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# Identification, evaluation and change detection of highly sensitive wetlands in South-Eastern Sri Lanka using ALOS (AVNIR2, PALSAR) and Landsat ETM+ data

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**Abstract.** Sri Lanka is an island consists of numerous wetlands and many of these ecosystems have been indiscriminately exploited for a commercial, agricultural, residential and industrial development and waste dumping. Eastern River Basin Region in Sri Lanka is rapidly urbanizing, which leads more threats to the surrounding wetland ecosystems considerably. Therefore, it is important to identify and designated them as reserved areas where necessary in order to protect them under the National Environmental Act of Sri Lanka. Mapping and change detection of wetlands in the selected region is a key requirement to fulfill the above task. GIS and Remote Sensing techniques were used to identify and analyze the wetland eco systems. In this study Landsat ETM+, ALOS-AVNIR2, ALOS-PALSAR images were analyzed for identifying and change detection of wetlands. The secondary information and data were collected through a questionnaire survey to recognize the possible threats and benefits. The collected data and information were incorporated in identification, analyzing and ranking the wetlands. The final outcome of the project is to correlate the satellite data with the field observations to quantify the highly sensitive wetlands to declare as Environmental Protection Areas under the National Environment Act of Sri Lanka.

## 1. Introduction

Wetlands are the most important ecosystems all over the world it defined as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six meters [9]. Wetlands provide many good services such as, reduce wave damage flood storage and conveyance, and sediment loading, erosion control, prevent and treat pollution, ground water recharge and discharge, produce crops and timber, habitat for wildlife and provide scenic beauty. Furthermore, it has historical, archaeological, heritage values and provides research opportunities too [3].

Currently many important wetlands have been overexploited for commercial, agricultural, residential and industrial development, directly affected to carrying capacity of water bodies and degradation of wildlife habitat. Not only that, natural phenomena such as spreading invasive plant on wetlands also becoming a major environmental problem [1].



### *1.1. Current status and conservation strategies of wetlands in Sri Lanka*

Coral reefs, Sand or salt flats, Marshes, Mangroves can be identified as marine and coastal wetland type in Sri Lanka while Fresh water swamp forest, Seasonal/intermittent freshwater ponds and marshes as inland wetlands [6]. Not only that, Sri Lanka is a classic example of “Hydraulic civilization” which had developed in 540 BC. Development of rice cultivation in the rolling planes of north and north central and the south east part of the country’s in grand scale. Therefore, numerous large and small tanks linked with rice fields in a unique cascade system creating manmade wetlands. Sri Lanka is an island consists 65,610km<sup>2</sup> area having a 1340km long coastal belt with numerous types of wetland ecosystems rich with flora and fauna species, some are endemic and some listed as threatened in red list [5]. Most of the wetlands in North Western part are destructed for shrimp farming since late seventies. All wetlands comprise of a combination of soils, water, plants and animals. The interplay between these elements allow wetlands to perform several functions that are beneficial to human kind, while generating healthy wild life, fisheries and forest resources. The combination of these functions together with the fish biological diversity and cultural heritage of wetlands make these eco systems invaluable to people all over the country. The importance of wetlands can be elaborated into three major categories as uses, functions and attributes.

Majority of the wetlands in Sri Lanka are facing various threats that are posed by anthropological activities. According to the directory of Asian wetlands [8] the most frequently reported threats appears to be siltation. It should be realized that this is usually not caused by factors in the wetland itself by actions on land adjacent or away from wetlands. The development of aqua culture ponds is one of the serious threats to wetlands located in coastal areas. Habitat destruction, degradation direct loss, exploitation of species and spread of invasive alien species can be considered as other major threats on the wetlands.

