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海岸林学会誌 (*Journal of the Japanese Society of Castal Forest*) 7 (1) : 37 −42, 2007

Types of Coastal Forests in Southern Sri Lanka and their Characteristics

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Abstract: The role of coastal forests in reducing the damage caused by the recent Indian Ocean tsunami is drawing attention. In the coastal regions of southern Sri Lanka, which was one of the affected areas, the current state of the coastal forests was ascertained through classification based on satellite photo readings with field surveys and by calculating the area ratio for each type of coastal forest. The coastal forests were divided into six types, the distribution of which differs greatly from coasts facing the open sea to the shores around lagoons. On a coast facing the open sea, natural forests characteristic of coastal areas were not found, but approximately 83ha of casuarina plantations have been established on sand dunes. Mangrove forests are characteristic of lagoon shores and do not exist on coasts facing the open sea. They occupy approximately 10% of the area within a range of 100m from the lagoon shores in this region. If coastal forests are to be used as protection against disasters, it is necessary to consider differences caused by these site conditions.

1 Introduction

On December 26, 2004, a huge earthquake of M9.0 centered off the coast of Sumatra caused a giant tsunami to surge along the shores of the Indian Ocean, resulting in enormous damage in many countries. This tsunami caused great damage, not only close to the epicenter in Indonesia and Thailand, but also more than 1400km away in Sri Lanka and India (Liu *et al.*, 2005)

It is well known in Japan that coastal forests reduce tsunami damage, and a number of functions of coastal forests in damage reduction have been classified (Ishikawa, 1992). It has been confirmed that coastal forests also reduced tsunami damage during the Indian Ocean tsunami (Danielsen *et al.*, 2006) and, prompted by this, attention has once again been drawn to the function of coastal forests in reducing damage caused by tsunamis.

Since August 2005, we have been conducting surveys of coastal regions in southern Sri Lanka that were affected by the disaster, with the aim of verifying the role of coastal forests in reducing the damage caused by tsunamis. During these surveys, it became clear that there was little basic information available regarding the coastal forests in these regions. Although there are descriptions of certain specific locations and vegetation, such as the types and characteristics of natural vegetation in national parks (Bambaradeniya, 2001) and the species composition and distribution of mangroves (Jayatissa *et al.* 2002), the current state of the region's coastal forests as a whole has not been defined.

This study aimed to ascertain the current state of southern Sri Lanka's coastal forests through classification based on satellite photo readings and field surveys and by calculating the area ratio for each type of coastal forest. In this case, the shores of lagoons were taken as coastal regions since lagoons are also saltwater areas. By analyzing the forests with a distinction made between a coast facing the open sea and the shore around lagoons, we were able to ascertain the characteristics of southern Sri Lanka's coastal forests.

2 Study area

The study area is a coastal region in southern Sri Lanka approximately 66km in length, from Tangalla (latitude 6° 00'05" North, longitude 80°46'30" East) to Kirinda (latitude 6°15'00"North, longitude 81°20'50"East) (Fig. 1). Excluding Bundala National Park and a number of lagoons, most of this region consists of inhabited areas scattered with a large number of resort hotels.

Because the region lies in a tropical monsoon climate zone, southwesterly seasonal winds blow in the summer

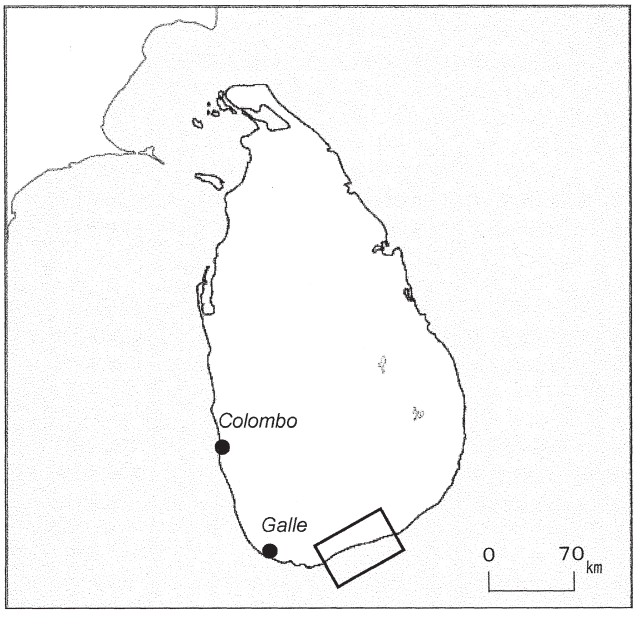

Fig. 1: Study area in southern Sri Lanka.

