CURRENT SCIENCE

Volume 122 Number 4 25 February 2022

GUEST EDITORIAL

Coastal agriculture and aquaculture in India: outlooks in the context of climate change

The United Nations has described climate change as 'the defining issue of our time' (https://www.un.org/en/global-issues/climate-change). According to the Intergovernmental Panel on Climate Change (IPCC) (*Climate Change: The Scientific Basis*, 2001, p. 881), the mean global temperatures could escalate between 1.4°C and 5.8°C by 2100. Coastal ecosystems are particularly vulnerable to the impacts of climate change, which range from shifting weather patterns impacting food production to rising sea levels that increase the risk of catastrophic flooding, and increased frequency and intensity of extreme weather events. Over the last century, sea levels have risen by 20 cm and future sea-level rise (SLR) is expected to be far higher, affecting around one-seventh of the world's population living at elevations less than 10 m amsl.

India has a 8118 km coastline (*Handbook of Fisheries Statistics*, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India (GoI), 2020, p. 176), with a total land area of ~10.78 million ha (including the islands) under coastal ecosystems (Velayutham, M. *et al.*, Report of the National Bureau of Soil Survey & Land Use Planning, Nagpur, 1999, p. 372). The coastal ecosystems span across 13 states and Union Territories, covering 84 districts of the country, and include estuaries and marshes, mangroves, lagoons and salt ponds, seagrass beds, coral reefs, croplands, mud flats, sandy beaches, creeks and coastal shelf ecosystems. According to the 2011 Census, India's coastal districts have a population of 171 million, representing 14.1% of the country's overall population. This includes vulnerable sections of fisherfolk who rely on traditional crafts, salt-pan workers, coastal agriculturists and fisherfolk whose livelihoods rely on aquaculture in coastal areas. Along the coast, there are also vulnerable urban centres, including two mega cities, viz. Mumbai and Chennai. Overall, nearly 30% of India's population relies on coastal and marine resources (Third Biennial Update Report to the UNFCCC, Ministry of Environment, Forest and Climate Change (MoEFCC), GoI, 2021, p. 479).

The coastal ecosystems are endowed with abundant natural resources. Yet the land and ocean masses exist in a precarious equilibrium, with climate change acting as a threat multiplier. The resultant SLR, flooding, and increased frequency and intensity of extreme weather events may cause major coastal community displacement, besides other consequences such as damage to infrastructure and crops. The sea level has been rising at a rate of ~1.7 mm/yr along the Indian coast, with varied rates in different regions. It has the potential to intensify inundation of low-lying areas during extreme events like storm surges, as well as promote coastal erosion. Between 1990 and 2016, India lost 23,500 ha of land to coastal erosion. According to Kankara, R. S. *et al.* (National Assessment of Shoreline changes along Indian Coast, Report of the Ministry of Earth Sciences, New Delhi, 2018, p. 69), coastal erosion impacts around 33% of the coastline of India and some areas are more vulnerable than others. It has been estimated that 63% of West Bengal's coastline was impacted between 1990 and 2016, followed by Puducherry (57%), Kerala (45%), Tamil Nadu (41%), Odisha (28%), Andhra Pradesh (27%), Gujarat, Daman and Diu (26%), Karnataka (22%), Maharashtra (24%) and Goa (12%).

The anticipated SLR and coastal inundation may affect 36 million people in India by 2050 (Kulp, S. A. and Strauss, B. H., *Nat. Commun.*, 2019, **10**, 4844; https://doi.org/10.1038/s41467-019-12808-z). Although most existing policies in India address displacement caused by rapid-onset disasters such as monsoons and cyclones as part of disaster mitigation and rehabilitation strategies, displacement caused by slow-onset disasters such as coastal erosion is yet to be addressed. The combination of rising sea levels, soil and water salinization, cyclones and flooding, however, makes this one of the most difficult and challenging tasks.

The coastal ecosystems deliver a wide range of services, viz. material benefits (provisioning services such as food, fibre, timber, fuel, medicines and other resources); regulating services such as freshwater storage, hydrological balance, disease control, waste processing, flood/storm protection, erosion control, shoreline stabilization, regulation of water quality and carbon sequestration; cultural services such as amenity, recreational and aesthetic benefits that are of nonmaterial nature and which support people in spiritual, social and cultural dimensions and supporting services such as nutrient regulation, nutrient cycling and soil fertility, besides biodiversity conservation. These coastal ecosystem services are of high value not only to the local communities, but also for the national economy and global trade. SLR, enhanced cyclone impacts, storm surges during cyclones and other hazards, however, will adversely impact the capacity of coastal ecosystems to deliver such services.