Interest in conservation of wetlands can be traced back in the recent history to the late 19<sup>th</sup> century. The flora and fauna protection ordinance of 1937 can be considered as a major step in wetland conservation. Using this legislation, wetlands of importance to bird have been declared by the department of Wild life Conservation as sanctuaries and other protected areas. Sri Lanka signed the Ramsar Convention in 1971, but ratified it only in 1990. Interest in the development of the Muthurajawela Marsh was a major activity which led to a comprehensive study of the wetland and the preparation of an ecological profile and a management plan and the report was published in 1992. Since 1987 it was recognized that wetlands were falling under the responsibility of numerous agencies and such the need to introduce coordination was recognized. Accordingly by 1989, an interim wetland steering committee was established by the Central Environmental Authority.

During the past three decades the status of the wetlands in the Eastern and Northern provinces remained unknown and presently the areas are now rapidly populated and development projects are carried out in larger scales leads to the rapid exploitation of wetlands. Therefore, it needs to take immediate action to protect important wetlands under the National Environmental Act of Sri Lanka. To fulfill the above task, mapping and change detection of wetlands in a selected region is a key requirement.

## **2. Objectives**

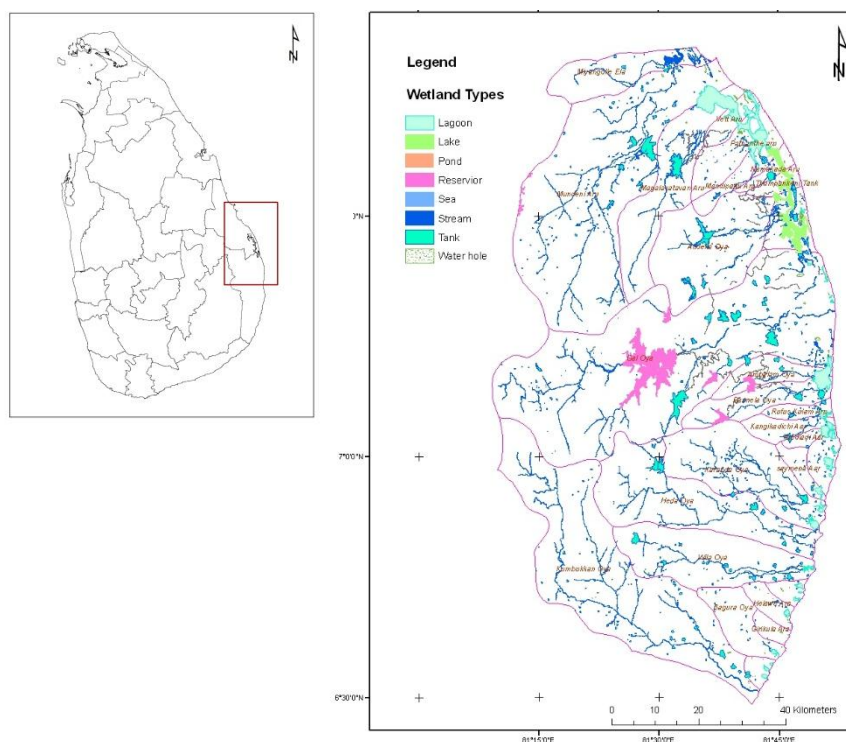
- To mapping and change detection of wetlands in South Eastern River Basin Region in Sri Lanka using Optical and PALSAR remote sensing techniques
- To Identification of important wetlands in the Eastern River Basin Region in Sri Lanka to declare as environmental protection areas under the National Environmental Act
- To Update the National Wetland Directory

The project is conducted by the Research and Development Unit (Geo-informatics) Unit of the Central Environmental Authority collaboration with the Japanese Aerospace Agency (JAXA) and the Geo-informatics Centre, Tokyo University, Japan, Asian Institute of Technology, Thailand. Survey Department of Sri Lanka, Department of Forest Conservation, Department of Wildlife

Conservation, Department of Irrigation, and National Wetland Steering Committee are the facilitators in this project.

