will increase in an attempt to dissipate heat, but the flow to the core of the body will decrease. There is a decrease in the efficiency of nutrient utilization due to an increased loss of sodium and potassium associated with heat stress. Dry matter intake decreases in dairy cows under heat stress. There is a decrease in milk production in cows under heat stress which could be either short-term or long-term depending on the duration and severity of the stress. If heat stress lowers milk production in early lactating dairy cows, potential milk production for the lactation will be reduced.

Heat stress induced by climate change is also reported to decrease reproductive performance in dairy cows. The main effects include decreased length and intensity of oestrus period, fertility rate, growth, size and development of ovarian follicles; increased risk of early embryonic deaths, and decreased foetal growth and calf size. Environmental conditions induced by climate change directly affect mechanisms and rates of heat gain or loss by all animals. Since ingestion of feed is directly associated to heat production, any alteration in voluntary feed intake will change the amount of heat produced by the animal (Mader *et al*., 1999). Other intensive livestock production systems such as poultry and piggery are also susceptible to heat stress. Some responses include reduced feed intake, laying performance (chickens), fertility levels, decreased activity and in the worst cases, increased mortality.

Heat stress has strong influence on livestock performance. Sudden changes in temperature, either a rise in T_{max} (>4°C above normal) during summer i.e. heat wave or a fall in T_{min} (<3°C than normal) during winter i.e. cold waves; cause a decline in milk yield of crossbred cattle and buffaloes. The estimated annual loss at present due to heat stress is estimated at about 2 million tonnes, i.e. nearly 2% of the total milk production in the country. Global warming is likely to lead to a loss of 1.6 million tonnes in milk production by 2020 and 15 million tonnes by 2050 from current level. The decline in yield may vary from 10-30% in first lactation, and 5-20% in second and third lactations (Srivastava, 2010). Northern India is likely to experience more negative impact of climate change on milk production of both cattle and buffaloes due to rise in temperature during 2040-2069 and 2070-2099 scenarios. The decline in milk production will be higher in crossbreds (0.61%) followed by buffaloes (0.5%) and indigenous cattle (0.4%). A rise of 2-6°C due to global warming (time slices 2040-2069 and 2070-2099) is projected to negatively impact growth, puberty and maturity of crossbred animals and buffaloes. Time to attain puberty of crossbred cows and buffaloes will increase by 1-2 weeks due to their higher sensitivity to temperature than indigenous cattle. Increase in temperature and humidity is likely to cause an increase in incidence of animal diseases (bacterial, protozoan and viral) that are spread by insects and vectors. Frequency and incidence of mastitis and foot diseases affecting crossbred cows and other high milk producers may increase due to increase in the number of stressful days.

2.4 Effect on Fisheries

Climate change is also likely to have impacts on aquaculture. Positive effects are manifested as longer growing seasons, lower natural winter mortality and faster growth rates in higher latitudes. New opportunities for brackish water aquaculture arise (as in Andaman & Nicobar Islands) where agriculture may become non-viable due to saltwater intrusion. The abundance and species diversity of riverine fishes are predicted to be particularly sensitive to climatic disturbances, since lower dry season water levels may reduce the number of individuals able to spawn successfully. A 1–3°C temperature rise relative to the last decade would result in the bleaching and possible death of most of the world's coral reefs (IPCC, 2007). This would have serious negative effects on coastal reef fisheries.

Sea surface temperature has increased by 0.2-0.3°C along the Indian coast in the last 45 years, and is projected to increase by 2.0-3.5°C by 2099. The projected sea level rise is 30 cm in 50 years. The small pelagics such as the oil sardine and Indian mackerel have extended their boundary of distribution to northern and eastern latitudes in the last two decades (Vivekanandan, 2011). They have extended their distribution to mid-waters as well. These distributional and phenological changes may have impact on nature and value of fisheries. If small-sized, low-value fish species with rapid turnover of generations are able to cope up with changing climate, they may replace large-sized high-value species. Such distributional changes would lead to novel mixes of organisms in a region and result in considerable changes in ecosystem structure and function. The sensitivity of small-scale fisheries to climate change threat is very high while adaptive capacity is low.