The smallholder production systems that dominate the coastal zone produce considerable food supplies. Paddy lands (e.g. acid-saline soils and the unique social-ecological systems of southwestern India and elsewhere), rice and fish/shrimp farming systems, coconut-based mixed farming systems, spice crops, the ubiquitous home garden systems and the time-tested agroforestry practices are among the major coastal land-use systems that contribute significantly to food and nutritional security. Clearly, coastal agriculture and aquaculture, notably rice and seafoods, account for a substantial part of the country's food output. Food security, especially in the low-lying coastal areas and small islands, is intrinsically linked to climate change and SLR. Destruction of plantations and agricultural crops owing to sea water intrusion and soil salinization is a case in point. The surge in alien invasive crop pests (e.g. coconut eriophyid mite, *Aceria guerreronis* and rugose spiralling whitefly, *Aleurodicus rugioperculatus*) is another factor that affects the productivity of agricultural and horticultural systems in coastal areas.

Climate change has resulted in widespread loss of productivity and infrastructure due to extreme events such as floods, as well as increased disease, parasite and algal-bloom hazards in aquaculture. A coastal multi-hazard vulnerability assessment was done considering the implications of future SLR and the MoEFCC formulated a National Policy for Coastal Protection, besides issuing guidelines to all stakeholders in this regard (Third Biennial Update Report to the UNFCCC, MoEFCC, New Delhi, 2021, p. 479). As part of an Integrated Coastal Zone Management Project (ICZMP), hazard-line mapping along the coastal belt of India, including the intertidal regions was undertaken. To enhance coastal agricultural adaptation and for ensuring food and nutritional security of an ever-increasing population, farmer participation to address climate-change issues, climate-smart agricultural production practices and sustainable intensification of coastal farming systems are imperative.

The estuarine and coastal ecosystems (ECEs) also have the potential to serve as an important carbon sink with carbon storage rates much above those of terrestrial habitats. ECEs are extremely productive systems, with net primary production rates among the highest in any ecosystem. By sequestering atmospheric carbon dioxide (CO_2), which has been increasing at an average annual rate of 2 ppm since the Industrial Revolution, the coastal ecosystems play an important role in regulating the global climate and carbon cycle. Mangroves, salt marshes and seagrasses sequester at least 136,000 tonnes of carbon into long-term storage each year globally (Heckbert, S. *et al*., Climate regulation as a service from estuarine and coastal ecosystems. *Treatise on Estuarine and Coastal Science* (eds Wolanski, E. and McLusky, D.), Academic Press, Amsterdam, 2011, vol. 12, pp. 199–216). Seaweed aquaculture, a form of restorative and near-zero-input farming practice, has the potential to mitigate the negative effects of climate change locally by capturing carbon, reducing agricultural greenhouse gas (GHG) emissions, and protecting shorelines from erosion.

Coastal communities that are highly vulnerable to SLR will see significant changes in agricultural patterns with reference to salt intrusion and increased soil salinity, coupled with floods and waterlogging from increased intensity and frequency of extreme weather events. To meet the rising food demand while also conserving coastal ecosystems in a changing climate, win–win strategies for ecosystem services and climate resilience are required. Integrated coastal zone management is critical for ensuring food security for the coastal population. Environment-friendly farming practices such as agroforestry and tree-based farming, which increase carbon stocks in the soil and biomass, as well as low-impact restorative aquaculture practices, are critical for sustaining the ecological integrity of these fragile ecosystems.

Resource inventories for coastal districts must be developed as a way forward. According to Kumar, B. A. and Devi, S. S. (Climate change and its impacts on marine fisheries and livelihood: an Indian perspective. In *Biodiversity and Livelihood* (eds Oommen, O., Laladhas, K. P. and Bharucha, E.), Bentham Science Pub., Singapore, 2020, pp. 121–134), flood forecasting and mapping, hydrological framework development and downscaled climate change projection modelling and coastal protection methods with community participation must be prioritized. Fine-tuning farming system options for best land and water utilization and optimizing returns are suggested, besides land shaping as an SLR mitigation tool for adaptation.

S. Ayyappan[1,*]
B. Mohan Kumar[2]

[1]Central Agricultural University,
Imphal 795 004, India
[2]Arunachal University of Studies,
Namsai 792 103, India
*e-mail: sayyappan1955@gmail.com