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Crop + Aquaculture practices for enhancing farm production in coastal degraded lands

A. Velmurugan*, S. Dam Roy, T.P. Swarnam, T.Subramani, and I. Jaisankar
ICAR-Central Island Agricultural Research Institute, Port Blair-744 101
Corresponding author:vels_21@yahoo.com

Abstract

In the coastal and humid tropical island region waterlogging and soil salinity are serious threat to the sustainability of rainfed agriculture due to sea water inundation and intensive monsoon rainfall. In addition there has been a perceptible change in surface temperature, rainfall, evaporation and extreme events linked to climate change affecting the tropical islands. Therefore an innovative management of waterlogged and saline soils of island ecosystem is imperative to provide livelihood to the local people. Land shaping measures combined with practicing different enterprises like crop + aquaculture, seaweed farming has great potential to address these challenges. Further, under island conditions rain water harvesting, storage and its efficient use should be an integral part of the strategy for sustainable agricultural production.

Keywords: *Island agriculture, salinity, waterlogging, land shaping, seaweed*

Introduction

The pressure of increasing global population, urbanization, and demand for diversified food / essential items from agricultural sector are eventually passed on to the land. At the same time land resources are also facing the consequences of global climate change. Together these two causes greatly impact the land resources particularly in the coastal areas. Soil salinity is wide spread and is one of the most important effects of land degradation. It is estimated to affect 10% of the world land surface (Szabolcs, 1989). Increased salinization of arable land is expected to have devastating global effects, resulting in 30% land losses within the next 25 years and upto 50% by the year 2050 in the absence of appropriate measures (FAO, 2004). Even though these changes are occurring at global level it poses serious threats to small islands and island nations. On the other hand in a quest to meet the food requirement, indiscriminate application of agricultural inputs has increased the risk of environmental degradation (Lal, 2004). The cause of such degradation is mainly regional, but the effects are globally manifested.

On the other hand, the climate regimes of small islands are dominantly influenced by maritime conditions, land form, physical extent, and geographical locations. Intensive monsoon rainfall, sea water intrusion, and high evaporation during dry season are primarily responsible for waterlogging and salinity, particularly in the coastal lowlands (Rasel *et al*., 2013) of Andaman and Nicobar Islands. Consequently in those areas agriculture will face the challenge of having to do with limited water at times with poorer quality and have to use saline or acid-saline soils. Under such situations it is highly desirable to use the land according to its production potential with required level of inputs and enhance the productivity and diversity by technological innovations. Different aquacultural practices suitable for the coastal regions and land shaping methods can help to improve the farm production, enhance its diversity and address land degradation as well (Velmurugan et al., 2014). Therefore some of the most prudent crop + aquaculture methods and technologies suitable for tropical island conditions to deal with waterlogging, salinity and climate change are discussed in this study.

The coastal concern

Physiography and soils

The topography of Andaman and Nicobar islands is rolling with low range hills to narrow valleys at the foothills forming undulating terrain ranging from steep slopes (>45°) to plains (<5°). The soils are formed by the dominant influence of climate and vegetation. Soils are medium to deep, red loamy including marine alluvium derived soils along the coast. They qualify for the Great Groups of **Hapludalfs, Dystropepts, Eutropepts** and **Sulfaquents** (along the coast). The soils have low to medium available water holding capacity, slightly to strongly acidic in nature and are moderate to low (40-70%) in base saturation. Seasonal salinity (4.0 – 5.9 dSm^{-1}) along with acidity (pH 4.8 – 5.4) is the major constraint for crop production (Singh and Mongia, 1985).

Land use

Forest covers nearly 86% of the total geographical area of 8249 km^2, agriculture and other land uses accounts for the remaining area. Agriculture is dominated by plantation crops in the hill slopes followed by rice in the valley and coastal plains wherein soil and climate play a major role in limiting rice productivity. Coconut and arecanut grown mostly in the side slopes of longitudinal hills alone accounts for 53% of cultivated area followed by oil palm and rubber grown in the undulating terrain. Pulses are mostly grown in North Andaman after the harvest of rice while vegetables are predominantly grown relatively in elevated lands in North and Middle Andaman Islands. After tsunami the coastal areas become waterlogged and rice could not be cultivated due to salinity which reduced the overall agricultural production (Velmurugan et al., 2014).

