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Changes of the mangrove cover of Rekawa lagoon, Sri Lanka, over a 38-year period: mitigating the significance of a surface increase

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Abstract

From an economic and ecological point of view, Rekawa lagoon is one of the most important brackish water bodies on the southern coast of Sri Lanka. The change of its floristically rich mangrove belt, over a 38-year period from 1956 to 1994, was studied using airborne remote sensing and ground surveys. The mangrove area of the lagoon has increased by 29.3% over the period concerned. Apparently this may suggest that mangrove conservation has been successful and perhaps one might claim that necessary steps should be taken to control the invasion of the land by mangroves. Paradoxically in depth analysis contrasts this view. The cause for the increase in mangrove area appears to be an increased freshwater inflow to the lagoon by recent irrigation works that have caused the water level to rise and the inundation of the low lying grassy or muddy plains by brackish water to occur more frequently, mainly at the western end of the lagoon. Actual increase of the mangrove cover is about 49.1%, but during the same period 21.2% of the previous mangrove cover has also been destroyed, leaving 29.5% increase as the net change. The disappeared mangrove area was dominated mainly by species with higher economic and ecological value, *viz. Rhizophora mucronata* and *Lumnitzera racemosa*, with closed canopies, whilst newly grown area is dominated mainly by less valuable species, *viz. Aegiceras corniculatum, Avicennia officinalis* and *Excoecaria agallocha*, with open canopies in low densities. Moreover, as revealed from the remote sensing study, the changes of crown sizes of mangrove species over the 38-year period indicate that the whole forest has been subjected to overexploitation. All these facts together led to the conclusion that ecological and economic value of mangrove vegetation of Rekawa has not increased commensurately with the spatial extent of the mangrove area over the period concerned. The need for active conservation and management measures is therefore still high.

Introduction

Mangrove lands are commonly considered as nuisance and wastelands with little or no value for man (Lugo and Snedaker 1974). Therefore, strong objections might not have arisen in the past against activities destroying mangroves such as clear felling and reclamations of these forests. The consequence is that mangrove forests worldwide are being destroyed at an alarming rate. However, with the eventual understanding of ecological and economic importance of mangrove ecosystems, now, an increasing pressure from environmental bodies urges concerned authorities for adequate conservation and management of this productive and valuable resource. In this regard, a careful assessment of changes, not only in spatial extent, but also in structure of mangrove forests over at least the last few decades, is an essential prerequisite on which to base correct management decisions.

Sri Lanka, a small island in the Indian Ocean, has about 75 riverine estuaries and 45 basin estuaries along its coastline of 1740 km (Samarakoon 1994). In contrast, the mangrove cover in Sri Lanka is estimated to be around 10,000 ha, a value far below the extent that would be expected. This smaller value of mangrove area in Sri Lanka appears to be due to the lower range of tidal fluctuation (<1 m), and then possibly because of the shrinkage of mangrove forests under anthropogenic pressure. Age old fragmentation of the mangroves in Sri Lanka by man has been recorded by De Silva and Balasubramaniam (1984). However, compared to the total area of mangroves in the country, the diversity of true mangrove species in the country is high. (Jayatissa *et al.* 2002).

Rekawa lagoon is located on the southern coast of Sri Lanka extending from latitude 6°02'24" N to 6°03'36"N and from longitude 80°48'00"E to 80°51'36"E, (Figure 1) covering a water surface area of 234 ha as calculated in this study. With respect to the species diversity of mangroves and the importance of fisheries of the lagoon, Rekawa can be considered as the most important lagoon on the southern coast. However, its mangrove area has not been assessed scientifically. Although some remote sensing work has been carried out recently to estimate the mangrove areas of some lagoons in Sri Lanka (Thomaes, 1996; Verheyden *et al.*, 2002), these investigations were limited to the evaluation of only the present status or short-term changes of the mangrove cover. Apart from the studies at Chilaw, Galle and Kalametiya lagoons (Dahdouh-Guebas *et al.* 2000, Dahdouh-Guebas 2001, Jayatissa *et al.* 2002), changes of the mangrove cover over a period of several decades have never been studied before for any of the mangrove communities in Sri Lanka.