### 2.1. Study area

Sri Lanka consists of 103 river basins according to the presence of major annual and perennial rivers. According to the “Mahaweli” management plan these basins are grouped in five (5) major river basins. The selected river basin is located in Eastern part of the country called “South- Eastern River basin” which consists different kinds of wetland systems including lagoon, estuary, marshland, man-made tanks, large reservoirs and streams. The total land area of selected river basin is about 8816 km<sup>2</sup> and having 23 sub river basins.

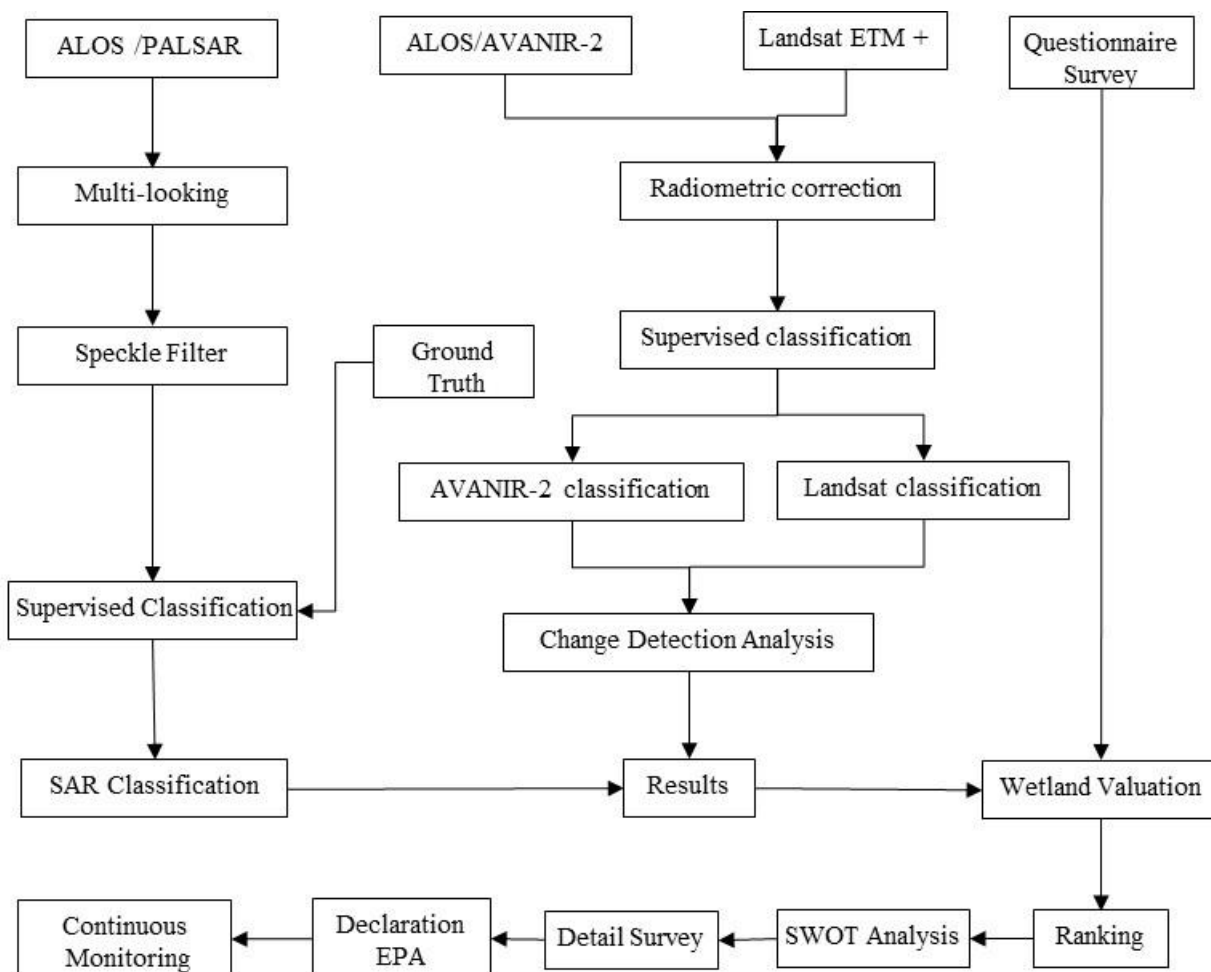


**Figure 1.** Wetland distribution of South-Eastern river basin of Sri Lanka.

### 3. Methodology

Topographic maps (1:50,000) prepared by The Survey Department of Sri Lanka have been used to identification of sites; together with the River Basin map of the Mahaweli Authority of Sri Lanka. Accordingly research boundary which was South Eastern River basin of Sri Lanka is delineated. Preliminary land cover maps used in the field verification are prepared with the Landsat ETM+ images. Field survey carried out in order to obtain GPS locations of surrounding environment and obtain information from the community directly involved with wetlands for their living and that data were used to update land cover maps. While conducting field survey, identified wetlands were subjected to detail study in respect to wetland valuation method (table 2) developed by the Wetland Steering Committee, Sri Lanka. Field verified data were then in cooperated with the Landsat ETM+ and ALOS-AVNIR2 images and classified with supervised classification method to identification of wetlands and water bodies while ALOS-PALSAR were also used for identification of wetlands with supervised classification. Accuracy assessment of the classified three images has been done using field verified data. Areas of land cover types have been calculated separately for the identification of land cover changes in past decade. Statistical analysis was done for the identification of unique

wetlands to be conserved through establishment of protection areas under the National Environmental Act (NEA) of Sri Lanka. According to the study identified 42 wetland eco systems were subjected to detail study including biological, physical and socio-economic parameters collected in questionnaire survey during the field data collection. The significant importance of each wetland is obtained and ranked for further study and to be declared as Environmental Protection areas as per the NEA in future. Furthermore, identification of mangrove areas and calculation of above ground level biomass through remote sensing techniques has to be done in future [4].