Despite the uncertainties and potential negative impacts of climate change on fisheries, there are opportunities to reduce the vulnerability to climate related impacts. As the first step, projections on fish distribution, and abundance catches need to be developed for planning better management adaptations (Vivekanandan, 2011). The following specific measures could contribute to coping with climate change: (i) evaluating the adaptive capacity of important fish groups; (ii) identifying adaptive fishing and post-harvest practices to sustain fish production and quality; (iii) supporting energy efficient fishing craft and gear; (iv) cultivating aquatic algae, which have positive response to climate change, for food and pharmaceutical purposes and for production of biodiesel; (v) increasing climate literacy among the fish farming communities; (vi) emerging Weather Watch Groups; (vii) establishing effective coast protection structures; and (viii) evolving decision support systems (DSS) for fisheries production systems.

3.0 POSITIVE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE

Increase in CO_2 concentration can cause CO_2 fertilization and it has been shown to increase crop growth, drymatter production and yield in specific regions although this effect is related to frequency of water stress or changes in climatic factors such as temperature or rainfall, and nutrient status. Most crops grown under enriched CO_2 environment showed increased growth and yield as enhanced CO_2 affects the growth and physiology of crops, enhancing photosynthesis and Water Use Efficiency (WUE). Differences in physiology of C3 and C4 plants make C4 plants more photosynthetically efficient than C3, especially when the level of CO_2 is high. If the direct effect of CO_2 is included, yields are projected to increase for rainfed crops under both the A2 and B2 emissions scenarios in the 2080s. The increase is likely to be highest for rainfed maize under the A2 scenario, possibly because the higher CO_2 concentration would boost the yield of rainfed maize under the current water-limited conditions prevalent in some regions of the country. In crop models, it has been seen that yields have slightly increased in maize. Simulated yield of winter maize showed an increase from the baseline in the range of 8.4–18.2%, 14.1–25.4% and 23.6–76.7% for 2020, 2050 and 2080 respectively. Maize with increased CO_2 and concurrent rise in temperature showed a decrease in duration and days to anthesis from the baseline with total drymatter production, grain weight and grain number showing an increase from the baseline to 2080. Global climate change may increase production of potato in Punjab, Haryana and western and central Uttar Pradesh by 3.46 to 7.11% in A1b 2030 scenario. The simulation results indicate that on an average, future climate would have a positive impact on productivity of rainfed soybean in the country. Increase in soybean yield in the range of 8-13% under different future climate scenarios (2030 and 2080) is projected. In case of groundnut, except in the climate scenario of A1B 2080, which showed a decline of 5% in yield, rest of the scenarios showed 4-7% increase in rainfed yields as compared to the baseline. Simulation studies using InfoCrop- Coconut model indicated positive effect of climate change on coconut yields in west coast and parts of Tamil Nadu and Karnataka and negative effects on nut yield in east coast of India in HadCM3 A2a, B2a and A1F 2020, 2050 and 2080 scenarios.

Some of the other positive effects include shift in the area of cultivation of some crops so as to create new economic and market zones which might benefit the people of the region. This has been particularly observed in some horticultural crops in temperate regions, an example is the shift of apple from lower altitudes to higher altitudes due to which farmers in the lower elevations have taken up cultivation of fruit crops like pomegranate and kiwi and also have taken up commercial vegetable production and floriculture with success. Similarly mango cultivation has been seen to shift to places of slightly lower temperature thereby contributing to extended availability in the market. One of the other possible positive effects of climate change can be seen in protected cultivation of horticultural crops which provide unique opportunities for assured, climate-resilient and enhanced production of quality products. The technology is expected to be in greater demand as it can create job opportunities for the unemployed.

4.0 MANAGING THE ADVERSE IMPACTS OF CLIMATE CHANGE: ADAPTATION AND MITIGATION

We need to prioritize adaptation options in key sectors such as stress tolerant crops, storm warning systems, water storage and diversion, contingency planning and infrastructure strengthening. Alternative agricultural practices as adaptive measures should emanate from the search for indicative adaptation options with a focus on prevailing farmers' practices in different areas with varying degrees of vulnerability (e.g. water scarcity or aridity) and other environmental constraints. Large areas of rainfed agriculture in this country serve mostly as a sink rather than a source of emissions. Although enteric fermentation remains a major source of GHG emissions, there are large opportunities to reduce these emissions through better feeding and manure management. There is a need to come up with guidelines on crop and animal husbandry practices which ensure reasonably high productivity while minimizing the GHG emissions. Location specific usable scientific results will form an important part of the adaptation strategies against climate variability. The focus should be on the dynamics, diversity and flexibility of adaptations, which can harness the opportunities in the changing economic, technological and institutional scenarios (Jodha *et al.*, 2012; Vermeulen *et al.*, 2012). Maximization of agriculture's mitigation potential and adaptation measures will necessitate investments in technological novelty. Increased efficiency of inputs and creation of incentives and monitoring systems that are inclusive of small and marginal farmers will play an important role in the success of both mitigation and adaptation, especially adaptation-led mitigation.