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and the waves are rough. There is a decrease in rainfall from the southwest coast to the southeast coast, which is a semi-arid zone with annual precipitation below 1000mm.

The coastal plain of southern Sri Lanka is formed of a terrace with lowland cutting in, and the proportion of the terrace is large. The coastline is defined by capes of bedrock: near a cape we find a rocky shore and between capes we find a sandy shore. The coastal lowlands consist of lagoons bordered by sand dunes and sand spits, swampy lowland, and areas where the natural levees of large rivers project over a lagoon or swampy lowland. There is only one beach ridge running along the present coastline, and there is no remnant of the former shoreline on the inland side.

3 Methods

3.1 Classification of vegetation and land use

QuickBird satellite imagery (DigitalGlobe Inc., taken on January 16, 2005) of the study area were purchased and, once this was deciphered, vegetation and land use maps for the study area were drawn up.

Panchromatic satellite images with a ground resolution of 0.6m were loaded into Adobe Photoshop Elements (ver. 4.0), and the contrast and brightness were set so that the satellite photos could be seen under uniform conditions. When this operation was complete, the vegetation and land use were classified on the satellite photos within a range of approximately 1km from the coastline. Multi-spectral satellite images with a ground resolution of 2.4m were also used in this classification. The ten types of vegetation and land use listed below were classified. Based on this, field surveys were carried out in August and December 2006, and the classified vegetation and land uses were fixed.

Palm forest: Palm crowns are shaped like stars, and were easily distinguished (Figs. 2 and 3).

Casuarina forest: The color of this forest zone is darker than other forests and was easily distinguished by its generally weak contrast, due to the casuarina's needle-shaped leaves. The locations determined from the satellite photos were consistent with location maps held by the Forest Department, which manages the area (Fig. 2).

Mangrove forest: Can be distinguished by its color, generally lighter than other forests, and its blurry canopy as well as by the fact that it is located at the edge of rivers or lagoons, or in wetlands. However, confirmation by field survey was necessary (Figs. 2 and 3).

Other forest: Forests other than the three above-mentioned types were difficult to classify using satellite photos and so they were grouped together. The majority is dry thorny scrubland, with arid zone forest also included.

Residential area: An area was classified as residential if town areas and housing were clustered within a certain range.

Arable land: Land used for rice paddies and cultivated fields.

Wetland: Natural vegetation such as herbaceous communities and sparse shrubs can be found here. Wetland was confirmed by field surveys.

Sand dune: Bare land along the coast that appears completely white in satellite photos. Because the photographs were taken immediately after the tsunami, the sand dunes were extended beyond their usual area.

Wasteland: Not sandy beach, but rocky beach and cliffs including saltpans.

Unknown: A small number of areas could not be made out due to clouds or their shadows. Such areas were labeled as "unknown".

3.2 Area ratios of vegetation and land use

Using the vegetation and land use maps that were drawn up, the area ratio of each vegetation and land use in the coastal region was calculated. Specifically, area ratios for the ten types of vegetation and land use were calculated for two ranges, one within a width of 100m from the coastline and the other within a width of 300m from the coastline. The area was calculated using Photoshop by measuring the number of pixels devoted to each classified vegetation and land use, and the ratio was calculated assuming the sum total to be 100.

Since lagoons are also saltwater areas, the same kind of area ratio was calculated within a width of 100m and a width of 300m from each lagoon shoreline, as distinct from the coastline.

Combining the two, the same kind of area ratio was calculated within a width of 300m from coastlines that include lagoons.

3.3 Classification of coastal forest

Some definitions of coastal forest have been proposed by Wakae (1961), Endo (1976), and Nobori *et al.* (2000). In this paper, coastal forest was defined as "a forest community formed in a region influenced by coastal seawater and sea breezes, including forest formed not only on sand dunes but also on hills and cliffs, and naturally regenerated forest, whose composition and structure frequently differs from that found inland."

Field surveys were conducted in accordance with this definition, and the coastal forest in the study area was classified according to its species composition and structure. The nomenclature used for trees was in accordance with Ashton *et al.* (1997).

4 Results

4.1 Areas of forest and land use in coastal regions

The shares of each forest and land use in the coastal region of the study area are listed in Table 1.

In coastal regions within 100m from coastline facing the open sea, sand dunes occupied approximately 70%, the residential area was small at approximately 3%, and there was no arable land at all. The total forest accounted for approximately 25%, but there was no mangrove forest whatsoever.