Climate change

The term climate change means “any significant in the statistical distribution of weather patterns over periods ranging from decades to millions of years”. Climate change may be limited to a specific region or may occur across the whole Earth. If the weather parameters show year-to-year variations or cyclic trend, it is known as climate variability (IPCC, 2001). The most important factor affecting the coastal and island region is the sea level rise. Lowlying or areas within 1-2 m elevation from the mean sea level are highly vulnerable. The changes and its impact on tropical islands have emerged as an important issue in sustaining island agriculture.

The need for sustainable production technology

The emerging situation in population explosion in many of the small islands and island nations are posing major challenge in terms of demand for food and other products. In Andaman and Nicobar Islands the demands for cereals and vegetables is projected to increase by one third and that for pulses, milk and animal products by 60% within the next two decades. Presently 2/3rd of rice comes from mainland India to meet the demand. The production statistics indicates that additional agricultural land is needed to meet the growing demand for food grains, vegetables, and fruits. In all likelihood, it is improbable in the near future primarily due to the government regulations and limited geographical extent of islands. The challenge can be partly addressed by increasing the productivity of agriculture while the remaining gap between demand and supply has to be met through supply from mainland India which may not be sustainable in long-run (Srivastava and Ambast, 2009).

There is also a perennial problem of waterlogging and salinity in the coastal areas which impose severe limitation on crop production though they peak at different seasons. The situation is no better in the hilly and uplands where leaching of soluble salts due to heavy rain leads to the development of soil acidity. In saline and water logged coastal areas, traditional long duration rice varieties are grown with limited management practices resulting in low productivity while lack of technological implementation hampers fruits and vegetable production. Meanwhile the demand for land to meet the developmental needs also growing which exerts pressure on agricultural land use. More particularly after 2004 Indian Ocean tsunami the pressure created by increasing population and tourism sector for safer sites is alarmingly rising.

One way of solving the food crisis in tropical islands require determined efforts to reduce the demand gap by evolving and practicing efficient and judicious methods from the existing land resources. But due to geographical limitations it is difficult to go for input intensive agriculture and the geographical location and extent don't allow the construction of large scale reservoirs. The other possibility lies in the reclamation of marginal and degraded lands to explore its suitability for annual crops in addition to phased conversion of existing plantation area into high density plantations (Table 1). Cropping intensity can be increased through appropriate intercropping and crop rotations with in the opportunity provided by the climatic window.

Presently the agro-ecosystem conditions of tropical islands are normally witnessed in the form of low cropping intensity and production besides monocropping of rice with poor agricultural diversification which is inadequate to ensure livelihood security. All such conditions and projection certainly demands innovative technologies to sustain the agriculture production in Andaman and Nicobar islands and elsewhere in the tropical islands.

Table 1. Area under agriculture and problem soils in some of the Indian Ocean Islands

Sl.No	Island / Island developing states	Land area (Km^2)	% area under agriculture	% of waterlogged / saline soils to agriculture area*
1	Sri Lanka	65610	43	3
2	Andaman & Nicobar Islands	8249	6	6
3	Mauritius	2030	43	6
4	Seychelles	460	6.5	11
5	Maldives	298	23	7
6	Lakshadweep	32	75	8

* Erosion not included (Data compiled from faostat.fao.org, www.worldbank.org & GOI reports)

Evaluation of technologies for coastal degraded land

Although salinity has adversely affected agriculture for thousands of years, the recognition that salt-affected land can be used for agriculture has slowly evolved along with the ecological problems associated with intensive cultivation. At the same time climate change and associated events have fast becoming a serious concern to cope with for the small islands. Consequently island conditions certainly demands specific methods and technologies to enhance and sustain the agricultural production. Development of aquaculture centric farming is an ideal option to utilize these areas for productive purpose. To be successful, this requires some special land manipulation techniques / land shaping methods to bring them under agro-aquacultural use. Some of the land shaping techniques suitable for Island and coastal lowlands are broad bed and furrow system, rice-cum-fish and farm ponds (Ambast *et al*., 2011).