Climate modeling coupled with socio-economic scenarios, forms a useful tool for exploring the long-term consequences of climate change and adopting this approach will also help in evaluating the available response options. The use of socio- economic driven models will allow a cohesive perspective with emphasis on economic viability on mitigation and adaptation options which is important because the cost of adaptation and mitigation will decide the success of the strategy. Development of shared socio-economic pathways and integrated socio-economic scenarios will be a useful focal point for collaborative efforts between integrated assessment and impact, adaptation and vulnerability researches (Kriegler, *et al.*, 2012). Models in the future will become gradually refined as the understanding of factors influencing migration behaviour, such as risk awareness, social networks, and labour market connections, is enhanced (van Vuuren, *et al.*, 2012). Several adaptation measures have been developed by the National Agricultural Research System (NARS) consisting of Indian Council of Agricultural Research (ICAR) institutes, State Agricultural

Universities (SAUs) and Deemed Universities having agricultural faculty, particularly during the last one decade. The focus has been on improving the yields with the existing technology and timely availability of water. Developing adaptation strategies exclusively for minimising the negative impacts of climatic change may be risky in view of the large uncertainties associated with its spatial and temporal magnitude. There is an urgent need to identify "*No Regrets*" adaptation strategies that are needed for the sustainable development at various levels.

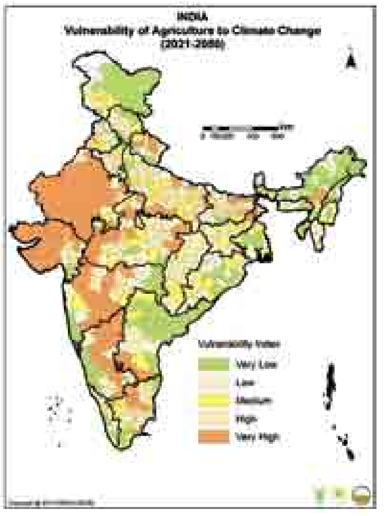
Conservation agriculture, an approach to farming that seeks to increase food security, alleviate poverty, conserve biodiversity and safeguard ecosystem services, can also contribute to making agricultural systems more resilient to climate change. In many cases, conservation agriculture has shown to reduce farming systems' greenhouse gas emissions and enhance their role as carbon sinks. Conservation Agriculture can increase the ability of small farmers to adapt to climate change by reducing vulnerability to drought and enriching the local natural resource base. The promotion of scientific agroforestry forms a key component in the war against climate change. Agroforestry systems buffer farmers against climate variability, and reduce atmospheric loads of greenhouse gases. Agroforestry can both sequester carbon and produce a range of economic, environmental, and socioeconomic benefits. For example, trees in agroforestry systems improve soil fertility through control of erosion, maintenance of soil organic matter and physical properties, increased N accreditation, extraction of nutrients from deep soil horizons, and promotion of more nutrient cycling.

In our planning exercise, greater emphasis needs to be given on adaptation and a country-wide upscaling of best bet practices should be attempted. Apart from the use of technological advances to counter climate change impacts, there has to be a sound policy framework and strong political will on the part of the government. The framework should address the issues of redesigning social sector with focus on vulnerable population, introduction of new credit instruments with deferred repayment liabilities during extreme weather events, and weather insurance as a major vehicle of risk transfer. Concerned institutions at national, state and local levels (SHGs, Rural Credit Institutions, Agricultural Cooperatives and Producers' Companies) should be strengthened towards enhancing the overall resilience.

Mainstreamed in the National Mission on Sustainable Agriculture (NMSA), one of the eight missions set up under the Prime Minister's National Action Plan on Climate Change (NAPCC), the National Initiative on Climate Resilient Agriculture (NICRA) project of the ICAR has made an excellent beginning towards rendering Indian agriculture more resilient to climate change (Box 2).