Within 100m of the perimeter of lagoons, sand dunes accounted for only about 4% and wetlands occupied 24%. The total forest exceeded 60%, and mangrove forest occupied approximately 10%.

Coasts facing the open sea and lagoon shores differ greatly in this way. Each can be said to have a characteristic landform and forest: on coasts facing the

open sea it is sand dunes and casuarina forests, while around lagoons it is wetlands and mangrove forests.

Of the approximately 4,000ha spread over a range of 300m from coasts and lagoons combined, 57% was forest. The majority of this was "other forest", followed by palm forest and mangrove forest. Casaurina forest occupied a mere 2% of the total.

Table 1. Share of each land use in coastal region.
Shown as ratio (%) of area of each land use to total area.

	Share (%) in each coastal region		
	100m from coastline	100m from lagoon	300m from coast and lagoon shore
Coconut plantation	6.8	5.1	6.8
Casuarina forest	4.5	0.3	2.1
Mangrove forest	0	9.8	5.2
Other forest	13.4	45.7	42.7
Residential area	3.3	6.2	9.4
Arable land	0	0.4	1.0
Wetland	0.2	23.8	11.7
Sand dune	68.5	4.2	15.5
Wasteland	3.1	1.4	2.5
Unknown	0.2	3.2	3.1
Total area	720.0ha	886.1ha	4006.5ha

4.2 Types of coastal forest

Four types of forest vegetation were distinguished using satellite photos: coconut palm forest, casuarina forest, mangrove forest, and other forest. The "other forest" was further divided into arid zone forest and dry thorny scrubland based on field surveys. In addition, because many trees were often found in residential areas, this was added as a "home garden woodland" category. Consequently, southern Sri Lanka's coastal forests were broadly divided into six types. The structure and distribution characteristics of each coastal forest type are given below.

4.2.1 Home garden woodland (Photo 1)

There is large amount of greenery all over Sri Lanka. Even in large towns, shade is provided everywhere by roadside trees and large trees on street corners. Also, in every residential area, there are many trees planted in the gardens. In the residential areas of towns in the southern coastal region, the scenery resembles a forest with houses in it. This type of forest is called yashikirin, or "homestead woodland", in Japan, but a name better suited to the forest's function and purpose would be "home orchard". This is because the trees planted are mainly fruit trees, such as coconut *(Cocos nucifera)*, mango (*Mangifera indica*), papaya (*Carica papaya*), banana (*Musa banana*), jackfruit (*Artocarpus heterophyllus*), wood apple (*Limonia acidissima*), pomegranate (*Punica granatum*), and lime (*Citrus aurantiifolia*). Most trees other than these, such as teak *(Tectona grandis)*, portia tree (*Thespesia populnea*), and neem (*Azadirachta indica*) are used for lumber, flowers or medicine.

Each home has only a few of each of these tree species, and one characteristic of a home garden woodland is that it is composed of many different tree species. Residential areas often extend close to the coastal beach line and, in places where sand dunes have not developed, these home garden woodlands were often found to be the foremost line of coastal forest.

4.2.2 Coconut palm plantation (Photo 2)

The coconut palm is indispensable in the lives of the Sri Lankan people. The fruit is widely used in drinks and food, and alcohol is made from the flowers. The leaves are used as a roofing material, ropes are made from the fibers, and the trunk is used as lumber. For this reason, coconut palms are often planted in residential areas and on hotel grounds, and there are many coconut palm plantations.

The coconut palm is generally divided into two varieties (tanbili and pol) according to its use. There is a difference in the color and size of the fruit, but otherwise, there is not much difference between the two varieties, so no distinction was made in this research.

Coconut palm forests in coastal regions were not found on unstable sand dunes, but they were frequently found as the foremost line of vegetation in areas of the coast where sand dunes have not developed.

The vegetation on the floor of the coconut palm forests is sparse. Hardly anything is growing because livestock is turned loose in the forests.

4.2.3 Casuarina forest (Photo 3)

In Sri Lanka, since the 1980s, *Casuarina equisetifolia* has been planted on coastal sand dunes as a national enterprise with the objective of protecting against sea wind. A total of 65.5ha were developed on the southern coast from 1986 to 1997, according to data from the Forest Department. But 82.6ha of plantations were identified in the satellite photos. The planting density is 2500 trees/ha (2m intervals). After planting, no thinning, pruning, or other tending work is done, so the bole height is low and it is dark inside the forest. In these dense forests there is little vegetation on the forest floor, with only the prickly pear cactus (*Opuntia dillenii*), a non-native plant, found there. However, in the gaps where the planted trees have died, tall trees such as the neem tree and shrub species such as *Dichrostachys cinerea* have encroached, and there are many areas where cactus grow thickly.

