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RESEARCH ARTICLE

Linkages between changes in land cover (use) patterns, local perceptions and livelihoods in a coastal wetland system in Sri Lanka

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Abstract: The Muthurajawela-Negombo wetland system in Sri Lanka provides critical ecosystem services for local people. The wetland has, however, undergone considerable ecological change over the past few decades. A multi-scale, inter-disciplinary approach that combined geospatial analyses with livelihoods analyses was used to assess environmental change in the wetland and the impact of this change on local livelihoods. While a geospatial model was used to determine broad changes in land use patterns in the wetland, an in-depth case study covering one village was conducted, using local perceptions to explore the inter-linkages between environmental change and livelihood systems at the household level. The findings of this study suggest that there have been significant changes in the wetland cover/use patterns during the period under investigation and that these changes have been observed and experienced by local communities. There are differences in local perceptions on whether these changes are for the better or worse. This may be linked to whether the land cover types are directly accessed and used in the household livelihood system, and to the geographic location of the land cover types in relation to the village. The findings indicate the usefulness of adopting this type of approach where both conservation and development needs are considered to address environmental concerns and related livelihood issues in wetlands.

Keywords: Coastal wetland, environment, geospatial model, livelihoods, local perceptions, socio-economic.

INTRODUCTION

Coastal ecosystems are among the most productive in the world with coastal wetlands providing many ecosystem services that contribute to human well-being, for example in terms of providing food and a source of income (Agardy & Alder, 2005). Many communities that live near coastal wetlands are highly dependent on these services and are therefore directly impacted by the degradation of the wetlands. There are many reasons for the degradation of these systems, which stem from both anthropogenic activities and natural events (WRI, 2005). In Sri Lanka, as in many other parts of the world, coastal wetland systems are being threatened at an increasing pace as a result of commercial and development activities, increasing population densities, high incidence of poverty and the over-exploitation of natural resources (Ministry of Transport, Environment & Women's Affairs, 1995; IUCN Sri Lanka, 2003).

Monitoring the changes occurring in a wetland is critical to understand its structure, functionality, environmental influence and restoration processes. Moreover, changes in the landscape pattern in tropical coastal belts that include wetland systems can lead to socio-economic concerns (Dahdouh-Guebas *et al.*, 2005). The use of geospatial tools such as Remote Sensing (RS) and Global Information Systems (GIS) in environmental change detection processes has been well recognised and accepted during the past decade. Advances in sensor technology have led to quantitative analysis of different environments. Simulation models have provided an effective assessment approach to quantify rapid changes in vegetation structure and to predict the pace of wetland conversion (Muchoney & Haack, 1994; Sturtevant, 1998; Kent & Mast, 2005). Inter-disciplinary approaches that take into consideration both ecological and socio-economic parameters, as well as a multilevel approach

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that incorporates data at different scales, can help to address the uncertainties and resilience of complex wetland systems and obtain a better understanding of the system in a social context (Nagabhatla *et al*., 2008, 2009).

A pilot study was undertaken in the Muthurajawela-Negombo wetland complex off the western coast of Sri Lanka to test the usefulness of an inter-disciplinary and multi-scale approach that takes into consideration both the ecological and socio-economic parameters of wetland management (Figure 1).

The overall objective of this study was to investigate the impact of environmental change in wetlands on livelihood systems at the household level. Broad research questions addressed were:

- What are the main environmental changes detected at wetland site level in terms of changes to land cover/use patterns?
- How have environmental changes been perceived to impact and influence local livelihood systems at the household level?

In terms of the GIS methodologies used in conjunction with livelihood analyses, studies reported in the literature include those of Jayatissa *et al.* (2002) and Dahdouh-Guebas *et al.* (2005) who tested the use of aerial photography (digitization) in a coastal lagoon system on the southern coast of Sri Lanka, taking into account the socio-economic data collected from the adjoining communities. This approach however did not incorporate quantitative linkages between different ecological and socio-economic variables. It also did not take into consideration local perceptions on the impact of the environmental changes on local livelihood systems. A methodology that combines geospatial tools for environmental change detection analyses with socio-economic/livelihoods analyses at different scales, has been adopted in a Ramsar wetland site in India (Kolleru Lake) with useful results (Nagabhatla *et al*., 2009).

The Muthurajawela marsh and Negombo lagoon complex (MMNL) is situated along the west-coast of Sri Lanka close to the city of Colombo (Figure 2). The MMNL has been listed as one of 12 priority wetlands in Sri Lanka in 1996 (CCD, 2005). The marsh together with the lagoon covers an area of approximately 6,232 ha and its origins have been dated to about 5000 BC (CEA/ Euroconsult, 1994). As described by Mahanama (2002), the lagoon and marsh are interdependent ecological systems that have been identified as one wetland ecosystem. The marshes cover an area of approximately 3100 ha, which represents a large area of brackish marsh that merges into an estuarine lagoon of about 3200 ha towards the northwest. The main river, the Dandugan Oya with a catchment of 727 km^2, is the key water source for the marsh. The Negombo Lagoon has an opening to the sea on the northern side, where the city of Negombo is located along with its harbour (CEA/ Arcadis Euroconsult, 2003). According to Samarakoon (1993), there are numerous urban centres situated along the borders of the MMNL wetland, where the population density varies between 2500 and 8000 persons per km^2. This high population density has put more pressure on the already vulnerable wetland ecosystem. In the marsh area, southward of the lagoon, many poor families have encroached into the wetland (CEA/ Euroconsult, 2003).

