Indian Farming 76 (07): 25-28; July 2026

Climate-resilient farming system for coastal saline and waterlogged areas

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Prolonged waterlogging (June to December) and deep clayey soils creates difficulties for crop production in coastal areas. In kharif *season, lowland-rice is grown and the land remains fallow for the remaining period. In* rabi *season, clayey soils are too hard and difficult to manage for agriculture with additional problems of salinity build-up and fresh water scarcity. Adverse effects of climate change are further compounding the problems. These problems could be overcome by adopting 'Alternate raised and furrow bed integrated with aquaculture and agroforestry system'. Problematic deep clayey soils and saline soils should be prioritised for such system. The article discusses about the possible ways to mitigate waterlogged problem and alternative ways to utilise clayey soils in coastal regions.*

Keywords: Aquaculture, Deep clayey soils, Land modification, Suitable species, Sustainable development goals

INDIA is a peninsula with a huge coastline of 7516.6 km, out of which the mainland covers 6,100 km and the remaining by the island territories. The coastal ecosystem represents the transition from terrestrial to marine influences and vice versa. About 33.6% of the coastline is erosion prone, especially, in the eastern coast due to the rise in sea-level, flooding and high intensity storms. Western coast is prone to land slide and flooding with huge runoff from Western Ghats. Mangrove destruction, increased population density, weak economic status of people, pollution, sand mining, salinity intrusion, and industrial and trade activities are disturbing the natural ecosystem. As per the World Bank's Climate Risk Profile, south-western coast of India has a 'wet tropical climate with high annual precipitation', and it is likely to be wetter in future. The rainfall in eastern coast is strongly controlled by the monsoon with high year to year variation. Such unpredictability in terms of withdrawal and onset, amount, intensity and dry spell frequency is likely to be more with climate change. This interferes in crop planning and farm productivity. The cyclonic storms and depressions hitting the coastal India, originate and intensify mostly over the Bay of Bengal, followed by the Arabian Sea.

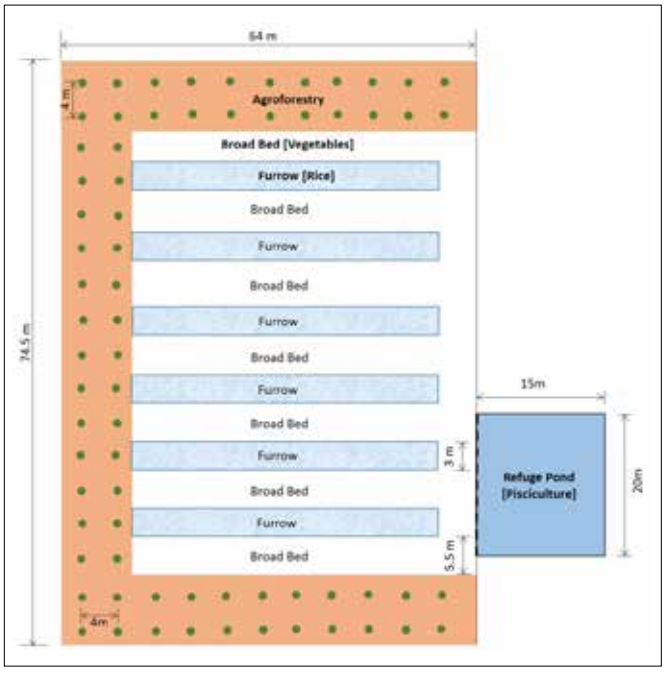
Out of 11.6 million ha under waterlogged land, about 9.44 million ha is due to rainwater accumulation in low lying topography and the remaining area is due to seepage accumulation in canal command. The problem of waterlogging is likely to increase in future with more rainfall intensity expected in tropical areas with less rainy days. Sea level may rise by 50 cm by the year 2100 and bring more area under surface ponding. Anthropogenic waterlogging is due to obstruction of natural drainage with the construction of highways, railways, settlements, and industries. About 20% of the waterlogged area falls in eastern region where surface waterlogging is a major cause rendering the area sub-productive. The physiography is gradually sloppy experiencing increased ponding depth of 30 cm in shallow lowland to 50 cm in intermediate lowland, 100 cm in semi-deep water and exceeding 100 cm in deep water situation. Problem for agriculture increases with the rise in ponding depth.