The objectives of this study were two-fold. Firstly, an assessment of the aerial coverage and demarcation of species assemblages of the mangrove vegetation of Rekawa lagoon were made using airborne remote sensing techniques. Secondly, the forest structure of mangroves was studied and the results of remote sensing analysis were verified, based on field surveys.

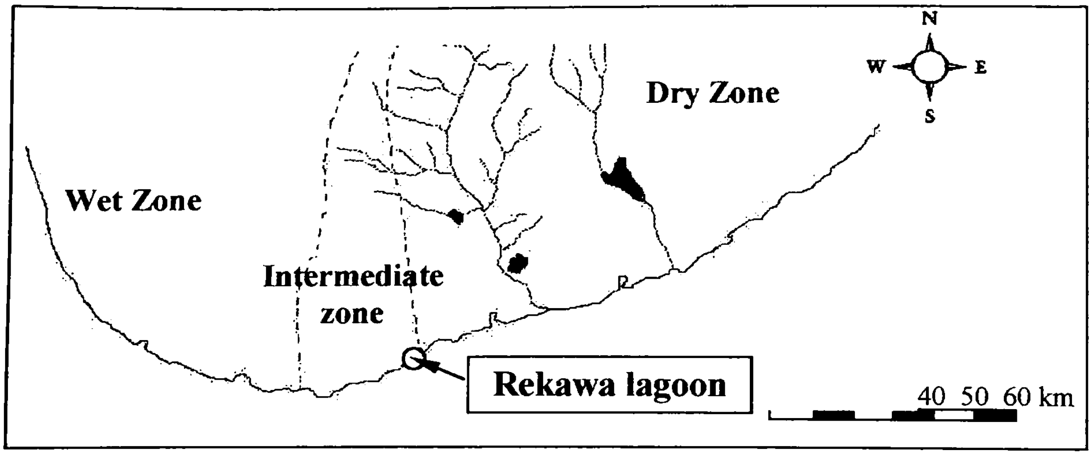

Figure 1. Map of southern Sri Lanka showing the location of Rekawa lagoon

Materials and methods

The major body of the Rekawa lagoon is long and narrow runs more or less parallel to the coast. Its western end is connected to a deeper canal that opens into the Ocean. The main freshwater inlet, also conveying inland irrigation drainage water, is connected to the deeper canal from its western side. The distal part of the freshwater inflow canal runs through a grassy muddy plain as a rather complex branching network, with a man-made opening into the Ocean, which is now permanently choked (Figure 2). Regions of the freshwater inflow canal system and the major body of the lagoon appear to be of different hydro-ecological settings. Therefore, the Rekawa lagoon system was divided subjectively into two zones (as shown in Figure 3), as the network of freshwater inflow canals (hereafter 'Zone 1') and the major body of the lagoon with the deeper canal up to the lagoon mouth (hereafter 'Zone 2'). The changes of the two zones are henceforth considered separately.

A. Remote sensing

Two sets of aerial photographs of the lagoon area, one taken in 1956 with the scale of 1:40,000 and the other taken in 1994 with the scale of 1:20,000 were used for mapping. Both sets of aerial photographs were scanned and geocoded using standard topographical maps (1:50,000 in scale) into a Geographical Information System (GIS) (Arc Info). The lagoon, mangrove area and adjoining land uses were identified by photo-interpretation and the final land cover/ land use coverage was obtained by on-screen digitizing. Differences in crown characteristics, *viz.*, tonality, texture, and structure are recognizable in aerial photographs and could be used to distinguish between different mangrove species/ species assemblages as described by Dahdouh-Guebas *et al.* (2000). The characteristics that were used to identify assemblages or species of mangroves are given in Table 1. The coverage of 1956 and that of 1994 were superimposed to obtain area statistics of changes in the mangrove cover.

