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GUEST EDITORIAL

Climate smart agriculture – Renewing agricultural practices for food security

Agriculture is affected by climate change. For instance, rising CO_2 levels may increase plant productivity but deplete plant nutrient content, especially zinc (Myers, S. S. *et al.*, *Lancet Global Health*, 2015, **3**, e639–e645). Long-term and increased precipitation recharges aquifers and brings up the water table, but it also leads to soil erosion, nutrient runoff and reduces phosphorus uptake in the soils (Sun, F. *et al.*, *Soil Biol. Biochem.*, 2020, **151**, 108056). Increasing temperatures cause frequent pathogen attacks leading to crop loss. Heat waves, along with drought, are experienced in many parts of India (Sharma, S. and Mujumdar, P., *Sci. Rep.*, 2017, **7**, 15582). The Indian Council of Agricultural Research (ICAR) has reported that an erratic rise in temperatures terminates the life cycle of crops early, which affects the crops' yield. ICAR has elaborated on technologies developed for minimizing the impact of heat waves on crops (Bal, S. K., *Heatwave*, 2022; *Tech. Bull.*, ICAR/CRIDA/TB/01/2022, 2022, p. 50). The impact of global climate change on agriculture and its allied sectors, such as fisheries, livestock, and policy, in combination with meteorological data, has been detailed in case studies from India (Aggarwal, P. K. *et al.*, Case Studies from ICAR, 2009, p. 148). Apart from other challenges, worldwide, farmers attribute low yields, pathogens, pests, animals, plant diseases and invasive weeds as major consequences of climate change on agriculture.

Farmers have resorted to different chemicals, fertilizers, pesticides and herbicides as easy remedies because of a lack of awareness of alternate, environmentally friendly measures that guarantee stable productivity even under adverse climatic situations. It is true that crop productivity increased by using artificial fertilizers and agricultural intensification during the Green Revolution, globally. Using fertilizers, Colorado witnessed up to 500% and 100% increases in maize and wheat yields respectively. While ushering most countries out of famines, post-green revolution saw a phase that led to shrinking of crop diversity to promote the high-yielding specific crops, monoculture, over-exploitation of fertilizers, causing soil, water and air pollution. According to the UNEP report, Costa Rica produces the highest number of pineapples using chemical fertilizers, excess use of which could harm the environment. In Punjab, India, rice and wheat farming practices are declining due to depletion in soil health and an increase in negative effects on plant development (Nambiar, K. K. M., *Soil Fertility and Crop Productivity under Long-Term Fertilizer Use in India*, ICAR, New Delhi, 1994). In adopting a single crop, monoculture allows agriculturists to utilize machinery; however, it has negative effects on the environment. Monoculture reduces organic matter in the soil, alters soil pH, and decreases microbial biodiversity (Zhao, Q. *et al.*, *Long-Term Sci. Rep.*, 2018, **8**, 6116). The agricultural sector emits major greenhouse gases (GHGs), namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), directly influencing climate change (Food and Agriculture Organization (FAO), 2015; EPA, 2020). Majorly, soils release CO_2; however, under oxygen-depleting conditions, CH_4 is released due to the relative increase in methanogens over methanotrophs (Lu, Y. *et al.*, *Environ. Microbiol.*, 2005, **7**, 326–336; Chistoserdova, L., *Genome Biol.*, 2005, **6**, 208). Burning crop residues, slash and burn, unregulated use of chemical fertilizers affect CO_2 emission, sulphur and phosphorus cycles in soils and lead to eutrophication (Ju, X.-T. *et al.*, *Proc. Natl. Acad. Sci.*, 2009, **106**, 3041–3046). Hence, transformation and reforms in agricultural practices are needed to protect natural resources and aid adaptation to climate using environmentally friendly and sustainable techniques.

Climate-smart agriculture (CSA) is an integrated approach to managing agriculture with respect to climate change in local contexts. The FAO supports the establishment of CSA for 'better production, better nutrition, a better environment and a better life for all, leaving no one behind' (FAO, Strategic Framework, 2022–2031). Elaborating, the CSA practices integrate management of livestock and fisheries, support to food growers, ecosystem conservation, food security and adaptation to the impacts of climate change.

