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GUEST EDITORIAL

Sustainable agriculture in a changing world

The 'agricultural imperative' has been appreciated globally, wherein food production needs to be doubled by 2050, to feed the projected nine billion population, with lower resources and reduced carbon footprints. It is also a key for the Sustainable Development Goals. Current global food production is over three billion tonnes annually, with Asian farming contributing over 48% to the world's food basket. There are however challenges regarding food and nutrition demands, with child malnutrition at significant levels across the world, including South Asia.

Farming in India, accounting for 16% of India's gross domestic product (GDP), engages over 55% of the total workforce. With a net sown area of 140 million ha (Mha), the food grain production in 2019–20 is over 296 million tonnes (Mt) (www.http://agricoop.nic.in), with equally significant increased production levels in horticultural crops, milk, meat, fish and eggs. These have enabled not only self-sufficiency of food in the country, but also a sizeable export of agri-commodities. Even during the ongoing COVID-19 pandemic situation, food production systems have been meeting the demands, with innovative interventions across the value chain. There are also indications that the greenhouse gas (GHG) emission intensity in agriculture is reducing and fertilizer use efficiency is improving in recent years (Pathak, H. *et al.*, *Indian J. Fert.*, 2019, **15**(3), 262–285).

With the population expected to be over 1.6 billion by 2050, annual food demand is likely to rise to 400 Mt, requiring a minimum of 4% annual growth in agriculture. Based on the past trend and emerging scenarios, outlooks for smallholder farmers in India by 2030 are: (i) small and marginal farmers would constitute about 90% of the farming population, producing about 75% of food from different sub-sectors; (ii) farming would emerge as an 'agri-preneurship plus' enterprise; (iii) with the 'rurban' migration, the gender mix would change to a higher female participation in active farming; (iv) considering the status of natural resources as well as labour situation in farming, mechanized and precision farming would significantly increase; (v) financing mechanisms would become more diverse, with active corporate and private players; (vi) greater partnerships would emerge between the governments and farming stakeholders with emphasis on secondary agriculture, agri-infrastructure and market orientation; and (vii) rural household income composition would get more diversified in terms of off-farm and non-farm activities.

Farming, one of the oldest systems, is diverse, heterogeneous, unorganized and subject to vagaries at various phases from 'weather to market'. It is also facing the emerging challenges of climate change, natural resources degradation, abiotic and biotic stresses, shrinking farm-land-holdings, urbanization and so on, specifically hovering around water, labour and markets. Adding to these are the post-harvest losses to the tune of Rs one lakh crore annually, which managed, would add to the food availability in the FAO's paradigm of 'save and grow'.

Climate is the most important determinant of agricultural productivity. If climate goes wrong, agriculture and in turn, the economy cannot go right. India, endowed with favourable climatic conditions and rich agro-biodiversity, is also considered to be one of the most vulnerable regions to witness climatic changes at a large scale. Recent observations show that temperature is rising and becoming highly variable. Amount, intensity, variability and extreme events of rainfall (unseasonal rain, drought and flood) are rising, while the duration of rainfall is reducing (Shukla, P. *et al.* (eds), IPCC, 2019, p. 242). Perceptible negative impacts are projected on production of food grains, livestock as well as aquatic systems, both quantitatively and qualitatively.

Sustainable intensification of land resources is inevitable for food security of increasing population. Soil degradation, however has reached alarming proportion in many parts of the world with 30–50% of the world's arable land affected by soil erosion and related processes. India has 121 Mha, i.e. 36% of the geographical area degraded with soil erosion, salinity, alkalinity, acidity, water logging and other edaphic stresses (NAAS, Policy Paper No. 87, 2017, p. 14). These are being addressed through combinations of reclamation measures and cultivation practices, enabled by technology and policy interventions.

With 4% of world's renewable water resources, the country has only 43 Mha fully irrigated, 23 Mha partially irrigated and 74 Mha rainfed. In the recent past, both drought and floods have been seen to be stress factors in farming. India's rechargeable annual groundwater potential is around 432 billion cubic metres (BCM), with over 90% utilized in some parts of the country, as can be seen from the depletion of the groundwater table in Punjab, Haryana, parts of Rajasthan, Gujarat, western Uttar

Pradesh, as also in the Deccan plateau. As regards the sectoral water requirements, irrigation is projected at a minimum of 561 BCM with the availability of 784 BCM by 2025; and 628 BCM of 973 BCM by 2050.