Table 1. The identification key used to distinguished common species of mangroves in aerial photographs of Rekawa

Tonality	*Texture*	*Structure*	*Other attributes*	Species
Light gray	Fine grains and turbid	Discontinuous canopy	None	*Avicennia spp.*
Medium gray (or light gray)	Coarse grains	Discontinuous canopy	Can be found in a wide range of edaphic factors	*Excoecaria agallocha*
Medium gray	Coarse grains	Crowns hard to distinguish	Often at the waters edge with *Rhizophora*	*Bruguiera* spp.
Gray	Fine grains	Continuous canopy, crowns are not separately visible	Often at the waters edge. Single to 2-3 joined crowns are 'cauliflower'like	*Rhizophora* spp.
Gray (or Dark gray)	Fine grains	Discontinuous canopy	Often lower than the surrounding trees	*Aegiceras corniculatum*
Dark gray	Very fine grains	Continuous canopy with crowns hardly distinguishable	None	*Lumnitzera racemosa*
Black	Coarse grains	Continuous canopy with crowns hardly distinguishable	Not in low saline areas. Restricted to areas with seepage of sea water	*Ceriops tagal*

B. Vegetation and environmental factors

Different assemblages of species identified in aerial photograph interpretation were checked during field visits and each assemblage was sampled by transects which were established more or less perpendicular to the shore of the lagoon. Data on the species present, distance from the center to the nearest tree of each quarter, GBH, height and crown diameter of the nearest plant were recorded for individuals with GBH >13cm, along the transects at 10 m intervals, according to Point-Centered Quarter Method (PCQM), as described in Cintrón and Shaoffer-Novelli (1984). Values of relative density, relative dominance and relative frequency of each constituent species were calculated and the Importance Value (Curtis, 1959) for each species was given as the sum of the three respective parameter values.

Profile diagrams of the mangrove vegetation were prepared according to Davis and Richards (1933 and 1934) to show the physiognomy of the mangrove forest. Data on the species present, height and G130 of trees, crown diameter, distance between trees and gradient of land elevation were collected along a 1 m wide transect running landward from the water's edge.

Results

Out of the true mangroves in the world given in Tomlinson (1986), 12 species (Table 2) were recorded from Rekawa lagoon in this study in addition to over 20 species of mangrove associates. Except for *Nypa fruticans* (Thunb.) Wurmb., and *Sonneratia caseolaris* which are represented by few individuals at one locality (possibly, a recent introduction by man), all the other true mangrove species were quite common in Rekawa lagoon. Among mangrove associates, *Cynometra iripa* Costel, a rare species, and *Phoenix zeylanica* Trim., an endemic species in Sri Lanka, were present.

Table 2. The list of mangrove species recorded from Rekawa lagoon (Mangrove associates are not included)

	Species	Family
1	*Aegiceras corniculatum* (L.) Blanco	Myrsinaceae
2	*Avicennia marina* (Forsk.) Vierh	Avicenniaceae
3	*Avicennia officinalis* L.	Avicenniaceae
4	*Bruguiera gymnorhiza* (L.) Lamk	Rhizophoraceae
5	*Bruguiera sexangula* (Lour.) Poir.	Rhizophoraceae
6	*Ceriops tagal* (Perr.) C. B. Robinson	Rhizophoraceae
7	*Excoecaria agallocha* L.	Euphorbiaceae
8	*Heritiera littoralis* Dryand.	Sterculiaceae
9	*Lumnitzera racemosa* Willd	Combretaceae
10	*Nypa fruticans* (Thunb.) Wurmb.	Arecaceae
11	*Rhizophora mucronata* Lamk.	Rhizophoraceae
12	*Sonneratia caseolaris*	Sonneratiaceae

The distribution of the mangrove vegetation in Rekawa lagoon in 1956 and 38 years later, in 1994, is shown in Figure 2. As seen in the maps of 1956 and 1994, a mangrove belt with a varying width and extensive patches at some places, fringes the lagoon.