While water scarcity, sea water intrusion and salinity build up during the dry season, it affects the cropping period and productivity. Salinity ingression is associated with the groundwater pumping and such problems were reported up to 14 km from the coast line. In addition, surface ingression of saline water occurs with high tides due to tropical cyclones, and earthquakes such as *tsunami*. This results in salinisation of soil and water. Frequency and intensity of lightning and thunderstorms have increased in recent years due to rise in surface temperature and thermal gradient in troposphere. Adverse effect of moist heat (due to high temperature and humidity) is evident on health and work efficiency of agricultural labourers. This emphasises the need of agroforestry to keep the microclimate cool.

Negative impact of climate change on coastal areas is huge because of high concentration of people in sea ports, urban centres, markets and go-downs, road and rail networks, industries, and intensive agriculture. Coastal India is vulnerable to flood, drought, cyclones, salinity, waterlogging, and thunderstorms. All these mandate an integrated and multi-pronged resilient farming system for sustainable management of soil, water and biodiversity.

Alternate raised and furrow bed integrated with aquaculture and agroforestry system

***Land modification*:** The objective was to partly convert the coastal waterlogged area from lowland rice–fallow system to an integrated system using aquaculture, agroforestry and vegetable cultivation. It involves creation of 6 furrows and 7 raised and broad beds surrounded by two rows of agroforestry plants in three sides (windward sides) in one ha area. The fourth side has one lateral furrow connecting the six furrows and a refuge pond at the downside. Broad beds (5.5 m at base and 5.0 m at top) are created using the excavated soil in alternate pattern with furrows. Furrows are 3 m wide at ground level and 2 m at base with a depth of 1 m from surface. At the downside, all the furrows are connected to a lateral furrow of 45.5 m length and 5 m width. The lateral furrow is connected to a water harvesting farm pond (20 m × 15 m) which serves as refuge pond ensuring fish growth during long dry spells. The total water surface area for growing fish was 1427.5 m^2 (refuge pond 300 m^2 + furrows 900 m^2 + lateral furrow 227.5 m^2).



Schematic layout of 'Alternate raised and furrow bed integrated with aquaculture and agroforestry system' in farmer's field

***Multi-purpose biodiversity promotion*:** Agroforestry species such as *Casuarina* (N fixing and salinity tolerant), *Eucalyptus*, *Acacia* (timber value) and bamboo can be included. These are fast growing wind-break species with bio-drainage potential for waterlogged areas. Bamboo groves have high tenacity against winds and storm surges and hence, are useful in saving lives. This was experienced during the super cyclone which devastated the coastal Odisha in the year 1999. The agroforestry species serves as bird shelter. Harvested bird guano (accumulated excreta) improved soil health and also, a part falling on water was directly used as fish feed. Multi-layer fish farming using Indian Major Carps (*Rohu*, *Catla* and *Mrigal*) in refuge pond and aerobic fish species such as *Anabaes* and *Magur* in furrows was successful. Suitable high value crops identified for growing on raised beds include brinjal, ridge gourd, and okra besides raising nursery for sale in *kharif* season while tomato, bitter gourd, country bean and snap melon in *rabi* season. In areas with labour scarcity, agroforestry species may be grown on raised beds in place of labour intensive vegetable crops. For the agroforestry system, further intensification is possible by multi-tier intercropping with shade loving crops such as black pepper, pine apple, yam, elephant foot yam, etc.

Brinjal on raised bed (Longitudinal view)

Agroforestry species (5-year-old plants) grown on raised beds (Lateral view)

Benefits of the system

***Economic benefits*:** This system resulted in higher net return of ₹168,481/ha for the period (2018 to 2020) with B:C ratio 1.98 as compared to the conventional system of rice–fallow with a net return of ₹40,000/ha.

***Environmental benefits*:** Agro-ecological benefits were noted with the described land modification model. Such benefits include:

- Promotion of biodiversity in terms of birds (mostly darter, egret and stork), earthworms, different vegetable crops and agroforestry species (*Casuarina, Eucalyptus*, palm, tamarind and bamboo).
- Soil amelioration occurred due to bird guano rich in phosphorous, nitrogen and calcium. A part of guano falling into water in furrows promoted planktons and free floating weeds such as *Azolla* and *Lemna* which served as natural fish feeds.
- Addition of bird guano, no tillage on beds, and leaf mulching promoted earthworm activities and soil properties.
- Suitable species such as bamboo and *Casuarina* in the system are useful as effective windbreak in cyclone prone coastal areas and function as second line of defence after the mangroves in shoreline.
- Palmyra palm is a suitable agroforestry species, especially as lightening arrester in addition to its role as windbreak, and minor fruit crop with timber value.
- Soil salinity was reduced very fast from raised beds during rainy season and helped in crop diversification and second season cropping in early *rabi* season.
- About 30–40% increase solar energy harvest and minimal pest incidence was possible due to minimal mutual shading by the inter-cropping system of vegetable crops on raised beds and fish in furrows.
- Refuge ponds and furrows could effectively harvest both the seasonal and unseasonal rainwater, and thereby met the water need for cropping in *rabi* season.
- The hydrostatic pressure from ponded water and recharge of groundwater might have checked the intrusion of saline groundwater.