With multiple activities on the land resource including the farming practices, nutrient deficiencies of different kinds are being increasingly reported. Annually, 8–10 Mt of NPK is mined from soil and 93%, 91%, 51% and 43% soils are rated low in nitrogen, phosphorus, potassium and zinc respectively (Minhas, P. S. *et al.*, Springer, 2017, p. 520). Fertilizers, therefore have played a crucial role in enhancing crop production and globally, 120 Mt of N fertilizer is used in agriculture, and in India, the consumption is about 17 Mt annually. However, nearly half of the nitrogenous fertilizer applied is leaked into the environment through volatilization, leaching or emissions resulting in multiple adverse effects on terrestrial and aquatic systems and on human health. Efforts for enhanced use efficiencies of different nutrients through both improved crop varieties and management practices are continuously being made.

A multi-pronged strategy with integration, diversification, clustering, customized farm mechanisation, value addition and market access is required to realize the full potentials of farming. Developing varieties tolerant to multiple abiotic and biotic stresses using stress-tolerant QTLs, genes and alleles in elite cultivars is an efficient way of achieving higher yields and sustainability. As for example, crop varieties such as *CR Dhan 801* and *CR Dhan 802* for rice, and several other crops, which are tolerant to multiple stresses, viz. submergence, salinity, drought, heat and pest and diseases have been developed (Bhattacharya, P. *et al.*, Springer, 2020, p. 211).

Methods and tools for conserving, storing and enhancing water use efficiency through pressurized, low cost and demand-driven micro-irrigation systems are being deployed in farming with notable success. Rice being the most water-demanding crop, technologies such as alternate wetting and drying and dry direct-seeding have been developed to reduce water consumption and mitigate GHG emission (Bhattacharya, P. *et al.*, Springer, 2020, p. 211). Farmers are successfully using drip irrigation in several horticultural and field crops including sugarcane, another high water-demanding crop. Use of neem-coated urea, soil health cards and leaf colour charts for enhancing fertilizer use efficiency are becoming common practices. Microbe-based technologies for nitrogen fixation, nutrient recycling, bio-residue management and alleviation of abiotic and biotic stresses have also been found useful. Another significant development is the Conservation Agriculture (CA) to reduce the carbon foot-print of production systems, that improves productivity and enhances adaptability by modulating soil moisture and temperature regimes. It also provides for on-farm use of crop residues and with due refinements and incentives, can reduce the prevailing crop burning practices in some parts of the country.

Mechanization in agriculture with renewable energy sources using solar-powered machinery such as water pumps, sprayers and weeders is gaining momentum. Weather stations and installation of rain gauges and visualizers at village level; information and communication technologies for short-term weather forecasts and advisories at block level; use of mobile agro-met advisory system, rural mobile phone-based social networking, community awareness programmes, etc. along with contingency plans are enabling improved cropping practices. Greater thrust is needed with regard to agri-infrastructure both during the production and post-harvest phases, the latter in terms of processing and storage facilities. Innovations, both institutional and farmer-originated, have evidence-based impacts on improving productivity and sustainability. There is however, scope for customizing them to local needs of the farms, and scaling up for a wider reach among the farmers.

The 'new agriculture' should be more holistic, with regard to productivity, profitability and sustainability, with a continuum of agriculture-food-nutrition-health-environment-employment. The focus is on farm production as well as farmers' income, towards which some of the recent governmental policies have stated the intent, as well as formulated schemes to enable them. With an emphasis on both crop and animal-based farming and value addition, as also techno-socio-economic tools such as Farmer Producer Organizations (FPOs), Agri-Startups, systems and practices are being designed to make farming both sustainable and remunerative. Foresight and partnerships that are knowledge-based and skill-oriented would be critical for farming as an enterprise, in order to build resilience in food production systems.

Creating awareness and demonstrating efficacies of new technologies pertaining to climate risk mitigation among stakeholders for large scale adoption are equally important. Efficient agriculture, both on-farm and beyond-farm, would make farming a sustainable economic activity, preventing the 'rurban migration', from villages to cities in search of livelihoods. In the 'seed-to-market' approach for profitable agriculture, innovations are the key to reduce efficiency losses at various levels. With different kinds of stresses impacting farming, dimensions of speciality agriculture and secondary agriculture have to be incorporated, for a win-win for both the producer and the consumer. Transformational changes happening in all sectors of economy in a changing world have to be factored in for making farming 'smart'.

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