**Figure 2.** Image analysis methodology for change detection of wetlands and declaration of EPA process.

#### 4. Results and discussion

The current and previous status, extent, conditions of the wetlands will be identified using past Landsat ETM+ (2005) and new satellite images (ALOS-AVNIR2 optical data from February/2005 and July/2009 respectively). Accuracy assessment was done using the GPS data and overall accuracy of wetlands and water bodies is over 85%. The current land use map created using the topographic maps and the major land cover type listed in the table1. The majority of the land cover type belongs to forest, paddy and homestead in selected study area.

Three remote sensing, sensors were used for land cover classification and change detection. These included Landsat ETM+, ALOS-AVNIR2 optical data from February/2005 and July/2009 respectively. ALOS-PALSAR data of March/2009 was also used to evaluate feasibility of SAR data for wetland mapping. As shown in the flow chart below supervised classification technique was used for both optical and SAR data. Ground truth data was vital for the classification of the PALSAR data as it's nearly impossible to visually distinguish land cover using SAR data. For optical data a combination of collected field data and visual analysis of the images were used.

#### 4.1. Landsat data classification

Land cover classification in year 2005 showed the study area which is mostly covered by paddy fields and scrub. The Landsat data was highly accurate in identifying the wetland with an accuracy of 72%. Overall Landsat classification accuracy was 80%.

#### 4.2. ALOS AVNIR2 classification

Accuracy assessment in the classification for ALOS-AVNIR2 showed 79% accuracy. Overall analysis shows some water bodies at the bottom left of the map is misclassified as mangrove. Lack of Short Wave Infrared band in ALOS-AVNIR2, which produces unique spectral signature that enables to distinguish mangroves from other vegetation types, makes it difficult to identify mangroves. However, mangrove areas are accurately demarcated using high resolution IKONOS images with the GPS ground sampling locations (Figure 5.)

