# Significance of agro-forestry system for island ecosystem

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## Abstract

The tropical islands are increasingly being affected by resource degradation and climate change posing serious challenge to the sustainability of the region and livelihood of the people. Trees play a predominant role in protecting and sustaining the productivity of coastal and island eco-regions either by agroforestry or as mangrove ecosystem. Agroforestry system involves the conscious and deliberate use of land for the concurrent production of agricultural crops including tree crops and shrubs/vines. There are different agroforestry models suitable for the region even in waterlogged and degraded areas. Mangroves are also important to coastal and island regions for a variety of reasons, including aquaculture, agriculture, forestry, protection against shoreline erosion, as a source of fire-wood and building material, and other local subsistence use.

**Keywords**: Tropical Island, tree species, land degradation, conservation, livelihood

## Introduction

The burgeoning population and climate change have emerged as a seriously challenge to the survival and sustainability of several tropical islands resulting in natural disasters, natural resource degradation, poverty, loss of traditional culture and the detrimental effects of invasive species (IPCC, 2007). The irreversible loss of biodiversity (CBD, 2006) and other adverse impacts necessitate identification of strategies of sustainable utilization and enhancing resilience against climate change. In the Indian tropical islands of Andaman and Nicobar, around 15% of cultivated land lies within the coastal low-lying ecosystems with elevation of <20 m above mean sea level. These regions face twin problems of water logging during monsoon season and water scarcity for irrigation during the post-monsoon season (Velmurugan et al., 2016). Soils are prone to poor drainage, acid/saline conditions caused by rapid salt imbalance, and sea water intrusion during the periods of high tide (Velmurugan et al., 2014a).

The coastal region is generally mono-cropped with rice (Oryza sativa), and have low productivity with severe consequences to the livelihood of coastal population. Further, the December 2004 Indian Ocean tsunami severely impacted coastal regions of Indian Ocean, and highlighted vulnerability to extreme events (Willroth et al., 2012). Therefore, adoption of appropriate land management strategy is essential to manage land and water resources of the region also of those prone to sea level rise in a changing climate (Cruz et al., 2007). Land shaping methods are proposed as a viable option for agricultural area affected by salinity and waterlogging (Velmurugan et al., 2015a, b). In this context, tree species in agroforestry or mangrove ecosystem play a predominant role in protecting and sustaining the productivity of island eco-regions. In this article we provide some insight into how different tree species can be used to address this challenge through different agroforestry systems.

## Agroforestry models for island eco-region

Agroforestry is a collective name for a land-use system and technology whereby woody perennials are deliberately used on the same land management unit as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. In an agroforestry system there are both ecological and economical interactions between various components (Lundgren and Raintree, 1983). Based on the nature of components, agroforestry systems can be classified into agri-silvicultural systems, silvipastoral systems and Agrisilvipastoral systems.

Although these systems are conceptually well distinguished but in island ecosystem they often exist in interspersed form. They are more valuable in maintaining the agro-ecosystem balance and adaptable in problem soils as in the case of waterlogged or saline soils than any other cultivated plants. Based on the purpose and land conditions suitable system is selected but more often agri-silvicultural system is practised. This is known to enhance farm income and provides ecological services (Dagar, 1995). Some of the tree species suitable for problem soils grown under different agroforestry models are given in table 1. The details are described in the following sections.

## Multipurpose tree species garden

It is most important agroforestry model, practised by the tribals in Nicobar Islands, in which various kinds of tree species are grown mixed without any specific design. The major function of this system is production of food, fodder and wood products for home consumption and commercial purpose. Major woody species used in this system are *Areca catechu, Phoenix dactilifera, Artocarpus spp., Cocos nucifera, Mangifera indica, Syzygium aromaticum* etc. In Nicobar Islands fruit trees are included in the multipurpose tree gardens which are mostly evergreen or moist deciduous type (Fig. 1). This is practised as rainfed systems in undulated inland terrain and in coastal areas. Unlike annual crops majority of the tree species included in the model can be grown even in saline areas with little care. The system is much more stable than growing only annual crops but it lacks specialization.

**Fig. 1 Multipurpose tree garden in the tribal areas of Car Nicobar, India**

Coconut as a base crop provides lots of organic wastes which can be composted effectively and recycled to supply plant nutrients and improve the soil conditions (Swarnam and Velmurugan, 2014). This also helps in organic matter addition and water conservation which sustain the production system.