4.2.4 Mangrove forest (Photos 4 and 5)

Mangrove is the generic name for plants that grow in estuarial salt marshes in tropical and subtropical zones. Mangrove forests do not form in places that are hit directly by waves. Consequently, in Sri Lanka, with its strong seasonal winds, mangroves were not found at all on coasts facing the open sea, but were frequently found on river banks near estuaries and around lagoons.

Forest stands in which *Rhizophora mucronata* is dominant have a tree height of 3-5m, and are composed of species such as *Bruguiera gymnorrhiza*, *Avicennia marina*, *A.officinalis*, *Lumnitzera racemosa*, and *Excoecaria agallocha*. In these forests, aerial roots (stilt roots and respiratory roots) spread out, creating a unique appearance.

There are also mangrove forests composed principally

of *Sonneratia caseolaris* with tree heights over 20m. An individual tree reaching a diameter at breast height of 71cm was found growing in the forest (Photo 5). Respiratory roots are found in these forests, but there are almost no stilt roots despite the fact that these are mangrove forests.

4.2.5 Arid zone forest (Photo 6)
Within the study area, a mature natural forest could be found only in Bundala National Park. Because this region is an arid zone with little precipitation, forests with the highly stratified structure seen in tropical rainforests are not found here.

Arid zone forests are dotted with limited tall tree species, with subarbor species and shrub species occupying the spaces in between. Most of the tall trees are *Manilkara hexandra*, called "palu". As for subarbors and shrubs, there are many woody plant species with thorns, such as *Limonia acidissima*, *Salvadora persica*, and *Dichrostachys cinerea*.

4.2.6 Dry thorny scrubland (Photo 7)
A good deal of scrub forest can be found on the coast that was evidently formed after the land was disturbed by human activity and then neglected. The component trees are mainly of the above-mentioned species occupying the subarbor/shrub layer in arid zone forests, with trees such as neem and portia mixed in.

The areas surrounding lagoons are covered with thickets of mesquite (*Prosopis juliflora*), a non-native shrub species with a high salt tolerance. The floors of these thickets are often covered with prickly pear cactus, another non-native species.

4.2.7 Sand dune vegetation (Photo 8)
In addition to the six types of coastal forests mentioned so far, vegetation is commonly formed on top of sand dunes on the beach line side. Places where the subarbor species *Pandanus odoratissimus* was growing in a belt shape 2-5m in width were often found. *Scaevola taccada* and *Calotropis gigantea* were often found to be the dominant species of shrub, and *Spinifex littoreus* and *Ipomoea pesoapre* were the dominant species of herb and grass.

5 Discussion
Because the landform and vegetation of southern Sri Lanka's coastal region differ greatly between coasts facing the open sea and lagoon shores, the region is divided broadly into two parts for this examination.

5.1 Characteristics of coastal forests facing the open sea
Because strong southwesterly seasonal winds blow during the summer, many sand dunes have developed along the coast of southern Sri Lanka. Sand dunes occupy approximately 70% of the area within a range of 100m from coastline facing the open sea. The satellite photos that were deciphered were taken immediately after the tsunami, and we believe that the sand dunes had been extended slightly beyond their usual area. Even so, there is no doubt that the majority of this region's coast is sandy coast.

Natural forests characteristic of coasts, which form on this kind of sand dune were not found, even in the national park where vast natural forests remain. Under natural conditions, forests with high tree height did not form on the sand dunes, and herbs and shrubs dominated. In places within the national park where sand dunes had not developed, arid zone forests extended nearly to the coast. Bambaradeniya (2001) and Bambaradeniya *et al.* (2002) do not mention vegetation types for natural forests characteristic of coasts. For these reasons, it would appear that natural forests characteristic of coasts never existed in this region.

Because residents of a sandy coast are exposed to damage by blown sand and sea breezes, casuarina forests have been artificially planted on sand dunes in some places as protection against the wind and blown sand. However, there are only 83ha of casuarina forests, an area of less than 5% of the coastal region. This is because the forestation operation covered only state-owned land and was implemented by the Forest Department, a state organization, as the main body. The Forest Department took the damage caused by the Indian Ocean tsunami seriously and recognized the importance of casuarina forests. However, judging by the current state of affairs, plans for large-scale planting have not been made.