Paddy cum fish system (P-F System)

In the coastal areas integrating aquaculture with agriculture by paddy cum fish system assures higher productivity and year round employment opportunities for farmers. Trenches of 3-4 m width and 1.5 m depth are dug around the rice field of suitable dimension. The excavated soil is used to raise the embankment all around the field to make the system (Fig. 1). The bunds built strong enough to make up the height to withstand high rainfall and runoff due to geographical and topographical conditions of the paddy field. During the rainy season the central land is used for paddy cultivation followed by vegetables during dry season. Bunds are used for year around vegetable cultivation due to the availability of fresh water. Fresh water fishes such as grass carp, catla, rogue, mirgal can be grown using the stored water in the trenches. The plots utilised for rice cum fish system is mainly based on organic fertilization with a varieties of animals excreta such as poultry dropping, pig excreta, cow dung and plants residues. Rice-fish systems enabled a higher cropping intensity (200%), increased fish production (1.5 t ha^{-1}), water productivity (42.2 Rs m^{-3}) and enhanced net return (Rs. 196500).

Farm pond with broader dykes

Farm ponds, as one of the suitable options of land shaping, form the centre of integrated farming system. It stores *in-situ* rainfall or harvest surface runoff from surrounding areas depending upon the available rainfall in a region. In high rainfall areas, like A&N Islands where average annual rainfall is about 3100 mm, even *in-situ* rainwater storage in farm pond serves the purpose (Fig. 2). Gupta et al., (2006) suggested that excess rainwater available during May to December should be stored *in situ* in the dugout farm ponds to provide supplemental irrigation during dry season. Apart from polyculture of IMC, fresh water prawn can also be grown. The fresh water prawn *Macrobrachium rosenbergii* is known for its fast growth, stress tolerance and high market values. But institutional support is very essential for breeding and seed production of fresh water prawns to sustain its production. The broader dykes and availability of fresh water favour year around cultivation of vegetables which increased the cropping intensity (190%).