## Agri-silvi-pastoral system

Another important agroforestry measure suitable for island conditions is growing multipurpose tree species along with grasses or seasonal crops. The climatic conditions and physiography of Andaman and Nicobar and other tropical Islands offer ample scope for growing fodder trees, shrubs and grasses together in silvipastoral system with appropriate silvicultural management (Jaisankar et al., 2014). Silvopastoralism is one such agroforestry practice that intentionally integrates trees, forage crops, and livestock into a structural practice of planned interactions (Clason and Sharrow, 2000). The primary role of this system is production of green fodder to support the livestock production on a sustainable basis without much constraint on soil resources and environmental degradation. Some of the suitable multipurpose trees employed in agroforestry are *Leucaena leucocephala, Acacia albida, Cassia siamea, Casuarina equisetifolia, Azadirachta indica, Acacia Senegal and Cocos nucifera*. Apart from this some of the tree species like *Tamarix, Prosopis, Salvadora, Acacia farnesiana, Casuarina (glauca, obesa, equiselifolia), Acacia tortilis, A. nilotica, Pongamia pinnata, Albizia lebbeck, Ziziphus mauritiana, Parkinsonia aculeata etc.* can also be grown in saline soils (Dagar, 1995). This system also supports organic farming in the island, by enriching the soil with organic matter, nutrients and providing space to accommodate spice crops (Velmurugan et al., 2014b).

## Tree borne oil seeds

It was observed that Andaman and Nicobar Islands have wide diversity of tree borne oil seeds (TBO's) with high oil content and adaptability to marginal and coastal areas. A study conducted in these islands revealed that Jatropha is one of the most important species which are widely distributed with varying amount of oil viz., *J. curcas* (37 %), *J. gossypifolia* (40 %) and *J. podagrica*

(35 %). Apart from this, *Aphanomixis polystachya* (38 %), *Calophyllum inophyllum* (51 %), *Pongamia pinnata* (36 %), *Sapium baccatum* (49 %) and *Simaruba glauca* (53 %) were other potential oil yielding TBO's (Jaisankar *et al*., 2015). In Nicobar group of Islands *Calophyllum soulattri (49%)* was identified as a potential TBO which are traditionally used by the tribals. There is a wide biodiversity of these TBO's which has the potential to be exploited commercially grown on saline, and other degraded lands in a mixed stand or along with shelter belts in an island ecosystem.

**Table 1: Suitable trees and grasses for various problem sites**

| Strees condition | Suitable trees/ shrubs | Grasses |
|---|---|---|
| Deep sandy soils | *Acacia aneura, A. tortilis, Ailanthus excels, Albizia lebbeck, Azadirachta indica, Cassia siamea, Eucalyptus camaldulensis, E. melanophloia, E. terminalis,* | *Cenchrus ciliaris, Dichanthium annulatum and Panicum antidotale* |
| Sandy and rocky | *Acacia. senegal, A. tortilis, Agave spp. Azadirachta indica, Butea monosperma, Cassia siamea, P. chilensis* | *Cenchrus ciliaris, C. setigerus* |
| Very High salinity (Ece > 35 dS/m | *Hibiscus Pongamia pinnata, Desmodium umbellatum, Barringtonia asiatica, Manilkara littoralis* | |
| High salt tolerant (Ece 25-35) | *Casuarina, Thespesia populnea and Cocos nucifera (on specific sites)* | |
| Tolerant (Ece 15-25) | *Casuarina sp., , Pongamia pinnata, Eucalyptus camaldulensis, Albizia lebbeck, Ziziphus mauritiana, Parkinsonia aculeata* | |
| Moderately tolerant (Ece 10-15) | *Casuarina Azadirachta indica, Dendrocalamus strictus, Butea monosperma, Leucaena leucocephala, Tamarindus indica, Balanites roxburghii,* | |

## Alley Cropping (Hedgerow Intercropping)

Alley cropping, which is typically regarded as the inter-cropping of trees and crops simultaneously, are mostly characterized by systems which inter-crop valuable nut and hardwood trees with cash crops using widely spaced rows between trees for planting crops. Some of them are given in the table 2.

**Table 2: Tree species and Crops suitable for Agroforestry system**

| State | Tree crop | Associated agricultural crops |
|---|---|---|
| Mainland (India) | *Anacardium occidentale (Cashew)* | Hill paddy, groundnut, sweet potato |
| | *Tectona grandis*<br>*Bombax ceiba*<br>*Eucalyptus spp.* | Paddy, tapioca, ginger, turmeric |
| | *Tectona grandis, Bamboo*<br>*Santalum album*<br>*Tamarindus indica*<br>*Acacia nilotica* | Millet, pulses, groundnut, cotton |

| | | |
|---|---|---|
| | *Acacia mearnsii* | |
| | *Ceiba pentandra* | |
| | *Cashew, Rubber* | |
| Andaman and Nicobar | *Pterocarpus dalbergioides* | Paddy, Vegetables and Tuber crops |
| Islands | Coconut | Pineapple, Amaranthus, tubers |
| | Arecanut | |
| | *Gliricedia sepium* | |
| | Jack fruit | |

It consisting of closer spaced tree rows typically planted with fast growing multipurpose trees which are often nitrogen fixing and provide secondary products such as fodder, fuel wood or mulch (Fig. 2). Furthermore, the deep roots of trees appear to minimize below-ground competition with crops, enabling these systems to be agro-ecologically sound and economically viable. Compared to conventional mono-cropping systems, alley cropping systems may prove to be more sustainable and profitable. Alley cropping practices appear to be a rational alternative land use for improving agricultural sustainability while at the same time being economically viable.