Table 3. Important values of species recorded in each assemblage, as determined by transects established across different assemblages of mangrove species. (For transect locations see Figure 2)

Mangrove species	Important values					
	Ass. 1*	Ass. 2	Ass. 3	Ass. 4	Ass. 5	Ass. 6
Aegiceras corniculatum	-	99	81	72	28	38
Avicennia marina	-	44	-	14	40	-
Avicennia officinalis	-	24	138	24	12	-
Ceriops tagal	212	-	-	-	-	-
Excoecaria agallocha	14	30	77	92	116	262
Heritiera littoralis	-	13	-	-	-	-
Lumnitzera racemosa	29	72	4	98	103	-
Rhizophora mucronata	46	18	7	-	-	-

* Ass. 1 – Mixed mangroves with *Ceriops tagal*, Ass. 2 – Mixed mangroves without *Ceriops tagal*, Ass. 3, Ass. 4 and Ass. 5 – Co-dominated by *Avicennia* spp., *E. agallocha* and *L. racemosa* Ass. 4 - Ass. 6 - Dominated by *E. agallocha*

Altogether nine assemblages of true mangrove species were observed in aerial photographs, corroborated by groundwork, and are shown in Figure 2. Importance values of species, sampled along transects established across major assemblages, were used to verify the identity of assemblages (Table 3).

Figure 3 shows the changes in mangrove vegetation obtained by overlaying the maps of 1956 and 1994 (Figure 2 top and bottom). It displays the disappeared, newly grown and unchanged areas of the mangrove vegetation at Rekawa over the 38-year period from 1956 to 1994. In certain parts of the 'unchanged' areas, the mangrove structure and species composition have changed. The overall change of the mangrove area over the period was an increase of 29.3 ha, which is 28.4% of the total cover of the mangrove vegetation in 1956 (Figure 4). However the actual increase of the mangrove cover is about 49%, (i.e. 50.5 ha), but during the same period 20.6% (i.e. 21.3 ha) of the previous mangrove cover has also been destroyed, leaving 28.4% increase as the net change.

Table 4. Changes in the extent of cover of the total mangrove and different assemblages of species of Rekawa lagoon from 1956 to 1994 as determined using aerial photographs.

Species assemblage (Dominant/ co-dominant species)	Area (ha) 1956	Area (ha) 1994	Change from 1956 to 1994
Avicennia marina	0.0	0.8	+ 0.8
Ceriops tagal	6.0	6.8	+ 0.8
Excoecaria agallocha	8.9	8.4	- 0.5
Lumnitzera racemosa	1.7	2.9	+ 1.2
Rhizophora mucronata	7.5	0.0	- 7.5
Aegiceras corniculatum, E. agallocha	4.1	4.0	- 0.1
Avicennia spp, *E. agallocha, L. racemosa*	6.6	9.5	+ 2.9
Mixed mangrove with *C. tagal*	14.8	13.3	- 1.5
Mixed mangrove without *C. tagal*	48.7	63.5	+14.8
Grassy planes + sparse mangroves	5.0	23.4	+ 18.4
TOTAL	103.3	132.6	29.3

Table 4 shows the 'assemblage-wise' partitioning of the increase or the decrease of the mangrove cover of Rekawa lagoon. It reveals that the area of increase is mainly covered by two assemblages, 'mixed mangroves without *C. tagal* and 'grassy plains with sparsely distributed mangroves'. The disappeared assemblages were mainly from 'assemblage of mixed mangroves with *C. tagal'* and 'assemblage dominated by *R. mucronata*. Although the disappeared area of the former assemblage was completely converted to a non-mangrove category (coconut plantations), that of the latter was partly converted to other two assemblages of mangroves (mixed mangroves with *C. tagal* and mixed mangroves without *C. tagal*) and to water.