BOX 2. NATIONAL INITIATIVE ON CLIMATE RESILIENT AGRICULTURE (NICRA)

NICRA is a network project of the Indian Council of Agricultural Research (ICAR) launched in February, 2011. The project is formulated to take up long term strategic research to address the impacts of projected climate change on Indian agriculture and also demonstrate the existing best bet practices to enable farmers cope with current climate variability. Under the strategic research, phenotyping of germplasm collections of wheat, rice, maize and pulses is being done for climate induced stresses like drought, heat stress and submergence, and selected lines are being used for developing stress tolerant high performing varieties. High throughput phenotyping systems and field facilities for studying the impacts of elevated temperature and carbon dioxide on crops and network of flux towers are some of the state of the art facilities already commissioned under the project at leading institutes. A comprehensive program on pest surveillance in relation to weather variables, crop simulation modeling with a systems approach for understanding impacts and designing adaptation strategies, nutritional and genetic strategies for reducing heat stress on milch animals, understanding the impact of climate variability on pollinators and flowering phenology of fruit crops are other areas of research being pursued in the project. The carbon sequestration potential of agroforestry and conservation agriculture systems are being estimated across the country for mitigation. The project is working on mechanisms of adaptation financing in the context of development planning in India.



The first ever vulnerability atlas of India at district level has been prepared which is likely to aid in prioritizing investments in vulnerable regions. The most significant contribution of the project has been the demonstration of best bet practices in 100 vulnerable districts in the form of stress tolerant varieties, water harvesting, conservation agriculture, farm mechanization through custom hiring centers which helped the farmers to cope with the annual climate variabilities, yielding encouraging outcomes. The promising experiences of the Village Climate Risk Management Committees (VCRMC) and the Climate Smart Village pilots encompassing water, carbon, energy and nutrient smart technologies should be judiciously up- and out-scaled.

5.0 THE WAY FORWARD: POLICY OPTIONS AND ACTIONS

5.1 Tools, technologies and infrastructure

- Standardise methodologies for vulnerability assessment and climate smart agriculture; enhance the density of weather observatories; establish rain gauges at block/village level; and enable access to and efficient management of weather related information by modern tools like remote sensing and GIS.
- Institutionalize a mechanism to collect and collate micro-level information continuously (climate, crops, socio-economic, natural resources etc.) and establish credible database as well as efficiently disseminate it which can be used as an input for macro-level policies.
- Invest in research and development of locally-adaptable crops, management practices, input sources etc., decision support system (DSS), and models for analysing the impact of climate change and mitigation strategies, particularly in arid and semi-arid regions in view of their greater vulnerability.
- Develop and diffuse drought, heat and submergence tolerant crop cultivars. Change planting dates to avoid terminal heat stress or cyclones at maturity stage.
- Improve techniques for water (rainwater harvesting, micro-irrigation), nutrient (SSNM) and energy (reduced tillage) conservation to adapt the crops to climatic stresses and also contribute to mitigation.
- Encourage adoption of location-specific conservation techniques (cover cropping, *in situ* moisture conservation, rainwater harvesting, groundwater recharge, locally-adapted cropping systems etc.) for water efficient agriculture and demonstration of such technologies on farmers' fields.
- Blend farmers' traditional/indigenous knowledge on natural resource management and climate coping strategies with advanced technological interventions eg. varieties, crop management, resource conservation technologies, rainwater harvesting and storage.
- Manage climate risks through weather-based agro-advisories, and affordable weather insurance products. The Government of India should move from reactive (relief payments) to practice (promoting insurance) approach in dealing with climate variability.
- Harness non-conventional energy sources in agriculture and other allied sectors which contribute to mitigation.

5.2 Prioritization and convergence of programmes

- Prioritize regions vulnerable to climate change with a particular focus on arid and semi-arid regions; and prepare and implement comprehensive district-wise agriculture and livelihood contingency plans.

- Integrate climate change initiatives such as INCCA, NAPA, NMSA, NICRA, NDMA etc. with national agricultural policies/programmes of food security, disaster management, natural resource conservation, livelihood enhancement etc., to enable rural communities take advantage of new technologies and tools.

- Encourage diversification of rural income through off-farm and non-farm livelihoods; build significant stake for climate change adaptation interventions in the newly-launched national livelihood mission.

- Ensure access to government support/relief programs (food security, agricultural and enterprise subsidies, rural finances, poverty reduction programs, technology adoption support etc.) on part of the vulnerable sections of the society.