The MMNL complex has a long history of human use and settlement with records dating back to the 15th century, when the marsh was mainly functioning as a wet-rice paddy land area (Hoogvorst, 2003). In more recent times, between the early 1970s and the late 1980s, a series of high profile political settlement programmes were initiated in the Muthurajawela marsh area, targeting mainly marsh encroachers (IRMP, 2003). The case study site Seedawatte was one such settlement scheme. According to interviews conducted with key informants in Seedawatte, the origin of the village dates back to 1972, when under the Land Reforms Act, the land that was at this time part of a coconut plantation belonging to the Machado Company, was taken over by the Government under the "extension of villages" project. A prominent local MP played an important role in 1972 in ensuring that this piece of land was then divided into plots of 40 perches and distributed among 49 landless families from the area. These were the earliest settlers of Seedawatte.

Since the early 1990s, the Muthurajawela marsh-Negombo lagoon area has been the focus of several coastal zone management policy issues and associated wetland

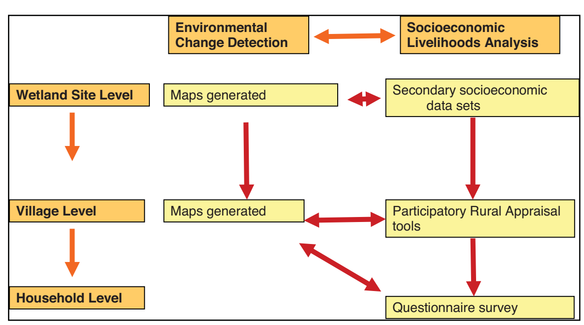

Figure 1: The multidisciplinary and multi-scale approach adopted to understand wetland issues and management.

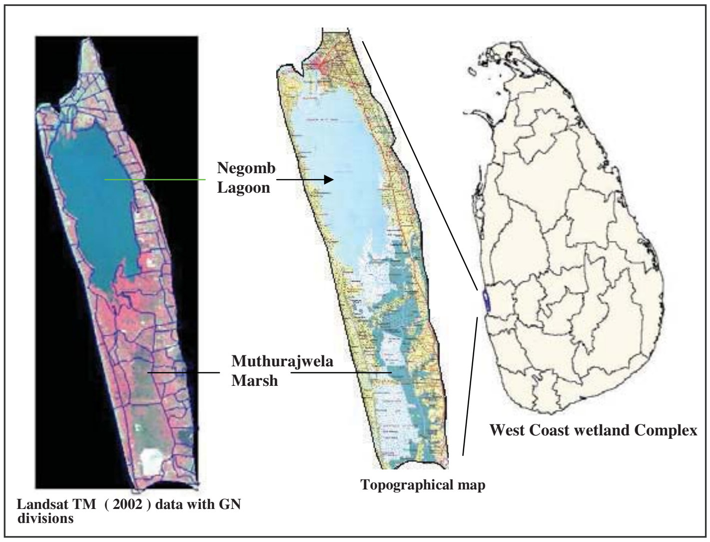

Figure 2: The Negombo lagoon and Muthurajawela marsh complex in Sri Lanka
Source: Nagabhatla *et al*., 2006

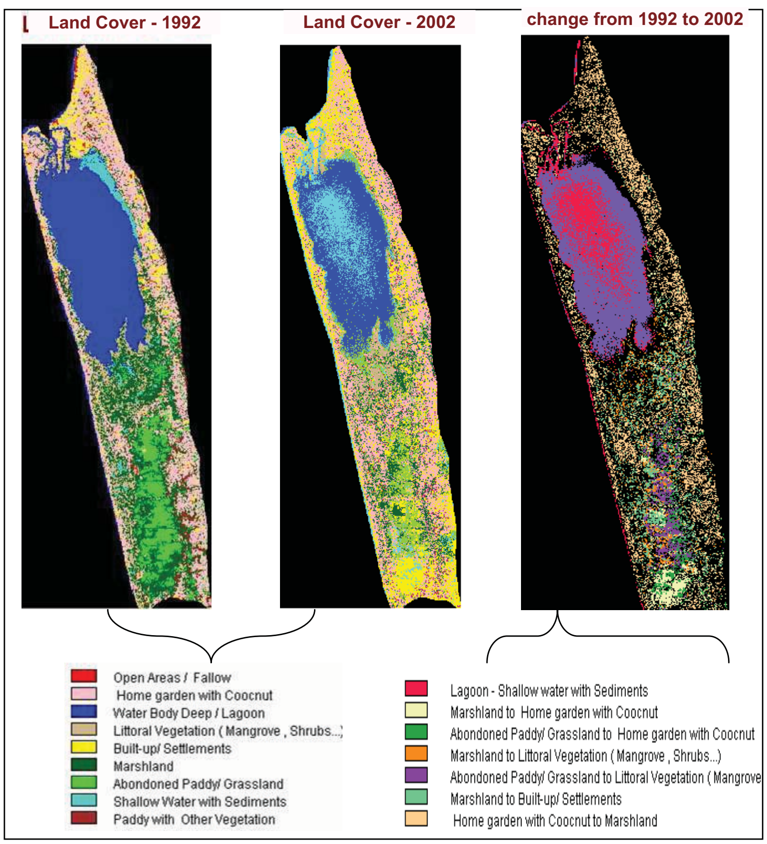

Figure 3: Wetland change between 1992 and 2002
Source: Nagabhatla *et al*., 2006

management procerses and projects. The Muthurajawela/ Negombo lagoon Master Plan was developed in 1990-1991, under the Greater Colombo Economic Commission (supported by the Netherlands Government). During the development of the Master Plan for the area, an important activity that was undertaken was the strategic multiple-use zoning of both the land and water comprising the wetland based on a detailed environmental profiling exercise (CEA/Arcadis Euroconsult, 2004). The zoning plan included a conservation zone (56% of the area), buffer zone (13% of area), resettlement zone (21% of area), existing residential zone (5% of area) and a mixed urban zone (5% of area).

METHODS AND MATERIALS

The study combined geospatial analyses and livelihoods analyses to determine environmental changes and the impact of these changes on livelihoods. The study was broadly divided into two phases.