**Fig. 2: Maize is grown in the alley formed by Gliricidia**

## Bio-shield along the coastal areas

Coastal vegetation has been widely recognized as a natural barrier for reducing the energy of storm surges and tsunami waves. After studying the impact of tsunami on coastal communities Kathiresan and Rajendran (2005) concluded that the presence of mangroves reduced the human death toll along the Tamil Nadu coast of southeast India. Guebas *et al*., (2005) showed by cluster analysis that the man-made structures located directly behind the most extensive mangroves were less damaged. Field surveys in Sri Lanka and Thailand after the Indian Ocean tsunami of 2004 showed that older *casurina* belts on the coast withstood the tsunami but failed to provide good protection because tree growth, forest type and density have significant effect on reducing the tsunami wave impact. Pandanus having wide diversity is also very much suitable in the coastal and island region as bioshield component (Jaisankar et al., 2020). The evidences suggest that vegetation barrier alone cannot completely stop a tsunami or storm surge and its effectiveness depends on the magnitude of the storm surge as well as the structure of the vegetation (Tanaka *et al*., 2007).

Based on the field level evaluation mangrove based vegetation barrier in the coastal area is proposed by several researchers as a best bioshield model against the sea surges and like events. The crown and stem of mangroves serve as physical barriers while the entangled root masses of mangroves dissipate the wave energy and guard the coastlines. Hence this is often referred to as bioshield or natural sea defense (Fig. 3). The specialized roots of mangroves trap and hold sediments and siltation from the uplands. Mangroves played a protective role in saving the lives of coastal dwellers in Andaman Islands by taking the brunt of destructive waves during the giant tsunami waves which struck the Indian Ocean region in 2004. Much of the ecological services of mangroves lie in protecting the coast from solar UV-B radiation, fury of cyclones, sea level rise, coastal erosion and other natural threats in the coastline. The bioshield also minimizes the effect of sea water intrusion and erosion in the agricultural land located behind the shield. Therefore, establishment of mangrove based shield in the sea front of the coastal and islands should be an ideal choice to protect them from sea surges and tsunami like incidents in the future.


**Fig. 3. Bio-shield protects against the sea surges and storms**

## Biodrainage

Introduction of canal irrigation without provision of adequate drainage causes rise in ground water table leading to waterlogging due to seepage and secondary salinization. In India, the total degraded land due to waterlogging is 6.41 M ha. As sub-surface drainage is costly and disposal of effluents has inherited environmental problems, a viable alternative is biodrainage, which is 'pumping of excess soil water by deep-rooted plants using bioenergy'. The impact of block plantations of *Eucalyptus tereticornis* was tested and found effective in reducing the ground water level. In an experiment it was observed that the ground water table underneath the strip plantations was 0.85m during a period of 3 years and it reached below 2m after 5 years. The average above ground oven dry biomass of 5 ½ years old strip plantation was 99.9 kg tree$^{-1}$ resulting in 24.0 t ha$^{-1}$ above ground biomass of 240 surviving trees. The average below ground oven dry biomass of roots was 8.9t ha$^{-1}$ and the total oven dry biomass was 32.6t ha$^{-1}$. The carbon in the oven dry biomass was 15.5t ha$^{-1}$. The average transpiration rate (measured by sap flow) of ground water by these plantations ranged from (litres day$^{-1}$ tree$^{-1}$) 44.5 – 56.3 in May to 14.8 – 16.2 in January. The annual transpiration rate was equal to 268 mm per annum. The farmers can ear INR 72000 ha$^{-1}$ at a rotation of 5 years and 4 months resulting in a benefit-cost ratio of 3.5:1.

## Conclusion

Tree species involving agroforestry system are indispensable component of management and restoration of island region affected by land degradation. Similarly it also provides gainful employment opportunities and enhances the productivity of farm land. There is an imperative need to formulate proper restoration practices for mangrove plantation in degraded coastal areas and conservation of existing stand to protect the coast against the sea surges and tides. Fast growing species such as *Avicennia* and *Sonneratia* can be utilized to establish the mangrove stand. The management plan should include afforestation, regeneration of degraded mangrove areas, protective measures and eco-development.

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