5.3 Partnerships and capacity building

- Create favourable environment to attract public and private funds for investment in Climate Resilient Agriculture (CRA). Much of the corporate social responsibilities funds from leading private sector players in the country should be channelized to promote CRA in vulnerable regions.

- Channelize investment in human resource development and capacity building through awareness and training among officials, extension workers and farmers, incentives to farmers for adoption of natural resource conservation practices and support to improve the existing indigenous technologies that are eco-friendly and sustainable in long-run.

- Revise and restructure university curricula and institutionalise teaching and research facilities in concerned educational institutions to develop graduates and postgraduates suitably trained in climate change management.

- Encourage role of the Non-Governmental Organizations, Civil Societies, Public and Philanthropic organizations for enhancing adaptation preparedness among the local community.

- Forge international/regional partnerships, especially with FAO, CCAFS of CGIAR, UNEP, IPCC for developing tools and technologies suited to local requirement through pooling financial and intellectual resources, and help judiciously implement the international agreements.

5.4 Mainstreaming CRA in planning

- Increase concessional credit to small and marginal farmers for adoption of climate resilient agricultural practices. Evolve a new verification system at field level to sensitise farmers through credit and input subsidies.
- Establish efficient co-operatives, community organizations and associations/ groups to tackle critical needs of farmers like resource mobilization, custom hiring, marketing their outputs and efficient natural resource management. Suitably empower Gram Panchayats to play a leading role at the grassroot level in developing and implementing concerned programs.
- Evolve national policy on disaster management in agriculture when major events like cyclones and floods devastate agriculture, horticulture and livestock.
- Implement the recommendation of the National Commission on Farmers (NCF) for establishment of a National Agricultural Risk Management Fund and its need-based timely distribution.
- Identify, critically document and share most successful stories in climate change management and organise pilot demonstrations of most successful modules, and in a partnership mode scale-up and scale-out the selected ones to establish climate smart villages throughout the country.
- Introduce soil and water conservation practices on a large scale for achieving long-term sustainability of the systems, including revitalization and management of Common Property Resources. Farmers must be given incentives to adapt CRA practices.
- Build on priority infrastructure like markets and information gateways and create opportunities in the non-farm sector in vulnerable regions to help the farmers to diversify their incomes.

The National Academy of Agricultural Sciences warrants that the Government of India must take immediate steps to converge the many programmes/projects on climate resilient agriculture funded by a multitude of ministries and government agencies. Obviously, there is a need to synchronize and implement the developmental programs with built-in monitoring and a participatory bottoms-up feedback loop in the system for meaningful climate resilience *per se* in agricultural sector in a mission mode.

REFERENCES

Aggarwal, P.K., Kalra, N., Chander, S. and Pathak, H. (2006). InfoCrop: a dynamic simulation model for the assessment of crop yields losses due to pests and environmental impact of agro-ecosystems in tropical environments. I Model description. *Agricultural Systems* **89**: 1-25.

Aggarwal, P.K. (2008). Global climate change and Indian agriculture: Impacts, adaptation and mitigation. *Indian Journal of Agricultural Sciences* **78**: 10-16.

Attri, S.D., Singh, K.K. and Mall, R.K. (2011). Simulation of growth and yield attributes of wheat genotypes under changing climate in recent years in India, pp. 221-234. In: *Challenges and Opportunities in Agrometeorology*. Springer Berlin Heidelberg.

Auffhammer, M., Ramanathan, V. and Vincent, J.R. (2012). Climate change, the monsoon, and rice yield in India. *Climatic Change* **111**(2), 411-424.

Byjesh, K., Kumar, S.N. and Aggarwal, P.K. (2010). Simulating impacts, potential adaptation and vulnerability of maize to climate change in India. *Mitigation and Adaptation Strategies for Global Change* **15**(5), 413-431.

Hebbar, K.B., Venugopalan, M.V., Prakash, A.H. and Aggarwal, P.K. (2013). Simulating the impacts of climate change on cotton production in India. *Climatic Change* **118**(3-4): 701-713.

IPCC, 2007. Climate change 2007: The physical science basis. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (Eds.). *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 p.

Jalota, S.K., Kaur, H., Kaur, S. and Vashisht, B.B. (2013). Impact of climate change scenarios on yield, water and nitrogen-balance and use efficiency of rice–wheat cropping system. *Agricultural Water Management* **116**: 29-38.