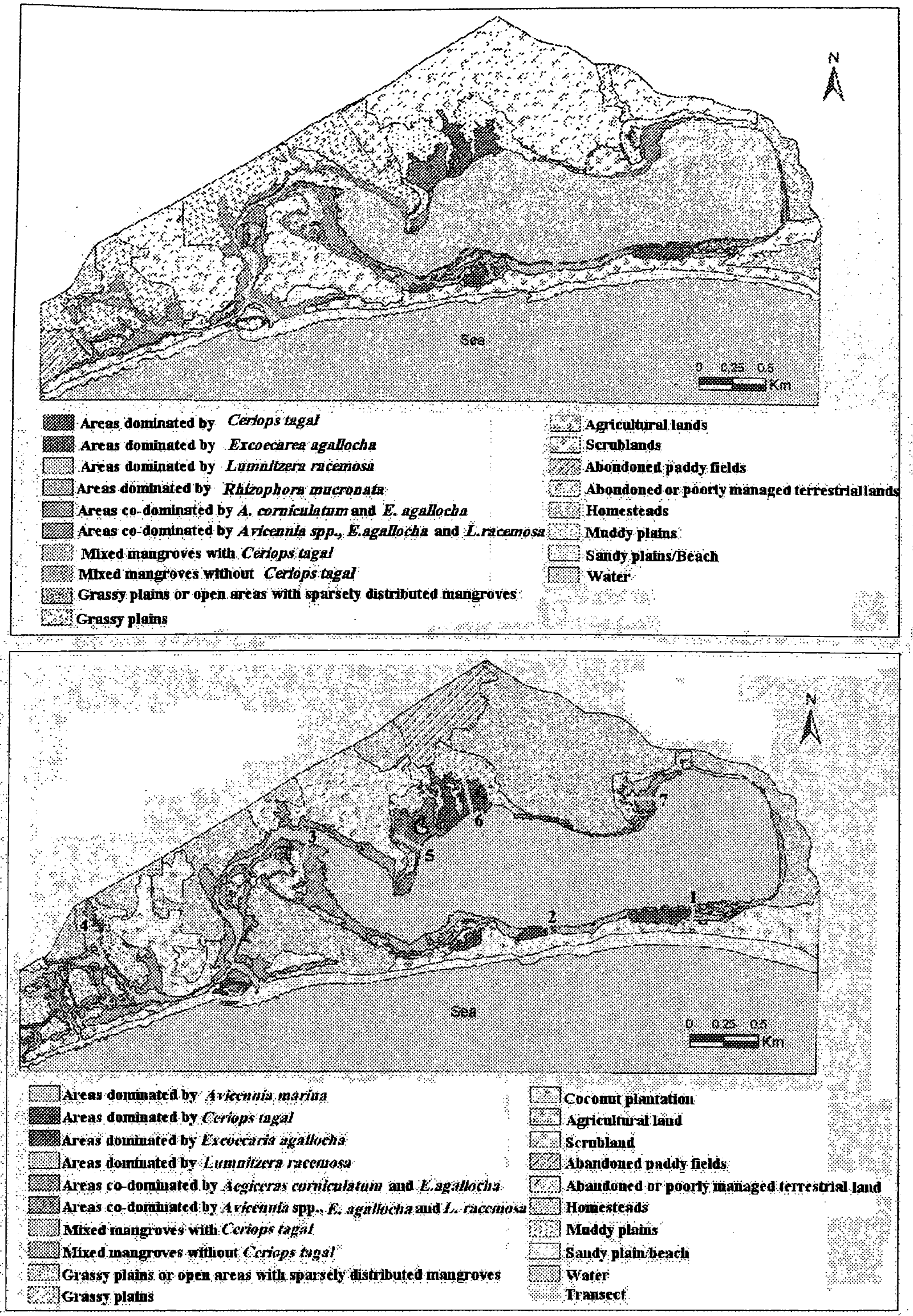

Figure 2. Map of Rekawa lagoon showing the mangrove cover in 1956 (top) and 1994 (bottom) (source – aerial photographs)

When changes of the mangrove cover over the 38-year period considered are separated into the above two zones, it reveals that more than 85% of the increase of the mangrove cover has taken place in Zone 1 (Table 5 and Figure 3).