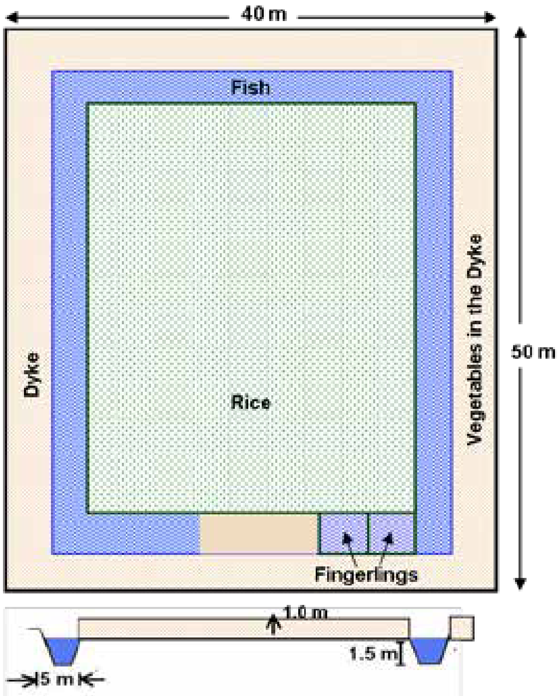

Fig. 1 Paddy-fish system

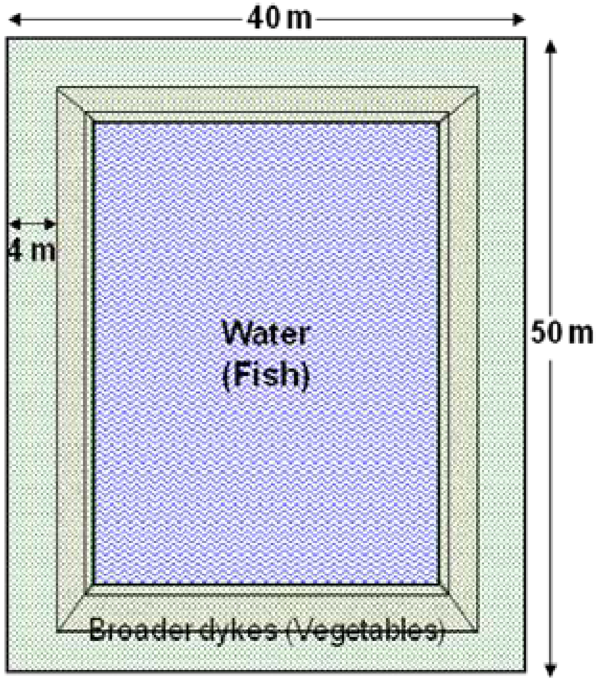

Fig. 2 Farm pond with broader dykes

Raised beds and furrow system

Construction of raised beds and furrow involved excavation of deep furrows alternated with raised beds by using the excavated soils in the same sequence as it existed in natural horizons. The raised beds system installed in the low lying waterlogged areas improved the drainage of the beds, harvested rain water (4476 m^3 ha^{-1}), prevented entry of tidal and runoff water into the furrow, and reduced the overall salinity (Table 2). Whereas the low lying areas were inundated during the monsoon season by 25 to 85 cm of water, soils under raised bed systems were adequately drained and had moisture content between field capacity and the saturation level. The depth of submergence (R^2 = 0.798) and soil salinity (R^2 = - 0.787) were correlated with the rainfall amount. Consequently, the BBF systems enabled a higher cropping intensity (218%), increased fish production (2.32 Mg ha^{-1}), water productivity (47.36 Rs m^{-3}) and enhanced employment generation (213 man days).

Table 2: Effect of crop + aquaculture intervention on productivity parameters

Interventions	Cropping intensity (%)	Fish productivity t/ha	Water productivity Rs/m³	Net Income Rs.
Raised bed system in saline water logged soil	220.0(5.66)[a]	1.3 (0.04)[b]	47.36	206600
Farm pond with broader dykes in Acid saline soil	190.0 (3.72)[c]	1.1(0.05)[c]	35.74	157800
Paddy fish cultivation	200.0 (2.50)[b]	1.5 (0.02)[a]	42.2	196500
Degraded land-Farmers practice	90.0(3.16)[d]	0.15(0.02)[d]	0.0	22000

Mean values, n=10; SE in parentheses; different letters within one column indicate a significant difference at $p<0.05$

Mud crab fattening

Another option available for using the coastal lowland is in the form of mud crab fattening in mangrove ecosystem as they are widely found in these Islands. Juvenile crabs can be collected from estuaries, lakes, back waters, creeks, mangroves and grown in grow out ponds constructed in tide fed estuaries, backwaters and creeks. The crab ponds can also be constructed by converting one portion of existing fish ponds and providing provision for brackish water inundation into that area. A pond of 0.1 ha area can be used for mud crab culture. With the stocking density of 500 numbers ha^{-1} of 50-60 g size crab for a period of six months production of about 780 kg/ ha can be achieved (Dam Roy *et al*., 2008).

Sea weed cultivation

Seaweed farming is the practice of cultivating and harvesting seaweed which is largely carried out as a diversification activity in mariculture. Many of the rocky beaches, mudflats, estuaries, coral reefs and lagoons of Andaman and Nicobar islands provide ideal habitats for the growth of seaweeds. Seaweeds refer to any large marine benthic algae that are multicellular, macrothallic, and thus differentiated from most algae that are of microscopic size (Smith, 1944). They form an important renewable resource in the marine environment as evidenced from its annual production of about 7.0 – 8.0 million tons of wet seaweed along the coastal regions of the world (McHugh, 2003).

Seaweeds belonging to different genera are mainly used for edible and industrial purposes all over the world. The edible seaweed are algae that can be eaten and used in the preparation of food that belong to one of several groups of multicellular algae viz., red algae, green algae, and brown algae. Alternatively seaweeds are also harvested or cultivated for the industrial extraction of alginate, agar and carrageenan substances collectively known as hydrocolloids or phycocolloids. Hydrocolloids have attained commercial significance, especially in food production as food additives. The food industry exploits the gelling, water-retention, emulsifying and other physical properties of these hydrocolloids. In India seaweeds are used as raw materials for the production of agar, aliginate and liquid seaweed fertilizers (NAAS, 2003). The sources of such materials are presented in table 3.