Phase 1 – Change analysis in the MMNL study site of 85 GN divisions

Under Phase 1, a geospatial method was designed, which used multi-temporal (1987,1992 and 2002) Landsat Thematic Mapper satellite imagery to spatially assess and capture change in land use patterns, along with the support of ancillary data and existing topographic maps. A land cover/use map was generated using a knowledge based supervised classification approach in the Earth Resources Data Analysis System (ERDAS). The map included land uses (such as coconut groves and plantations) and semi-natural marshlands and water bodies. Land cover/use classes were taken as a unit to assess the interchange between wetland and non-wetland areas. Base maps for 1987, 1992 and 2002 were generated to analyse wetland change, including from near-natural to heavily human-modified systems and *vice versa*. To explain the increases, decreases and interchanges in the wetland complex, the information about the changes was qualified (into natural and created land cover/use) and quantified (with area statistics in hectares; total area of the classified landscape was 11,922 ha). Analysis of spatial, ecological change supported by socio-economic data provided a pathway for identifying indicators of wetland loss using a simulated ecological sustainability application in IDRISI-LCM, an in-built algorithm designed for change analysis based research assignments.

In terms of the socio-economic aspect of the study, under Phase 1, secondary data was collected at Grama Niladhari (GN) level to complement the biophysical parameters incorporated into the geospatial model. A field form, which included the relevant socio-economic parameters for the model was designed and pre-tested before data were collated. The secondary data collected included population size, population density, livelihood patterns (employment), and road networks. The data sets were converted into thematic GIS layers, for example, the population density in the 85 GN divisions were reclassified into five categories and attributed with the arbitrary values such as low (with 1000-2000 people/ ha), medium (2000-3000), high (3000-4000), very high (4000-5000) and dense (>5000). Similarly the other parameters were re-grouped and assigned values. The vector layers were then integrated in the geospatial module base (LCM application in IDRISI-Andes) and referred while calculating the 'change analyses, 'net change', 'transition potentials' and 'change prediction tools' module in LCM. These modules produced many intermediate disaggregated products while calculating the conversion between different land cover/use units in the temporal scale (for further details on the geo-spatial analysis, refer Nagabhatla *et al*., 2008).

Phase 2 – Change analysis in the case study - Seedawatte village

Under Phase 2, a livelihood analysis in terms of environmental change, local perceptions on these changes and livelihood impacts was conducted using a case study approach, in one purposively selected site within the wetland – Seedawatte village, located at the southern end of the Negombo Lagoon, adjacent to the Muthurajewela marsh (within the conservation zone of the wetland). In the site selection process, the following criteria were considered: features of distinct environmental change/ land use change (taking into consideration the zones/ units in the wetland that were noted under Phase 1 to have undergone measurable change); geographic location (in terms of the lagoon and the marsh); size of population/ number of households (manageable number to undertake a rapid survey); number of households where in some form of natural resources were used (what resources are used/ extracted from the wetland); age of settlement/village (as investigating environmental change over a 15 – 20 year period, the settlement should be of a corresponding age or older); and practical issues concerning undertaking fieldwork in that site (for example, the willingness of the community to participate in a research project).

A landscape analysis was carried out using Temporal Landsat images from the years 1987, 1992 and 2002, in a square area of 1513.6 ha (that included the case study site Seedawatte village), to identify major changes in land cover over this time period. Google maps showing

Seedawatte village and the surrounding environments were studied to obtain a better visual understanding of the geographic setting of the village in relation to the different land cover types.

Concurrently, primary data were collected for the livelihood analysis using a combination of participatory methods and more conventional surveys. Participatory methods included community mapping of the village (using key informants to map out all the households, road systems and major landmarks in the village with each house given a number on the map and a corresponding list drawn up, which included this number and the family name of the household), wealth ranking exercises (broadly stratify the households in Seedawatte village in terms of different poverty levels, i.e. better-off households *vs* poor or very poor households), focus group discussions (FGDs) with different groups such as fishermen and fisherwomen [to obtain an overview of the natural resources dependent livelihoods (i.e. fisheries) with respect to Seedawatte village and specific issues local people may face based on the environmental changes over the last 15 years] and key informant interviews (to obtain some historical background of the site).

In addition, a household survey was conducted with a representative sample of households (based on primary livelihood activity and wealth rank) using a random stratified approach. The sample size was 85 households of a total of 135 households in the village (approximately 63% of the village). The questionnaire covered livelihoods and environmental change related aspects, looking at local perceptions. The questionnaire was first piloted in a neighbouring village and necessary amendments made. The finalised questionnaire was administered to one respondent in each household (either male or female) covering a total of 85 households. As far as possible an attempt was made to ensure that the respondent had the historical knowledge with regard to land uses by ensuring that he or she had been a long-time resident of the area (i.e. at least the last 15 years, which covered the period under investigation in terms of environmental changes).

RESULTS

The findings are presented under two broad areas: those at the overall site-level (i.e. covering 85 GN divisions) and those from the village level case study.

Changes in wetland cover/use patterns in the overall site (85 GN divisions)

The change detection maps, indicate significant changes in land cover/use patterns in the MMNL wetland complex between 1992 and 2002 (Figure 3). Two key changes recorded from the temporal outputs (1987-2002) were the conversion of the lagoon to a shallow water body and the conversion of the natural marshland vegetation for land use activities, such as expansion in settlements and built-up areas. The change in depth of the lagoon is associated with the inter-tidal dynamics and both the natural sedimentation process as well as activities linked to domestic and industrial waste. The increase in built-up areas and settlements can be attributed to the expanding population and increased industrialisation and development in the area surrounding the wetland. Also observed was substantial change in the agricultural zone from 1987. The fields that were left abandoned thereafter had semi-naturalised into marshland by the early 1990s (Nagabhatla *et al*., 2006, 2008).