Jodha, N.S., Singh, N.P. and Bantilan, M.C.S. (2012). Enhancing Farmers' Adaptation to Climate Change in Arid and Semi-Arid Agriculture of India: Evidences from Indigenous practices: Developing International Public Goods from Development-oriented Projects. Working Paper Series no. 32. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India : 28 p.

Kriegler, E., O'Neill, B.C., Hallegatte, S., Kram, T., Lempert, R.J., Moss, R.H. and Wilbanks, T. (2012). The need for and use of socio- economic scenarios for climate change analysis: A new approach based on shared socio-economic pathways. *Global Environmental Change* **22**: 807-822.

Lobell, D.B., Schlenker, W. and Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science* **333**(6042): 616-620.

Lobell, D.B., Sibley, A. and Ortiz-Monasterio, J.I. (2012). Extreme heat effects on wheat senescence in India. *Nature Climate Change* **2**(3): 186-189.

Mader, T.L., Gaughan, J.M. and Young, B.A. 1999. Feedlot diet roughage level of Hereford cattle exposed to excessive heat load.*Professional Animal Scientists* **15**: 53–62.

Ortiz, R., Sayre, K.D., Govaerts, B., Gupta, R., Subbarao, G.V., Ban, T. and Reynolds, M. (2008). Climate change: Can wheat beat the heat? *Agriculture, Ecosystems & Environment* **126**(1): 46-58.

Rao, S.P., Gopakumar, C.S. and Krishnakumar, K.N. (2013). Impacts of climate change on horticulture across India, pp. 13-20. In: *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*. Springer India.

Rupa, T.R., Rejani, R. and Bhat, M.G. (2013). Impact of climate change on cashew and adaptation strategies, pp. 189-198. In: Climate-Resilient Horticulture: Adaptation and Mitigation Strategies. Springer India.

Sharma, J., Upadhyay, A.K., Adsule, P.G., Sawant, S. D., Sharma, A.K., Satisha, J. and Ramteke, S.D. (2013). Effect of climate change on grape and its value-added products, pp. 67-80. In: *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*. Springer India.

Singh, B.P., Dua, V.K., Govindakrishnan, P.M. and Sharma, S. (2013a). Impact of climate change on potato, pp. 125-135. In Climate-Resilient Horticulture: Adaptation and Mitigation Strategie. Springer India.

Singh, P., Nedumaran, S., Ntare, B.R., Boote, K.J., Singh, N.P., Srinivas, K. and Bantilan, M.C.S. (2013b). Potential benefits of drought and heat tolerance in groundnut for adaptation to climate change in India and West Africa. *Mitigation and Adaptation Strategies for Global Change* **18**(1): 1-21.

Singh, S., Kattarkandi, B., Deka, S. and Choudhary, R. (2010). Impact of climatic variability and climate change on maize productivity in north India. *Current Advances in Agricultural Sciences* **2**(1), 5-9.

Soora, N.K., Aggarwal, P.K., Saxena, R., Rani, S., Jain, S. and Chauhan, N. (2013). An assessment of regional vulnerability of rice to climate change in India. *Climatic Change* **118**(3-4): 683-699.

Soora, N.K., Singh, Anil Kumar, Agarwal, P.K., Rao, V.U.M. and Venkateswarlu, B. (2012). Climate Change and Indian Agriculture: Impact, Adaptation and Vulnerability – Salient Achievements from ICAR Network Project, IARI Publication, 32 p.

Srivastava, A.K. (2010). Climate Change Impacts on Livestock and Dairy Sector: Issues and Strategies, pp 127-135. Lead Papers. 2010. National Symposium on Climate Change and Rainfed Agriculture, February 18-20, 2010. Indian Society of Dryland Agriculture, Central Research Institute for Dryland Agriculture, Hyderabad, India.

Suresh, K. (2013). Adaptation and mitigation strategies for climate-resilient oil palm, pp. 199-211. *In Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*. Springer India.

van Vuuren, D.P., Bayer, L.B., Chuwah, C., Ganzeveld, L., Hazelger, W., van den Hurk, B., van Noije, T., O'Neill, B. and Strengers, B.J. (2012). A comprehensive view on climate change: coupling of earth system and integrated assessment models. *Environmental Research Letters* **7**: 024012 doi:10.1088/1748-9326/7/2/ 024012.