Hence, CSA aims to mitigate the negative impacts of climate change and anthropogenic influences. For instance, in some cases, the use of organic compost results in similar efficacy to chemical fertilizers. They additionally improve the quality of the soil, nutrient availability and biodiversity, even in saline or acidic soils (Saharan, B. S., *Agriculture*, 2023, **13**, 196). Researchers from the University of Costa Rica's Environmental Pollution Research Centre have employed biochar generated from natural remnants and demonstrated that it upgrades not only soil fertility but also reduces the effect of chemicals on soil. CSA includes employing cover crops with crop residues and restricts CO_2 emissions from the soil since soil temperatures are maintained. Crop rotations integrating legumes enhance biological nitrogen fixation by directly recruiting nitrogen-fixing symbiotic bacteria that naturally increase the soil nitrogen content (Hirsch, A. M. *et al*., *Plant Physiol*., 2001, **127**, 1484–1492). Crop rotation using drought-resistant crops, including different millets, groundnuts, local varieties of rice, sorghum, legumes, chickpeas, buckwheat, pulses, vegetable crops, fruit trees, berries, medicinal plants and trees must be encouraged to promote a diversified farming system. Crop rotations result in increasing beneficial soil, reducing plant pathogens, weeds and insects (Karlen, D. *et al*., *Adv. Agron.*, 1994, **53**, 1–45; Karlen, D. L. *et al*., *Soil Tillage Res*., 1994, **32**, 313–327). ICAR has reported higher yields of many crops using intercropping. The inclusion of agroforestry benefits the conservation of ecosystem biodiversity and strengthens an agroecosystem's adaptation to climatic variability (Dhyani, S. K., *Indian J. Agric. Sci*., 2016, **86**, 1103–1112). Additionally, multi-purpose trees operate as shelter belts inducing micro-climatic events thereby modulating winds, reducing losses due to soil evaporation, moderating soil temperatures and aiding soil biodiversity. Farmers in Malawi, Africa, practice agroforestry and intercropping (Harawa, R., *Nutr. Cycl. Agroecosys*., 2006, **75**, 271–284), which has resulted in increasing nutrients in the soil, arresting emission of GHGs and improving nitrogen fixation (Kaczan, D., FAO reports, Rome, 2013). Interestingly, tree leaf litter works as a productive mulching agent during scanty rainfall to ensure steady crop growth and improve ecosystem functions.

Further, practices aiming at strengthening the resilience of agroecosystems include low-cost inputs, such as organic cow manure, decomposed crop residue, crop rotation, intercropping, multi-cropping, use of cover crops, agro-forestry and clean, guaranteed irrigation water. Vietnamese farmers have been successful in increasing food production and ensuring food security by resorting to improved plant varieties, using better irrigation and synchronizing sowing dates (Ho, T. T. *et al*., *The Agriculture*, 2019, **9**, 99). The International Rice Research Institute has bred rice varieties which can withstand either drought or floods or salinity or heat or cold environments to ensure food security during harsh climates. ICAR has also bred wheat varieties that can withstand high heat. Similar success stories involving climate-smart practices are strengthening food security in Nepal.

Additionally, by supporting conservation and regeneration of ecosystems' practices, CSA co-benefits humans and the planet. However, agricultural productivity may initially slow down during the transition period of adopting these practices. Therefore, the Government must be geared to provide assurance and insurance to vulnerable populations. McKinsey and Company has documented at least 33 operations that can help small-landholder farmers adapt to climate change. Such climate-smart practices, time-tested on-ground, safeguard the native potential of our natural resources while building a sustainable farming system resilient to harsh climate variability.

Another major challenge is overcoming malnourishment. Factors contributing to malnourishment include insufficient calories, unbalanced diet, inadequate knowledge of protein or micronutrients intake, inherently deficient food grains due to poor soil/cultivation practices (Neenu, S., *Chem. Sci. Rev. Lett*., 2020, **9**, 205–219), or adulterated water or food, shortage in food availability, supply chain problems, economic incapability to procure food, etc. In order to derive maximum benefit from good food, a global transformation of food production using sustainable methods has been recommended (Willett, W. *et al*., *Lancet*, 2019, **393**, 447–492). 'Annam Aushadham' (diet is medicine), as advocated by the Indian Vedic system, summarizes that a person who understands and follows how, what, how much, and when to eat acquires better health and well-being, and adapts to changing climate. India has a large repertoire of local crops, including fruits and vegetables. Among these, millets are ancient crops of India, mentioned even in the Vedas; these are still referred to by their local vernacular names. Interestingly, a wide variety of millets have a long shelf life and can be suitably grown using rainfed agriculture, on poor soils, under drought and in high mountain regions with different pH. They have higher nutraceutical properties than other cereals, so they can overcome malnourishment and ensure food security during adverse climate conditions. The Himalayan communities continue to practice baranaja, integrating rice, pulses, millets and vegetables among other crops in the mountain regions, which guarantees good produce despite variable weather conditions and hence could be recommended in other regions (Gururani, K., *Nutr. Cycl. Agroecosyst*., 2006, **75**, 271–284) for food security.

Plant–microbe interactions hold tremendous potential for sustaining agroecosystems (Trivedi, P. *et al*., *New Phytol*., 2022, **234**, 1951–1959.). Microorganisms assist plants in nutrient acquisition, growth, suppressing diseases and transformation of toxic chemicals; hence, harnessing beneficial microbes encompasses climate smart agricultural practices. Agriculture continues to be an effective contributor to India's GDP and food security. Resilient climate-smart agroecosystems must aim to foster harmonious interactions with all the other sectors. Our daily activities derive sustenance from food, which should be nutritious and grown sustainably. Our traditional festivals celebrate agriculture and weather; a holistic approach to ensuring climate-smart agriculture requires renewed vigour and vision.

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