To explain the degree of change and response of the MMNL wetland system, a change benefit ratio exercise was undertaken (Table 1) using a scale from 0 –5 (represented as + small increase; ++ medium increase; +++ moderate increase; ++++ significant increase; and – less decrease; -- medium decrease; and --- significant decrease). The analysis of this exercise (based on the aerial statistics from 1992 and 2007) reflects the gradient of change in different land cover/use units. It also helps to better understand the conversion of natural vegetation zones such as the marshy/scrub lands to anthropogenically managed zones such as home gardens and *vice-versa*.

Phase 2 – Changes in wetland cover and use around Seedawatte

Landscape change analysis was conducted for an area of 1513.6 ha surrounding the Seedawatte village to understand the dynamics in the systems. As expected, several observations similar to those made for the entire

Table 1: Land cover / use change in the wetland complex from 1992-2002

Wetland cover type	Change in area 1992-2000	Status of change 1992-2000
Water body / lagoon	-24.7	-- -
Shallow water / canals	8.8	+
Mangroves / Scrubland	25.1	+++
Marshland	-47	- - - -
Grassland (abandoned paddy)	-39.9	- - -
Home garden with coconuts	66.1	+ + + +
Settlements	11.6	++

Source: Nagabhatla *et al*., 2006

site under Phase 1, were made in the change analysis process.

Figure 4 shows that in 1987, the landscape appears to be acceptably intact with semi-naturalised wetland classes being juxtaposed. Canals flushing the water in the lagoon were well demarcated. In 1992, some increase in settlement areas can be observed in the spatial analysis. It was also inferred that increased agricultural activities in the surrounding landscape reduced the canal system disturbing the flow regulation and the flush mechanism in the lagoon. Spatial analysis in 2002 depicts the landscape as a fragmented unit. Sedimentation and canal blockage was also reported resulting in obstruction of the water flow system. Increase of the littoral zone was observed as more salt tolerant mangrove species (such as *Acrosticum* and *Hibiscus*) appear to be spreading in the highly saline marsh zone. The landscape was also interspersed with small settlement areas within the classified zone.

From the overall trends in land cover/use patterns (Table 2), the first key observation was that the lagoon area decreased between 1987 and 2002 and had been converted into a shallow water body (with an increase in sediment). This fact was corroborated during FGDs held with villagers from Seedawatte who fished in the lagoon. The villagers were of the opinion that the increase in sedimentation had decreased the depth of the lagoon in particular areas, which may have had a negative impact on the overall fishery productivity. They were of the view that sedimentation had increased over the years due to industrial effluents and other waste material being dumped into the canals that flow into the lagoon, in addition to increased sedimentation.

The second major observation was the increase in settlement areas since 1987 and likewise, an increase in the total home garden area. This too was validated by the interviews conducted in Seedawatte, as there had been a steady increase in the population in the village over this time period and thereby an increase in the settlement plus home garden areas. Key informant interviews revealed that starting in 1977, 40 additional families were settled in the village and each given a plot of 20 perches. There was a 4 acre piece of marsh land at the boundary of the village, which was reserved for the preparation of a playground and other communal activities, but another 12 families partially encroached on this land. During the time of our study Seedawatte comprised a total of 135 families and the original plots of land had been sub-divided amongst second generation settlers.

It was noted that the marshland area had increased between 1987 and 1992 and then decreased between 1992 and 2002 (Table 2). There appeared to be an ecological explanation for this phenomenon. Between 1987 and 1992 due to some local flooding and inter-tidal conditions the areas became saturated and water-logged forming marshes/mudflats. In addition to the above, abandoned agriculture fields were also converted into marsh land, resulting in an overall increase in area. However after 1992, the water regime and the physiological conditions turned most of this area into semi-naturalised vegetative communities, resulting in an overall change in statistics.

Direct use of natural resources from the environment in the immediate surrounding:

Secondary data sources from the GN office revealed that only a small percentage of the households in Seedawatte are dependent on natural resources based primary livelihood activities (i.e. as their main income generating activity). However the questionnaire survey revealed that almost all the households are dependent on natural resources for subsistence purposes.

Geographically, Seedawatte village is situated in close proximity to the Negombo lagoon, Hamilton Canal and the marsh, and slightly away from the ocean (Figure 5). These are therefore the main environments from which natural resources are accessed or utilized by the community.

In the household survey, respondents were requested to indicate what natural resources they accessed/used in the context of the above mentioned key environments (Figure 6). From the sample of households interviewed it appeared that a high percentage of households (67%) directly used the surrounding marsh area. A majority stated that they collected firewood from the marsh (52 respondents), while a few (3 respondents) mentioned the use of the vegetation (branches) to build fences, collection of leafy vegetables for home consumption or sale (5 respondents), collection of fodder for livestock (1 respondent) and collection of sedges for weaving mats (1 respondent).

Approximately 39% of the household sample indicated that they use the lagoon and 32 % was associated with Hamilton Canal. As expected, the lagoon was used mainly for the purpose of fishing; both fish and shrimp species. But interestingly, while 10 respondents indicated that they fished in the lagoon to derive an income, 20 respondents stated that they have caught fish mainly for their home consumption. A small number of respondents (4) indicated that they have used the lagoon on occasions for bathing purposes and to wash their clothes. The water from the Hamilton Canal was mainly used by families in Seedawatte to do their laundry and for bathing (although in the case of the latter, respondents specifically mentioned that they did not allow their younger children to bathe in the canal as they feared they may contract some disease). In addition, 12 respondents also indicated that they did some fishing in the canal and their catch was exclusively used for home consumption.