Venkateswarlu, B. and Shanker, A.K. (2012). Dryland agriculture: bringing resilience to crop production under changing climate, pp. 19-44. In: *Crop Stress and its Management: Perspectives and Strategies*. Springer Netherlands.

Vermeulen, S.J., Aggarwal, P.K., Ainslie, A., Angelone, C., Campbell, B.M., Challinor, A.J., Hansen, J.W., Ingram, J.S.I., Jarvis, A., Kristjanson, P., Lau, C., Nelson, G.C., Thornton, P.K. and Wollenberg, E. (2012). Options for support to agriculture and food security under climate change. *Environmental Science & Policy* **15**: 136-144.

Vivekanandan, E. (2011). Climate change and Indian Marine Fisheries-Marine Fishery Policy Brief-3. CMFRI, Cochin.

List of Participants in Brainstorming Session

1. Prof. R.B. Singh, President, NAAS, New Delhi
2. Dr. Abhijit Sen, Member, Planning Commission, Yojana Bhawan, New Delhi
3. Dr. S. Ayyappan, Secretary, DARE & DG, ICAR, Krishi Bhawan, New Delhi
4. Dr. Subodh K. Sharma, Advisor (CC), MoEF, Paryavaran Bhawan, New Delhi
5. Dr. A.K. Singh, DDG (NRM), ICAR, New Delhi
6. Dr. B. Venkateswarlu, Director, CRIDA, Santoshnagar, Hyderabad
7. Dr. T.K. Adhya, Former Director, CRRI, Malviya Nagar, New Delhi
8. Dr. P.K. Aggarwal, CCCAFS, IWMI, NASC, New Delhi
9. Dr. A. Arunachalam, Pr. Scientist (AF), KAB-II, Pusa, New Delhi
10. Dr. Beena Balyan, SRF, NDRI, Karnal
11. Dr. A.B. Bajaj, MoEF, Paryavaran Bhawan, New Delhi
12. Dr. Ritu Chakravarty, Sr. Scientist, NDRI, Karnal
13. Dr. Ramesh Chand, Director, NCAP, New Delhi
14. Dr. P.K. Chhonkar, Editor, NAAS, New Delhi
15. Dr. J.C. Dagar, ADG (A&AF), KAB-II, Pusa, New Delhi
16. Dr. Sreenath Dixit, P.S. (Agril. Ext.) & Consortium Principal Investigator, NAIP (Comp.3), CRIDA, Hyderabad.
17. Dr. B.S. Dwivedi, Head, Div. of Soil Science and Ag. Chemistry, IARI, New Delhi
18. Dr. P.L. Gautam, Chairperson, PPV&FRA, New Delhi
19. Dr. K.D. Kokate, DDG (AE), KAB-I, Pusa, New Delhi
20. Dr. Shalander Kumar, Head & PS, CAZRI, Jodhpur
21. Dr. Arbinda Mishra, Director (CC), The Energy and Resources Institute, New Delhi
22. Dr. N.S. Pasricha, 219-C, BRS Nagar, Ludhiana
23. Dr. H. Pathak, Sr. Scientist, Division of Environmental Sciences, IARI, New Delhi
24. Dr. R.K. Rattan, Head, CESCRA, IARI, New Delhi
25. Dr. S.S. Ray, Director, National Centre for Crop Forecasting, DoAC, New Delhi
26. Dr. S. Satapathy, Scientist 'F'/Director Climate Change Division, MoEF, New Delhi

27. Dr. K.K. Singh, Agromet, IMD, New Delhi
28. Dr. N.P. Singh, Senior Scientist, ICRISAT, Patancheru.
29. Dr. S.D. Singh, Div. of Environmental Sciences, IARI, New Delhi
30. Dr. S.V. Singh, Principal Scientist, NDRI, Karnal
31. Dr. R.C. Srivastava, DWM, Chandrasekharpur, Bhubaneswar
32. Dr. S. Surendran, SRF, NDRI, Karnal
33. Dr. Anand Swarup, Ex Head and Principal Scientist, Div. of Soil Science and Agril. Chemistry, IARI New Delhi