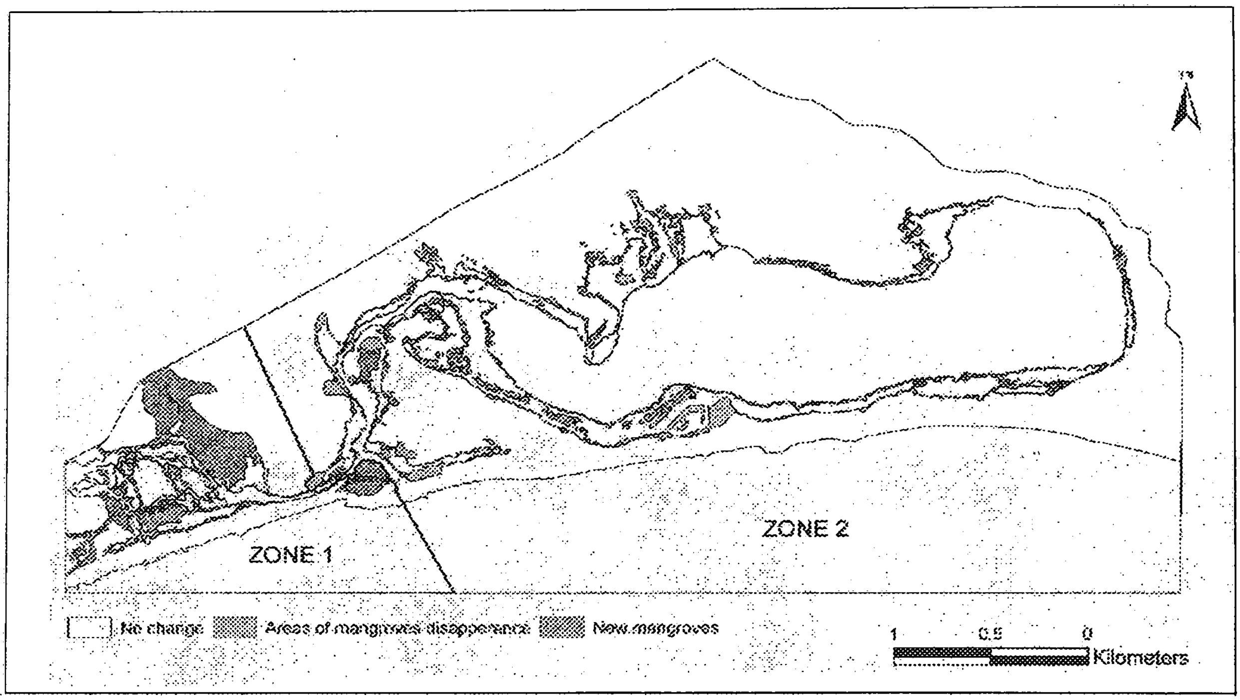

Figure 3. Map of Rekawa lagoon showing the changes of the mangrove cover, taken place during the period from 1956 to 1994 and the boundary of two geographical zones. (source – aerial photograph) **ZONE 1 – Freshwater inflow canal system, ZONE 2 – Lagoon proper**

Table 5. Changes in the extent of cover of the total mangroves and different assemblages of species in the two geographical zones (Figure 3) of Rekawa lagoon from 1956 to 1994 as determined using aerial photographs.