Most likely due to the geographic location of the village, only 15% of our sampled households used the sea directly. Five fish traders in the sample visited the fish landing sites and in addition a couple of respondents indicated that they were engaged in some artisan fishing for their own consumption at home.

Table 2: Spatial change analysis and associated environmental and livelihood trends in around the Seedawatte village in MMNL from 1987-2002 (Nagabhatla *et al*., 2008)

Wetland cover type	1987 area (ha)	1992 area (ha)	2002 area (ha)	Overall trend	Potential impact of change on the wetland ecology	Potential impact of change on livelihoods of community
Lagoon/ deep water	492.8	435.3	410.6	Decrease	Negative impact on the breeding grounds for fish and shrimp species; natural systems of water filtration/purification affected	Negative impact on lagoon fishing; decrease in income.
Shallow water	139	145.3	154.1	Increase	Increase in sediment in lagoon	Negative impact on lagoon fishing; decrease in income.
Littoral vegetation	231.4	266.8	291.9	Increase	Breeding grounds for fish and shrimp species, natural system of water filtration/purification, buffer against flooding	Provides fishing gear; firewood; feed for livestock.
Marshland/ shrubs	395.9	458.5	411.5	Increase/ decrease	Fragmentation of marsh, hence negative impact on species habitats; impact on buffer against flooding	Main source of firewood diminishing; fodder for livestock diminishing.
Grassland (paddy/ abandoned fields)	135.9	63.3	23.4	Decrease	Naturalised vegetation	Paddy cultivation being abandoned; grazing for livestock, conversion to home gardening
Home gardens (coconut)	95.7	117.1	183.2	Increase	Fragmentation of marsh, hence negative impact on species habitats	Used for subsistence purposes helps improve overall livelihood system; home consumption, addition for improved food security.
Settlements/ built -up	22.9	27.3	38.9	Increase	Fragmentation of marsh, hence negative impact on species habitats	More development within the settlement ; improves the general infrastructure of the village (roads, electricity, water); provide homes for encroaches of marshland, improved sanitation, poverty reduction.

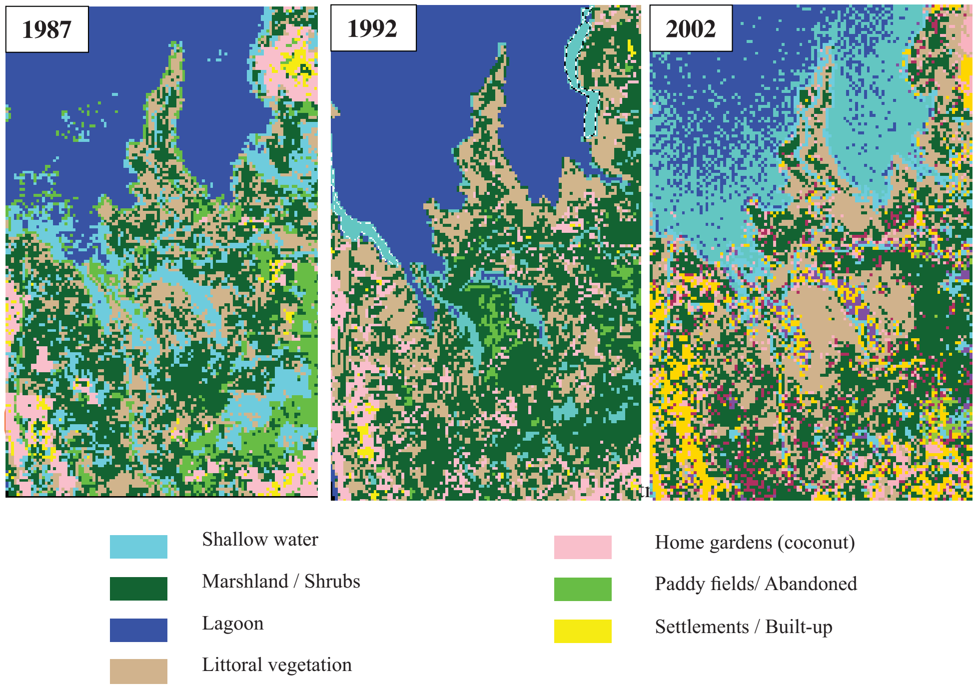

Figure 4: Land/water-use and vegetation change 1987–2002
Source: Senaratna Sellamuttu *et al.*, 2006

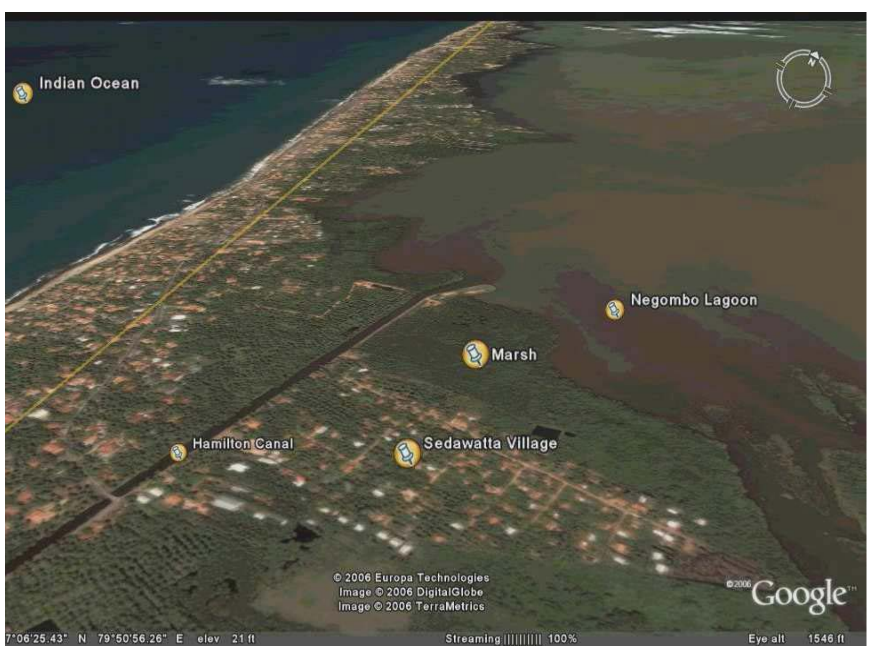

Figure 5: Location of Seedawatte village and surrounding environments
Source: Google Earth, 2006

