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GUEST EDITORIAL

Climate smart agriculture: are we poised to outsmart climate change impacts?

Despite the spectacular success of the green revolution and achieving self-sufficiency in food production, there are increasing concerns on sustaining the pace of agricultural growth to feed the large population of our country. Lack of yield breakthroughs, deteriorating soil health, groundwater depletion, declining size of operational holdings and labour shortage are some of the prime reasons for slow growth of agriculture. In the recent past, these constraints have been further aggravated by global climate change and climate variability. The impacts of climate change on agriculture are being witnessed globally, but countries such as India are especially vulnerable in view of the high population depending on agriculture, excessive pressure on natural resources and poor coping capabilities. The negative impacts of inter-annual climate variability are already evident. The rainfall deficiency during 2015–16 has brought down the production of coarse cereals and oilseeds sharply. Floods due to heavy rainfall, cyclones, heat wave, cold wave, frost and hailstorms are taking a heavy toll on crop yields every year in one part of the country or the other. The impact of future climate change on agriculture is very grim and worrisome. It is time that the nation woke up and addressed these challenges to avert a national catastrophe.

Studies by the Indian Council of Agricultural Research (ICAR) under the Network Project on Climate Change (NPCC) indicate that in the medium term (2010–2039), food production could reduce by 4.5–9% and in the long term (2070–2099) the production could decrease by nearly 25%. Because agriculture makes up roughly 15% of India's GDP, a 4.5–9% loss of production could translate into a loss of approximately 1.5 GDP per year due to climate change. For every one degree increase in temperature during the season, the production of wheat in the country may reduce by 4–5 million tonnes. In most parts of the country, during the main *kharif* cropping season, a 0.19°C 10 yr^{-1} rise in T_{min} has been recorded. This is estimated to negatively impact paddy yields in over 50% of the area (Bapujirao, B. *et al.*, *Global Planetary Change*, 2014, **117**, 1–8). With decreasing trends in summer rainfall in many places of eastern India such as Chhattisgarh, Jharkhand and eastern Madhya Pradesh, rainfed paddy yields are likely to decrease. Most climate models predict a marginal increase in total rainfall in the country but the numbers of rainy days are projected to decrease, causing heavy rainfall on a few days followed by long dry spells. This is likely to cause flash floods, inundation of crop fields and soil erosion. Warming during winter season has implications for production of *rabi* crops such as wheat, mustard and chickpea in the Indo-Gangetic plains. *Rabi* season contributes to nearly 50% of the total food production. Therefore, insulating *rabi* crops from the impacts of climate change is the key for ensuring food security. Horticulture crops are particularly vulnerable to disease, unseasonal rainfall, hailstorms and pest and diseases incidence caused by climate variability. For example, the yields of apple in Himachal Pradesh are declining because of rise in temperature and inadequate chilling requirement (Network Project on Climate Change, Final Report, CRIDA). Farmers are shifting their crop to higher elevations on the hills to realize acceptable yields.

Besides the direct effects on crops, climate change impacts natural resources like soil and water. Increased rainfall intensity causes more soil erosion leading to land degradation. Increased temperatures will also increase crop water requirement. A study by ICAR-CRIDA, Hyderabad on major crop-growing districts for four crops, viz. groundnut, mustard, wheat and maize indicated a 3% increase in crop water requirement by 2020 and 7% by 2050 across all the crops/locations. Irrigation requirement in arid and semi-arid regions is estimated to increase by 10% with every 1°C rise in temperature. The frequency of extreme weather events like hail storms is also increasing in recent years. Hailstorms usually cause localized damage and occur regularly in Punjab and Himachal Pradesh. However, during *rabi* seasons of 2014 and 2015, widespread hailstorms occurred in most parts of the country, including parts of Gujarat, Maharashtra, Karnataka and Telangana causing heavy damage to field crops and horticulture.

Climate change does not impact everyone equally. Rainfed agriculture is more vulnerable because of the dependence on monsoon. A vulnerability mapping by ICAR-CRIDA (Ramarao, C. A. *et al.*, Atlas on Vulnerability of Indian Agriculture to Climate Change, CRIDA, 2013, p. 116) indicated that many districts in the states like Rajasthan, Gujarat and Karnataka are highly vulnerable to droughts, whereas parts of eastern Uttar Pradesh and Bihar are sensitive to flood damage. Small and marginal farmers are more vulnerable due to their poor coping abilities. Extreme events like hailstorms severely impact horticulture crops like grapes, oranges, mango, banana, causing flower and fruit drop and sometimes farmers loose the entire crop.