Cover category	Area (ha) in Zone 1			Area (ha) in Zone 2		
	1956	1994	Change	1956	1994	Change
Assemblage (Dominant/ co-dominant species)						
Avicennia marina	-	-	-	0.0	0.8	+ 0.8
Ceriops tagal	-	-	-	6.0	6.8	+ 0.8
Excoecaria agallocha	-	-	-	8.9	8.4	- 0.5
Lumnitzera racemosa	-	-	-	1.7	2.9	+ 1.2
Rhizophora mucronata	-	-	-	7.5	0.0	- 7.5
Aeigiceras corniculatum, E. agallocha	-	-	-	4.1	4.0	- 0.1
Avicennia spp., *E agallocha, L. racemosa*	-	-	-	6.6	9.5	+ 2.9
Mixed mangrove with *C. tagal*	-	-	-	14.8	13.3	- 1.5
Mixed mangrove without *C. tagal*	12.9	23.0	+ 10.1	35.7	40.5	+ 4.8
Grassy planes + sparse mangroves	-	15.2	+ 15.2	5.0	8.1	+ 3.1
TOTAL	12.9	38. 2	+25.3	90.3	94.3	+ 4.0
Water surface	8.7	12.8	+4.1	235.2	234.3	-0.9

Table 6 shows the total area of disappeared and newly grown mangroves in each of the two zones of Rekawa lagoon whilst a comparison of Figure 2 and 3 shows assemblage types of disappeared mangroves with the present land uses of those areas, as well as previous land uses of newly grown mangroves with their present assemblage types. It reveals that invasions of mangroves over the 38-year period considered has taken place on low-lying muddy or grassy plains that occurred mainly in Zone 1. Moreover, much of the areas of newly grown mangroves are dominated by three mangrove species, *A. corniculatum* (L.) Blanco, *A. officinalis* L. and *E. agallocha*(see transect 3 in Figure 2b and Table 3).

Table 6. Areas of newly grown and disappeared mangroves in each zone of the Rekawa lagoon

	Disappeared		Newly grown	
	Zone 1	Zone 2	Zone 1	Zone 2
Area (ha)	2.9	18.3	28.2	22.3
Total area (ha)	**21.2**		**50.5**	

Many assemblages were present in 'disappeared mangroves', but the highest sacrificer was from the 'assemblage dominated by *Rhizophora mucronata*' and 'mixed mangrove with *Ceriops tagal*'. These are mainly replaced by open water whereas coconut plantations and homesteads are the main invaders on other parts of disappeared mangrove areas.

The water surface area of the network of freshwater inflow canals (i.e. Zone 1) has increased by 4.1 ha from 1956 to 1994 whilst that in the major body of the lagoon (i.e. Zone 2) remained more or less unchanged.

Discussion

Rekawa lagoon has the highest number of mangrove species, which can be observed from any single estuary or lagoon on the southern coast of Sri Lanka (Jayatissa 1987, Jayatissa *et al.* 2002). Homesteads and agricultural lands encircle most of the mangrove belt suggesting a high anthropogenic pressure on it. Some studies indicate that mangrove flora of Rekawa lagoon is extensively used by the residents in the vicinity for various purposes (Jayatissa unpublished data). Moreover, it is a very important center of prawn fishery in southern Sri Lanka (Maitipe 1986). Therefore, changes of the mangrove cover can be expected and knowledge on such changes is important to assess the present status and trends of the mangrove vegetation of this lagoon.

This study reveals that the area covered by mangroves in Rekawa was 103 ha in 1956 and 132 ha in 1994 and hence it has increased by 29.3 ha over the 38-year period. With respect to the mangrove area in 1956, this overall change is a 28% increase. However, the actual increase of the mangrove cover is higher and goes up to 49.1% (50.5 ha), while during the same time period, 20.6% (21.2 ha) of the original mangrove cover in 1956, had been destroyed.