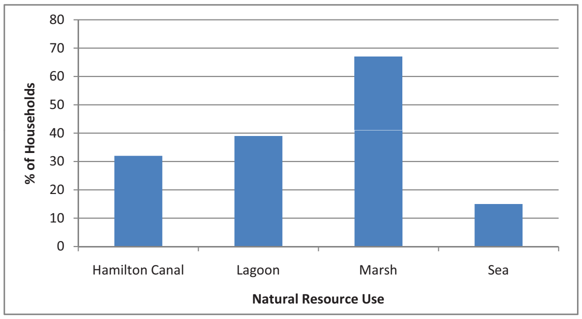

Figure 6: The percentage of households that directly use natural resources in their surrounding environment

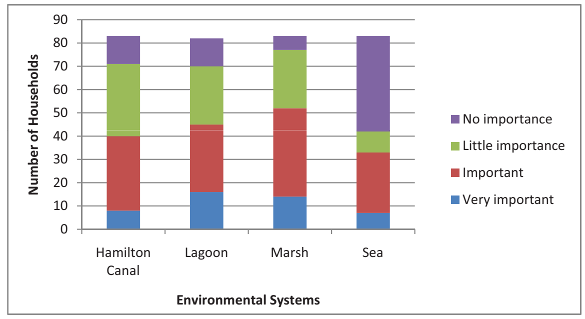

Figure 7: Perceived importance of surrounding environment to livelihood system

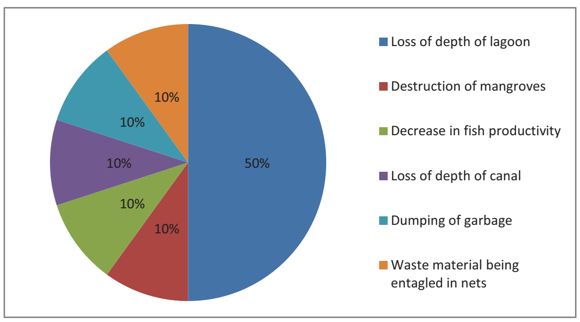

Figure 8: The magnitude of environmental related problems faced by fishers

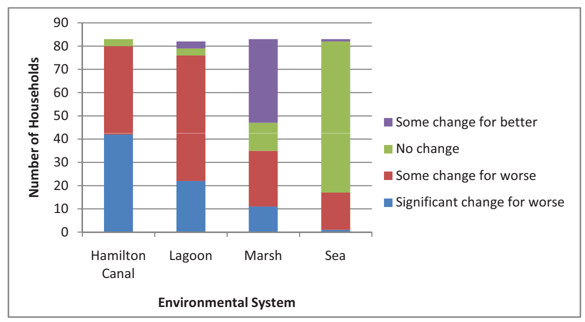

Figure 9: Perceived environmental changes affecting Seedawatte since 1992

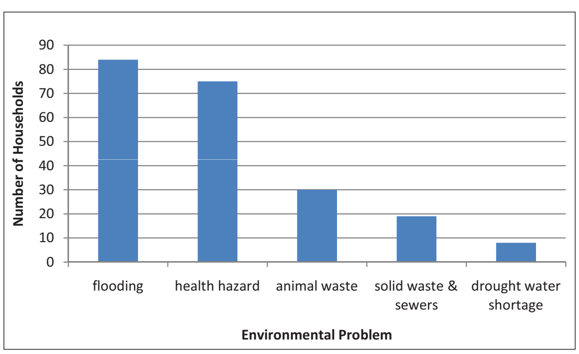

Figure 10: The main environmental problems that are facing Seedawatte

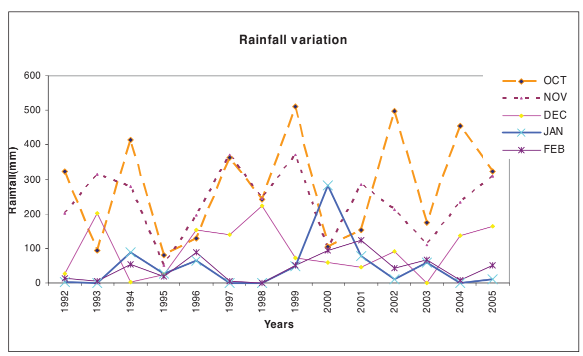

Figure 11: Rainfall data from Negombo (Source: Meteorological Department, 2006)

Perceived importance of the surrounding environment to the overall livelihood system

From the responses to the question, "How important are the following environments to your overall livelihood systems?", a similar trend emerged with regard to the lagoon, associated canal and marsh. The latter however had a slightly higher number of respondents in the "very important" and "important" categories, which is likely to be a result of the marsh emerging as the environment used directly by the largest number of households in the sample (Figure 7). As expected, a majority of respondents were of the view that the sea was of no importance to them, since very few in Seedawatte were engaged in sea fishing or related activities and geographically the sea was a relatively greater distance away from the village compared to the lagoon, canal and marsh.