In view of the economic impact of climate change on the agriculture sector and its implications on food security and farmers' welfare, adaptation and mitigation measures are urgently required at different levels. Adaptation, particularly, will play a prominent role in developing countries like India. As global warming is an issue that cuts across international borders, co-operation among developed and developing countries in technology exchange and financial assistance is of paramount importance. The recently concluded Paris Agreement has mandated partner countries to reduce greenhouse gas (GHG) emissions by a certain percentage so that temperature rise can be contained below 2°C. The establishment of Green Climate Fund is an important step in this direction.

Sustaining agricultural production in the face of climate change requires a series of scientific inputs and practices; these are now collectively referred to as 'Climate Smart Agriculture' (CSA). According to the Food and Agriculture Organization (FAO), CSA is an integrated approach that addresses the interlinked challenges of climate change and food security with the objectives of (i) sustainably increasing productivity to support equitable increases in farm incomes, (ii) adapting and building resilience of food production systems to climate change at multiple levels and (iii) reducing GHG emission from agriculture (including crops, livestock and fisheries). CSA is not a technology, but an approach which relies on use of modified production technologies, new policies and investments on managing risks. CGIAR has initiated a major research programme on the application of CSA approach to reduce the vulnerability of farming in developing countries (https://ccafs.cgiar.org/), while the ICAR has launched a major project on Climate Resilient Agriculture in India, i.e. National Initiative on Climate Resilient Agriculture (NICRA) (http://www.nicra-icar.in/). NICRA has the twin objectives of generation of appropriate climate resilient technologies for crops, horticulture, livestock, fisheries and poultry and their demonstration on farmers' fields through more than 150 Krishi Vigyan Kendras.

Globally, extensive research is under way on evolving climate resilient technologies and practices. Crop varieties are being developed with multiple abiotic stress tolerance. The first such example is the identification of *sub*-1 gene in paddy by the International Rice Research Institute (IRRI), The Philippines which confers submergence tolerance. The introduction of *sub*-1 in mega-variety like *Swarna* has resulted in *Swarna sub*-1 which is now grown successfully in large parts of eastern and north eastern India where paddy crop gets inundated during *kharif* season. The National Bureau of Plant Genetic Resources (NBPGR) has identified several promising heat-tolerant lines of wheat.

In an effort to mitigate climate change, several climate smart practices relate to water and nutrient management. Direct-seeded rice, for example, emits less methane compared to puddled rice. Neem-coated urea and application of nitrogenous fertilizers in wheat, maize and paddy based on leaf colour charts reduce the total N requirement and cuts down the N_2O emission. Burning of crop residue releases tonnes of carbon dioxide into the atmosphere in states like Punjab where paddy straw is burnt every year to clear the field for wheat planting. Zero tillage, where wheat is planted after paddy without cultivation, offers an alternative to burning. Experience of the NICRA project clearly indicated that by adoption of scientific water conservation methods, groundwater recharge, use of drought tolerant varieties, adjusting the planting dates, modifying the fertilizer and irrigation schedules and adopting zero tillage, farmers are able to realize satisfactory yields even in deficit rainfall and warmer years.

The country needs to provide robust agro-advisories to farmers on real-time basis. This requires a huge effort of weather data collection, assessment of crop condition, soil moisture, pest and diseases under field conditions on real-time and translating such data into a simple advisory. With the use of dynamic models like CLIMEX and DYMEX, we can assess the spatial distribution and abundance of important pests and study how future climate change may cause emergence of new pests and biotypes.

While the impacts of climate change and variability are to be assessed on regional basis, the adoption of climate smart practices can best be done at village level through the creation of Climate Smart Villages. These villages will basically adopt weather smart, water smart, energy smart, carbon smart and nitrogen smart practices. Besides technologies, policy inputs on prudent use of water, nutrients, carbon and energy are essential to promote CSA. To sum up, generation of new technologies, policies that support rational use of natural resources, sharing of global best practices and capacity building of farmers will go a long way towards making agriculture climate smart. The XIII Agricultural Science Congress with focus on Climate Smart Agriculture, jointly organized by the National Academy of Agricultural Sciences, New Delhi and the University of Agricultural Sciences, from 21 to 24 February 2017 at Bengaluru is a testimony, both, to the gravity of the impact of climate change on agriculture and, the concerted action deployed by governments and institutions in addressing these challenges.

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