Until 1999, there were no replanting campaigns for mangroves in Rekawa. Therefore this increase should merely be spontaneous. Almost all the areas covered by newly grown mangroves were low-lying mud plains or grassy plains that could be inundated very occasionally at the highest water level. In 1956, even when the anthropogenic pressure on mangroves was very low, there were no mangroves on these areas probably because soils were dry and too hard to support seedlings of mangroves during a major part of the year. During field surveys, clay soil that becomes hard during dry periods was observed in these areas. Therefore the only possibility for new growth of mangroves is an increase of the frequency of inundation of these areas by brackish water. It could happen if the freshwater input had increased and its inflow takes place frequently throughout the year. There are evidences for that the outflow of the drainage irrigation water from upstream paddy lands has increased at the beginning of 1980s and passed to the Ocean through the lagoon. In 1983, the Road Development Authority has constructed a canal, opening the lagoon's freshwater inflow canal directly into the Ocean as a measure to facilitate the outflow of excess irrigation. The people in the vicinity including fishermen protested against that, as it affected the lagoon fishery, and therefore the maintenance of the canal mouth to the Ocean was abandoned. The consequence was the gradual formation of a sand bar that blocked the canal (see Figure 2b). Moreover it is evident on the maps of the lagoon, that the water surface area of the network of freshwater inflow canals is higher in 1994 compared to that in 1956 (see Table 5).

Mangrove forests worldwide are seriously endangered ecosystems (Fernworth and Ellison 1997). In such a context, this increase of the mangrove cover of Rekawa lagoon can be considered as remarkable positive trend. Nevertheless, some argue that invasion of land by mangrove should be controlled (Samarakoon 1994) and may use this example to support their argument. However, an in depth analysis of this increase indicates otherwise.

As observed from aerial photographs and field surveys, the increased areas of mangroves are mainly dominated by three species, *A. corniculatum, A. officinalis* and *E. agallocha.* Of these three species, *A. officinalis* is the dominant species. Naidoo (1985) has shown that *Avicennia* is ideally suited as the pioneer in mangrove assemblages. However, these three species are among the less usable species in Rekawa area (Jayatissa, unpublished data). *E. agallocha* is used occasionally as branches for 'kraals', a local fishing-gear. It is also reported as a dominant species in highly disturbed mangrove forests (Dahdouh-Guebas *et al.* 2000) giving further evidence for its lesser use. *A. officinalis* is also not extensively used as firewood or timber. It is sometimes used only for short-term purposes e.g. temporary fences, some fishing gears etc. The trees that can be recorded with largest girths in mangrove forests in these areas are always *A. officinalis* (pers. obs). *A. corniculatum* is used for several purposes but it is a bush, not a tree species. On the other hand, the destroyed mangrove areas in Rekawa, were dominated mainly by *C. tagal, L. racemosa* and *R. mucronata* which are used for many purposes and are some of the most demanded species by mangrove users in the world (Saenger *et al.* 1983). There is at present no evidence for that this assemblage of less valuable species could be a successional stage, which would lead to a climax, or another successional stage with higher value species. Moreover, it is evident from aerial photographs that destroyed mangrove areas were with closed canopies, implying that those areas were mature and/or dense forests, whilst aerial photographs, as well as ground surveys, revealed that newly grown mangrove areas are covered by less dense mangroves with smaller trees. All these facts together raise a question as whether the value of newly grown mangrove areas can compensate the value lost with disappeared mangrove areas, although newly grown areas are larger than disappeared areas. The same discrepancy between mangrove utilization and mangrove vegetation has been observed in Kenya, where mangrove forest dominated by *R. mucronata* is being replaced by *C.s tagal* dominated stands (Dahdouh-Guebas *et al.* 2000, Kairo 2001) under human exploitation pressure.

Furthermore, the increase of mangrove areas cannot be considered as evidence to maintain that mangrove vegetation of Rekawa lagoon is subjected to lower human impact. The increase of the mangrove cover itself is a result of a freshwater diversion to the lagoon and it is also a human impact. The present land use of the disappeared mangrove areas also indicates that reclamation is a major reason for those disappearances. In addition, differences in crown sizes observed in aerial photographs of 1956 and 1994 indicate that removal of larger trees from the mangrove forest has increased over the period. For all these reasons, it is now possible to assert that the value gained due to the increase in mangrove cover area cannot compensate the diminution of the value of the Rekawa mangrove forest resulted from human impacts.

Acknowledgements
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