Perceived environmental changes that have occurred in the area since 1992

In terms of rating the environmental changes that had occurred in each of these systems over the past 15 years, participants were requested to use a five point rating system from significant change for the worst to significant change for the better. A large number of respondents were of the view that there had been either a significant change for the worse or some change for the worse with regard to the lagoon and associated canal. This is linked to major environmental issues associated with the canal – for example the polluting of the canals with solid waste material and industrial wastes. In the lagoon, loss of the natural depth of the lagoon, caused by increasing sedimentation and destruction of mangroves, which created a decrease in fish productivity, has been identified as reasons. FGD held with fishermen in Seedawatte revealed that in terms of the magnitude of the different environmental issues the fishermen faced, they were of the opinion that the decrease in lagoon depth was the most serious of problems, while all other issues were of similar magnitude as shown below in Figure 8.

With respect to the marsh the results (Figure 9) were somewhat different – The majority of the inhabitants of Seedawatte are of the opinion that the clearing of the marsh to develop their village has been a change for the better in terms of their own lives. Respondents spoke of the area being uninhabitable in the past and that clearing for development activities uplifted their living conditions. Thirty five respondents indicated that the change in the area had been either for worse or significantly worse. The reasons for this could be traced to the fact that those living furthest away from the main road that ran parallel to the Hamilton Canal (i.e. those closest to the marsh area), still had major problems with the water retention of the land especially during the rainy season. With respect to the sea, majority had reported no change over last 15 years.

Main environmental problems in the area

As indicated in Figure 10, the most serious environmental problem that affected the area according to 84 households was the flooding that occurred on an annual basis usually between the months of October to December.

This was validated by rainfall data (Figure 11) and spatial data from the site. Peak rainfall is observed in the month of October, which causes increase in saturation levels and water retention in the marsh system. Although there is a decline in rainfall in November and December, the water content and the flooding conditions persist in the area during these months due to continuous replenishment of the water content in the overall wetland system. Furthermore, this phenomenon can also be explained by the alteration in the landscape that has resulted from canal sedimentation and blockage and infilling of the marsh, which has heavily reduced the water retention capacity of the overall wetland-marsh system over the last decade, making it vulnerable to local flooding.

The village area, especially the area adjacent to the marsh and further away from the main road, becomes submerged, which has a number of negative impacts on the community. For instance there are several health issues that arise in association with the flooding, such as sores on feet/legs due to constantly having to walk through the stagnant flood water. In addition, respondents complained of a mosquitoe problem and a solid waste problem.

Problems linked to accessing natural resources from the surrounding environment

Environmental problems in the area were linked to the local community accessing natural resources from their surrounding environment. According to 18 respondents, the main problem resulted from the canal being polluted with solid waste material, chemical pollutants, industrial waste material and animal waste matter; making it difficult for villagers to access the water in the canal for activities such as bathing and washing their clothes. In addition, a couple of respondents indicated that there was some saline intrusion over the years. Both saline intrusion and pollution has led to changes in the species of fish living in the canal.

With respect to the lagoon, 14 respondents (majority) indicated that the main problem associated with accessing the lagoon resources was due to the solid waste material that floated into the lagoon along the canals. In addition, the increase of sediment over the years was also mentioned as a factor making accessibility to the lagoon more difficult.

Firewood from the marsh area is one of the main resources used by the community in Seedawatte. According to 41 respondents it was becoming more difficult to access areas for firewood. The village is situated close to the Muthurajawela core conservation zone and the community does not have access to gather firewood within this area. Firewood is also collected by cutting down mangroves along the edge of the marsh and lagoon, which is an illegal activity. Accessing areas for firewood becomes more difficult when there are heavy rains in the area. The study however did not gather information on how much firewood was used per week and how often people needed to collect the firewood from the marsh.

Six respondents indicated problems in accessing resources of the sea due to the presence of too many fish traders. Two respondents were of the opinion that unsustainable fishery practices had led to reduction in fish stocks.

DISCUSSION

In this study an attempt was made to test the usefulness of adopting an inter-disciplinary and multi-scale approach for monitoring wetland change, incorporating both environment and livelihoods aspects through the combination of GIS based methodologies and livelihoods analyses. While other studies have described changes in wetland systems using RS/GIS tools, taking into account socio-economic data collected from local communities, in this study an integrated approach was used at each phase of the research linking data collection methods at the different levels using findings of one phase to feed into and validate findings of the other phase and *vice versa*. In addition, our research has attempted to develop automated algorithms for environmental change detection analysis (IDRISI–Andes) and establish correlations between spatial and social parameters at the level of the overall wetland complex. Furthermore, we have attempted to get a better understanding of the impact changes detected in the overall wetland that have had on the livelihood systems of local communities at the household level, by studying local perceptions.

Our results suggest that there are significant changes in land cover/use patterns that have occurred in the MMNL wetland during the time period under investigation observable through GIS maps that were generated at different levels. For example the conversion of the lagoon into a shallow water body with sediments and the fragmentation and conversion of marshland into settlements were clearly visible from the spatial data. These environmental changes have also been observed and experienced by local communities over this time period and have had an impact on their overall livelihood systems. At the household level, most perceive these environmental changes observed in the lagoon and canal as a change for the worse; while for the marsh, interestingly, changes experienced were perceived to be both for the better and for the worse. These variations in perceptions appear to be based on whether these environments are directly linked to a household's livelihood system; in addition to the geographic location of these environments in relation to the village (i.e. the marsh, lagoon and canal which are closer to the village are considered of higher importance than the ocean, which is further away).

Different stakeholders hold different views and perceptions in terms of improvements in certain aspects and change for the worse in certain other aspects of the wetland. For example, improvements may be enjoyed by one stakeholder group while reduction of benefits is experienced by some others. This brings into play the trade-offs that may be associated with environmental and development needs associated with a particular wetland site. For instance, reduction in the extent of natural environment may be compensated by the increases of man-made capital such as infrastructure. However at the same time, the negative impact exerted by environmental changes in a wetland complex on livelihoods at a household level could in turn lead to further pressure being exerted by local communities on the natural systems, due to the scarcity of resources. Therefore in terms of the overall management of the wetland, using this type of inter-disciplinary and multi-scale approach helps highlight both environment-livelihoods aspects and therefore both conservation and development needs and provides a more holistic understanding of the various aspects to be taken into consideration in the long-term management and wise use of wetland systems. As the MMNL site is currently under a co-management model where the relevant government institutions manage the natural resources in the area in consultation with the local community, including resource user groups (CCD, 2004), this type of approach could be a valuable tool adopted in the decision-making process with regard to the sustainable long-term management of the wetland.