---

***Note**: The designations and affiliations of the participants are as on the date of BSS.*

NAAS Documents on Policy Issues*

1. Agricultural Scientist's Perceptions on National Water Policy - 1995
2. Fertilizer Policy Issues (2000-2025) - 1997
3. Harnessing and Management of Water Resources for Enhancing Agricultural Production in the Eastern Region - 1998
4. Conservation, Management and use of Agro-biodiversity - 1998
5. Sustainable Agricultural Export - 1999
6. Reorienting Land Grant System of Agricultural Education in India - 1999
7. Diversification of Agriculture for Human Nutrition - 2001
8. Sustainable Fisheries and Aquaculture for Nutritional Security - 2001
9. Strategies for Agricultural Research in the North-East - 2001
10. Globalization of Agriculture: R & D in India - 2001
11. Empowerment of Women in Agriculture - 2001
12. Sanitary and Phytosanitary Agreement of the World Trade Organization Advantage India - 2001
13. Hi-Tech Horticulture in India - 2001
14. Conservation and Management of Genetic Resources of Livestock - 2001
15. Prioritization of Agricultural Research - 2001
16. Agriculture-Industry Interface: Value Added Farm Products - 2002
17. Scientists' Views on Good Governance of An Agricultural Research Organization - 2002
18. Agricultural Policy: Redesigning R & D to Achieve It's Objectives - 2002
19. Intellectual Property Rights in Agriculture - 2003
20. Dichotomy Between Grain Surplus and Widespread Endemic Hunger - 2003
21. Priorities of Research and Human Resource Development in Fisheries Biotechnology - 2003
22. Seaweed Cultivation and Utilization - 2003
23. Export Potential of Dairy Products - 2003
24. Biosafety of Transgenic Rice - 2003
25. Stakeholders' Perceptions On Employment Oriented Agricultural Education - 2004
26. Peri-Urban Vegetable Cultivation in the NCR Delhi - 2004
27. Disaster Management in Agriculture - 2004
28. Impact of Inter River Basin Linkages on Fisheries - 2004
29. Transgenic Crops and Biosafety Issues Related to Their Commercialization in India - 2004
30. Organic Farming: Approaches and Possibilities in the Context of Indian Agriculture - 2005
31. Redefining Agricultural Education and Extension System in Changed Scenario - 2005
32. Emerging Issues in Water Management The Question of Ownership - 2005
33. Policy Options for Efficient Nitrogen Use - 2005
34. Guidelines for Improving the Quality of Indian Journals & Professional Societies in Agriculture and Allied Sciences - 2006
35. Low and Declining Crop Response to Fertilizers - 2006
36. Belowground Biodiversity in Relation to Cropping Systems - 2006
37. Employment Opportunities in Farm and Non-Farm Sectors Through Technological Interventions with Emphasis on Primary Value Addition - 2006
38. WTO and Indian Agriculture: Implications for Policy and R&D - 2006
39. Innovations in Rural Institutions: Driver for Agricultural Prosperity - 2007
40. High Value Agriculture in India: Prospects and Policies - 2008
41. Sustainable Energy for Rural India - 2008
42. Crop Response and Nutrient Ratio - 2009
43. Antibiotics in Manure and Soil A Grave Threat to Human and Animal Health - 2010
44. Plant Quarantine including Internal Quarantine Strategies in View of Onslaught of Diseases and Insect Pests - 2010
45. Agrochemicals Management: Issues and Strategies - 2010
46. Veterinary Vaccines and Diagnostics - 2010
47. Protected Agriculture in North-West Himalayas - 2010
48. Exploring Untapped Potential of Acid Soils of India - 2010
49. Agricultural Waste Management - 2010
50. Drought Preparedness and Mitigation - 2011
51. Carrying Capacity of Indian Agriculture - 2011
52. Biosafety Assurance for GM food Crops in India - 2011
53. Ecolabelling and Certification in Capture Fisheries and Aquaculture - 2012
54. Integration of Millets in Fortified Foods - 2012
55. Fighting Child Malnutrition - 2012
56. Sustaining Agricultural Productivity through Integrated Soil Management - 2012
57. Value Added Fertilizers and Site Specific Nutrient Management (SSNM) - 2012
58. Management of Crop Residues in the Context of Conservation Agriculture - 2012
59. Livestock Infertility and its Management - 2013
60. Water Use Potential of Flood-affected and Drought-prone Areas of Eastern India - 2013
61. Mastitis Management in Dairy Animals - 2013
62. Biopesticides – Quality Assurance - 2013
63. Nanotechnology in Agriculture: Scope and Current Relevance - 2013
64. Improving Productivity of Rice Fallows - 2013

***For details visit web site: http://www.naasindia.org**