Attempts were made in the past to determine specifically, the alginophytes and agarophytes at their place of abundance, keeping in mind their economic importance (Thivy, 1960). Table 4 provides the summary of different types and standing stocks occurring in India. In all, 271 genera and 1153 species of marine algae, including forms and varieties have been enumerated till date from the Indian waters (Anonymous, 2005). But, India presently harvests only 2.5 % of macro-algae annually compared to a potential harvest of 870,000 tonnes, thus lot of scope for harnessing the unutilized seaweed potential. However, estimates presented here may not give a accurate picture of the standing crop available at present, since most of the surveys were conducted at different times by different methods during the past 20 years from 1971 to 1991 (Subba Rao and Mantri, 2006).

Table 3. Different types of marine algae cultivated in India and their use

Sl. No	Type of algae	Scientific name	Cultivation method	Use
1	Red algae	*Gracilaria edulis, G. crassa, G. foliifera and G. verrucosa*	Long-line ropes and nets by vegetative propagation	Agar manufacturing
		Gracilaria edulis	Single Rope Floating Raft Technique	hydrocolloids
		Gelidiella acerosa	Bottom-culture method using coral stone as a substratum	hydrocolloids
		Kappaphycus alvarezii,	net bag and raft method	Carrageenan and as food
2	Brown algae	*Sargassum spp., Turbinaria spp., and Cystoseira trinodis*	Collection and using nets	Production of alginates and liquid seaweed fertilizers

Table 4. Standing stalks of seaweed and species composition along the Indian coast and Islands

S. No.	Location	Standing stalk as fresh weight (tons)	Species composition			
			Green	Brown	Red	BG
1	South Andaman	19111 (40 km^2 area)	29	15	11	Nil
2	North & Middle Andaman	6817 (25 km^2 area)	11	11	5	Nil
3	Little Andaman	120	7	6	5	Nil
4	Nicobar	7315	18	15	18	Nil
5	Lakshadweep	4955 - 10077	33	10	39	Nil
6	All India	6,77,000 to 6,83,000	340	211	470	10

In Lakshadweep the estimated potential (fresh weight) ranged from 4955 to 10,077 tons with an average value of 7519 tons (Anonymous, 1979). The Andaman and Nicobar Islands have been partly surveyed by Central Marine Fisheries Research Institute, Cochin and the highest standing crop of 19,111 tons (fresh weight) was estimated for an area of 40 km^2 in South Andaman. The total potential of the islands stands at 33363 tons but the level of exploitation is negligible due to policy issues and infrastructural inadequacy (Gopinathan and Panigrahy, 1983). Among them Green algae followed by Red algae constitute the major species composition. Recently, natural incidence of *Kappaphycus alvarezii* has been reported from Andaman Islands. Ecological studies have been undertaken regarding the cultivation of the species and no adverse effects to the ecosystem by the species have been reported. Therefore, large-scale cultivation of *Kappaphycus alvarezii* can be undertaken in Andaman Islands.

The island offers suitable marine environment for the commercial cultivation of red algae but it is desirable to reduce the bulkiness by preprocessing before sending it to the mainland industries. It is also wise to promote integrated cultivation of shrimps and seaweeds in aquaculture as seaweeds act as scrubbers in reducing nutrient load and cleaning the environment. To utilize seaweed recourses in a sustainable manner, conservation as well as proper husbanding of these resources is a prerequisite. Planned promotion of diversified uses of seaweeds as feed, fodder, feed additives, fertilisers, biocides and antimicrobials will ensure sustained market for seaweeds and provide alternate livelihood to those living in waterlogged-saline areas in Andaman and Nicobar islands.

Conclusions

Waterlogging and salinity in the island eco-regions are recognized as major constraints to agricultural production. Climate change is inevitable and being experienced across the globe but, the vulnerability of different places varies based on different factors. The small islands and small island developing states are more vulnerable to the perceived climate change. Therefore, agriculture should move towards more water efficient, saline tolerant and climate resilient crops and measures in these islands. Crop + aquaculture practices along with land shaping are a viable option to restore the land productivity and enhance the net income in the coastal degraded lands. In other words, combining specific reclamation measures suitable to practice aquaculture with proper soil, water, and crop management practices should break the stagnant agricultural production barrier now experienced under island condition.

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