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REFERENCES

1. Agardy T. & Alder J. (2005). Coastal Systems. *Ecosystems & Human Well-Being*, volume 1. Current Status and Trends. Millennium Ecosystem Assessment. Strengthening Capacity to Manage Ecosystems Sustainably for Human Well-Being, pp. 513-549. World Resources Institute, Washington DC, USA.
2. CEA/Euroconsult (1994). *Conservation Management Plan for Muthurajawela Marsh & Negombo Lagoon*. Central Environmental Authority, Ministry of Environment and Natural Resources, Maligawatta, Colombo 10.
3. CEA/Arcadis Euroconsult (2003). Integrated Resources Management Programme (IRMP) in Wetlands. *Final Project Completion Report*. Ministry of Environment and Natural Resources, 'Parisara Piyasa', Battaramulla.
4. CEA/Arcadis Euroconsult (2004). Lessons learned from 12 years of wetland work in Sri Lanka. Strategic Zoning. *Integrated Resources Management Programme (IRMP)*. Central Environmental Authority,Ministry of Environment and Natural Resources, 'Parisara Piyasa', Battaramulla.
5. CCD (2004). *Revised Coastal Zone Management Plan, Sri Lanka*. Coast Conservation Department, Ministry of Fisheries and Aquatic Resources New Secretariat, Maligawatta, Colombo 10.
6. CCD (2005). *Special Area Management Plan for Negombo Lagoon*. Negombo Special Area Management Community Coordinating Committee, Coast Conservation Department, Ministry of Fisheries and Aquatic Resources, New Secretariat, Maligawatta, Colombo 10.
7. Dahdouh-Guebas F., Hettiarachchi S., Lo Seen D., Batelaan O., Sooriyarachchi S., Jayatissa L.P. & Koedam N. (2005). Transitions in ancient inland freshwater resource management in Sri Lanka affect biota and human populations in and around coastal lagoons. *Current Biology* **15**(6): 579 –586.
8. Hoogvorst A. (2003). *Survival Strategies of People in a Sri Lankan Wetland: Livelihood, Health and Nature Conservation in Muthurajawela*, p.185. Wageningen University, The Netherlands.
9. IUCN Sri Lanka (2003). Wetland Conservation in Sri Lanka. *Proceedings of the National Symposium on Wetland Conservation and Management*, 19 – 20 June, International Union for Conservation of Nature, Horton Place, Colombo 7, p. 75.
10. Jayatissa L.P., Guero M. C., Hettiarachchi S. & Koedam N. (2002). Changes in vegetation cover and socio-economic transitions in a coastal lagoon (Kalametiya, Sri Lanka), as observed by teledetection and ground truthing can be attributed to an upstream irrigation scheme. *Environment, Development and Sustainability* **4**: 167 – 183.
11. Kent B. J. & Mast J.N. (2005.) Wetland change analysis of San Dieguito Lagoon, California, USA: 1928–1994. *Wetlands* **25**:780 – 87.
12. Mahanama P.K.S. (2002). Establish the socio-economic factors that result in the current pattern of human exploitation of the coastal wetlands. Effective Management for Biodiversity Conservation in Sri Lankan Coastal Wetlands: Socio-economic impacts, *Final report*, University of Moratuwa, Katubedda.
13. Ministry of Transport, Environment & Women's Affairs (1995). Appointment of a National Wetland Steering Committee. *Cabinet Memorandum*. Ministry of Transport, Environment & Women's Affairs, Unity Plaza, Colombo 4.
14. Muchoney D.M. & Haack B.N. (1994). Change detection for monitoring forest defoliation. *Photogrammetric Engineering & Remote Sensing* **60**:1243 –1251.
15. Nagabhatla N., Finlayson M., Senaratna Sellamuttu S., Zomer R. & Diphoorn L. (2006). Wetland dynamics – links with spatial, ecological and socio-economic related issues in the western coastal belt of Sri Lanka. Proceedings of *The Ninth Biennial Conference of the International Society of Ecological Economics (CD-Rom)*, 15 – 18 December, Delhi, India.
16. Nagabhatla N., Finlayson C. M., Senaratna Sellamuttu S. & Gunawardena A. (2008). Application of geospatial tools to monitor change in a micro-tidal estuary for the purpose of management planning. *Ceylon Journal of Science (Biological Sciences)* **37**(1): 73 – 86.
17. Nagabhatla N., Pattnaik C., Senaratna Sellamuttu S., Narendra Prasad S., Wickramasuriya R. & Finlayson M. (2009). Investigation of aquaculture dynamics in a Ramsar Site using earth observation systems in conjunction with socio-economic assessments. *Lakes & Reservoirs: Research and Management* **14**: 325–336.
18. Samarakoon J. (1993). Planning and implementation for sustainable management of Negombo Lagoon, Sri Lanka. *The Managing of Coastal Lagoons and Enclosed Bays*, pp. 269–291. American Societies of Coastal Management, New York, USA.
19. Sturtevant B.R. (1998). A model of wetland vegetation dynamics in simulated beaver impoundments. *Ecological Model* **112**: 195–225.
20. World Resources Institute (2005). Ecosystems and Human Well-being: Wetlands and Water Synthesis. *Millennium Ecosystem Assessment*. World Resources Institute, Washington DC, USA.