Most of the coastal region where humans reside consists of palm forests or residential areas. The palm is a species that has adapted to growing on the coast, possibly because it is indispensable in people's lives. For this article, home garden woodland in residential areas was considered to be a type of coastal forest. The reason was that this forest was judged to perform a sufficient number of the multifaceted functions of coastal forests. When the conservation of southern Sri Lanka's coastal region, where many people live, is considered, the application of this home garden woodland in residential areas could become an important issue.

5.2 Characteristics of coastal forest on lagoon shore
It was clearly shown in Table 1 that mangrove forests do not exist on coasts facing the open sea in southern Sri Lanka's coastal region but rather are specific to lagoon shores. Since the tsunami, it has been pointed out that mangrove forests reduced the tsunami damage (Danielsen *et al.*, 2005; Dahdouh-Guebas *et al.*, 2005). If mangrove forests are to be used as protection against such disasters, it is necessary to consider the site conditions.

Approximately half of the lagoon shore region was occupied by "other forest" (Table 1). The majority of this was dry thorny scrubland thought to have been formed after the land was disturbed by human activity and then neglected. In particular, the non-native mesquite forests that spread over a large area centered in eastern Bundala National Park are having a large impact on the region's biodiversity (Bambaradeniya *et al.*, 2002). Management of this scrub forest, including control of these mesquite forests, may be addressed in the future as a major problem.

Acknowledgements: Sincere thanks go to the Forest Department of the Government of Sri Lanka, which provided valuable data and information, and the Embassy of Japan in Sri Lanka, which provided much advice on field surveys. This research was conducted using the Discretionary Fund of the President of Yamagata University and Grant-in-Aid for Scientific Research No. 18255007.

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〔Received October 9 , 2007 Accepted December 20, 2007〕

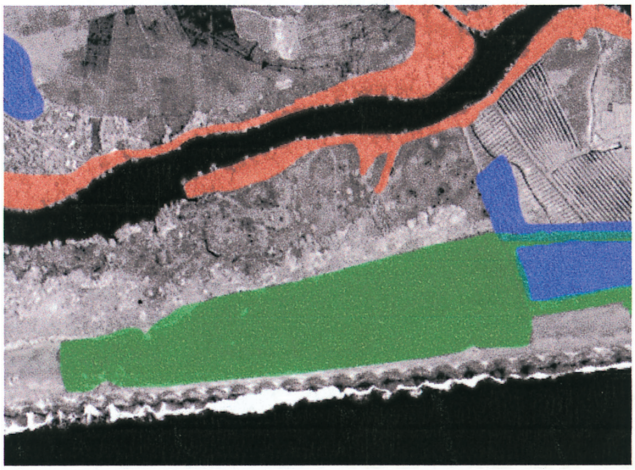

Figure 2: Distribution of casuarinas forest (green), coconut palm forest (blue), and mangrove forest (red).

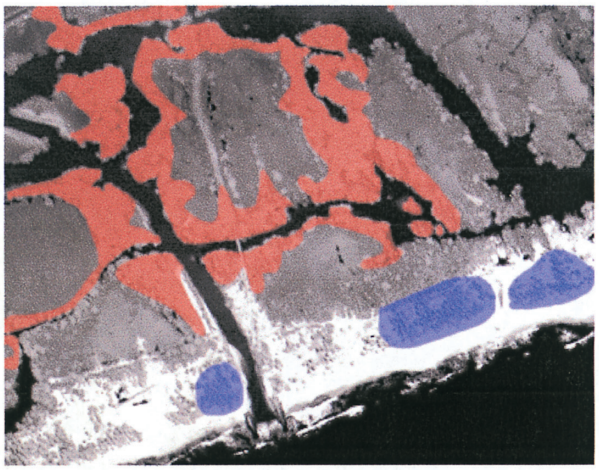

Figure 3: Distribution of coconut palm forest (blue), mangrove forest (red) and areas of denuded sand dunes by Tsunami (white).

Photo 1 : Home garden woodland

Photo 2 : Coconut palm plantation

Photo 3 : Casuarina forest on sand dune

Photo 4 : Mangrove forest around a lagoon

Photo 5 : Mangrove forest along a river

Photo 6 : Arid zone forest near the shore

Photo 7 : Dry thorny scrubland of mesquit

Photo 8 : Sand dune vegetation