***Social benefits*:** Affluent farmers leave the land fallow in coastal waterlogged areas due to little profit, climatic risk, and labour scarcity. This system is useful for such situations and can be adopted due to reduction in climatic risk and labour demand. Such systems can help in reducing the adverse impacts of cyclone on society and associated burden on government for post-disaster management. Huge carbon sequestration potential of such system may reduce the adverse effect of climate change on society.

Special importance of the system for coastal clayey soils

Deep clayey soils are prevalent in coastal areas due to the deposition of fine clay particles carried by flood water, over the years. Fine particles in clay cause slow absorption of water with swelling, surface sealing and waterlogging. During dry phase, wide cracks develop and the soil clods become very hard to work and manage for agriculture. The soils with expanding lattice minerals are known as 'hour minute clay', and offer limited opportunity time for tillage. Adding enough organic matter, promoting earthworm and microbial activity, crop rotation with deep rooted crops, avoiding wet tillage and heavy implements, zero and reduced tillage, and agroforestry are suggested for improving productivity in clayey soils. However, low seepage percolation loss (1–3 mm/day) in clayey soils can be considered as opportunity for retaining ponded water in furrows and pond for a longer period for the benefit of fish and crops. A lot of problems with the coastal clayey soils can be managed with the 'Alternate raised and furrow bed integrated with aquaculture and agroforestry system'. Selection of suitable crop and agroforestry species for such soils is important. For example, country bean (*Dolichos lablab*) and sword bean (*Canavalia gladiata*) grow well with the residual soil moisture and biological N fixation by *Rhizobium* bacteria in symbiosis with the roots. In spite of several benefits, wide adoption of such land modification system is not happening due to initial investment constraints, and little concern for environmental benefits. Also, the poor farmers with small and marginal land holding constitute 87% and a majority of them are not interested to divert the paddy land for other uses.

Sword bean climber (Clayey soil with cracks and dried banana plant in background)

Linking with Sustainable Development Goals (SDGs)

Technologies, innovations, and products should focus on environmental sustainability and support the attainment of the SDGs. The described technology developed with participatory approach in farmer's field support several SDGs.

Table 1. Sustainable Development Goals (SDGs) and benefits with the system

SDG	Benefits
1. No Poverty	Low productive waterlogged area was transformed as more productive. Income increased by 4.2 fold, and spread over a long period as compared to the rice–fallow.
2. Zero Hunger	High income improved purchasing power for food. Also, growing different vegetables, fruits and fish helped in diversification of food and nutrition.
6. Clean Water and Sanitation	Rainwater harvest was useful in rural sanitation by overcoming water scarcity in dry season. Unseasonal rainwater harvest was useful without worries. Groundwater recharge with the harvested water was also possible.
8. Decent Work and Economic Growth	Promoted sustainable economic growth, full and productive employment of family labour was achieved round the year as hobby for vegetable cultivation, and decent work was possible due to little menial jobs in agroforestry and aquaculture.
13. Climate Action	Mitigation role by promoting round the year vegetation growth, little tillage in pond, furrow and dyke areas, carbon sequestration with agroforestry and in pond areas (reduced CO_2 content), and low fertiliser use with N fixing crops (*Casuarina*, Tamarind, *Dolichos*). Also, served as adaptive role with windbreaks, diversified enterprises and income.
15. Life on Land	Sustainable use of saline waterlogged lands (overcame waterlogging, and declined soil salinity very fast), agroforestry promotion, check on coastal soil erosion, and improved biodiversity. More solar energy harvest and less pest problem led to increased land productivity and decreased pesticide use. Soil property improvement with waste recycling and biodiversity promotion for high life activity.

SUMMARY

Prolonged surface ponding, prevalence of clayey soils, salinity, fresh water scarcity in dry season, cyclones, lightning and thunderstorms, storm surges, and irregularity of monsoon handicap the coastal crop production system. However, land modification for fresh water harvest integrated with suitable crop, agroforestry and fish species could transform the challenges to opportunities. Farmers' income could be raised with several environmental benefits. Interested farmers should be supported with financial incentives due to inherent agroecological benefits. Also, financial support is needed in terms of initial investment for land modification to overcome the problem of weak economic condition of farmers.

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