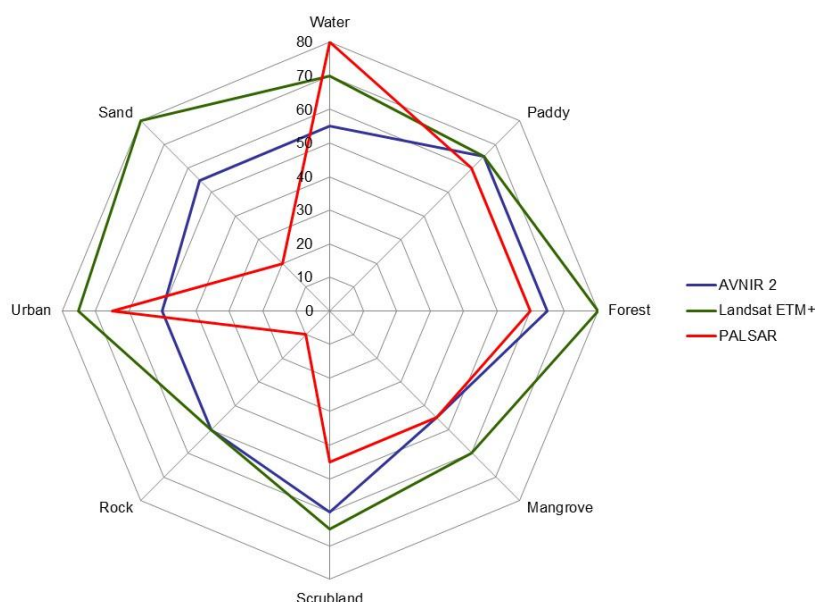
**Table 1.** The extent of land cover type in the south eastern river basin derived from the topographic maps.

Land Cover	Area (ha)
Chena	59,133
Forest	324,923
Home garden	107,544
Paddy	139,500
Rubber	2,552
Stream	11,253
Tank	18,156
Tea	2,770
Other Plantation	25,671
Other Area	352,869
Total	1,044,370

#### 4.3. Accuracy assessment of image classification

The accuracy of Landsat ETM+ data for mangrove mapping is 71% in contrast to the ALOS-AVNIR2 only showed an accuracy of 45%. However, ALOS-PALSAR can be used to identifying the shallow water body to an accuracy of 80% compared to the 70% accuracy in Landsat classification accurately. Other land cover classes had very similar accuracy level. According to the graph Landsat ETM+ was the most suitable for identification of different land use types with higher accuracy while the AVNIR2 was moderately suitable in this regard. As the island is within the tropical region the upper atmosphere was covered with clouds throughout the year and microwave images like ALOS-PALSAR was more suitable in delineation of forest and water logged area from other land cover types. It was observed, the dual polarization penetrates forest lands it was easily identifiable from

other features. Thermal band can be recommended for identification of rocky and highly urbanized areas as they emit more thermal energy during the day time.



**Figure 3.** Accuracy comparisons of Landsat (ETM+), AVNIR2 and PALSAR land cover classification.

Detailed study was done for the evaluation of each wetland type using the standard valuation method developed by the National Wetland Steering committee of Sri Lanka. According to that, three major parameters identified as attributes, functions and uses with sub categories under the different weighted values. Using SPSS statistical software the data are analyzed and find the significant values. The highest value was recorded from *Nawagiriya* Tank (Value 75.54) due to very high biological value while providing a source of drinking water. There were 14 wetland systems selected for further study in identifying the potential to establishment as environmental protection areas with the value over 60, considering the vulnerability. Land development and urbanization are considered as the major threats of degradation of wetlands.

The feasibility study on selected wetlands is carrying out to obtain physical, biological and socio-economical parameters to propose at the National Wetland Steering Committee to establish EPA under the National Environmental Act of Sri Lanka. The strength, weakness, opportunities and threats have been identified (SWOT) during the field survey in the selected wetlands (annexed 01 and 02) areas [7]. At the final stage zoning maps for possible threats from hap hazardously utilization of the area for numerous activities have been developed together with the proposed Environmental Protection Area map (figure 5) . Also zoning maps for possible expansion with the increase of population for settlements, tourism, agriculture and infrastructure have been developed for sustainable environmental management.





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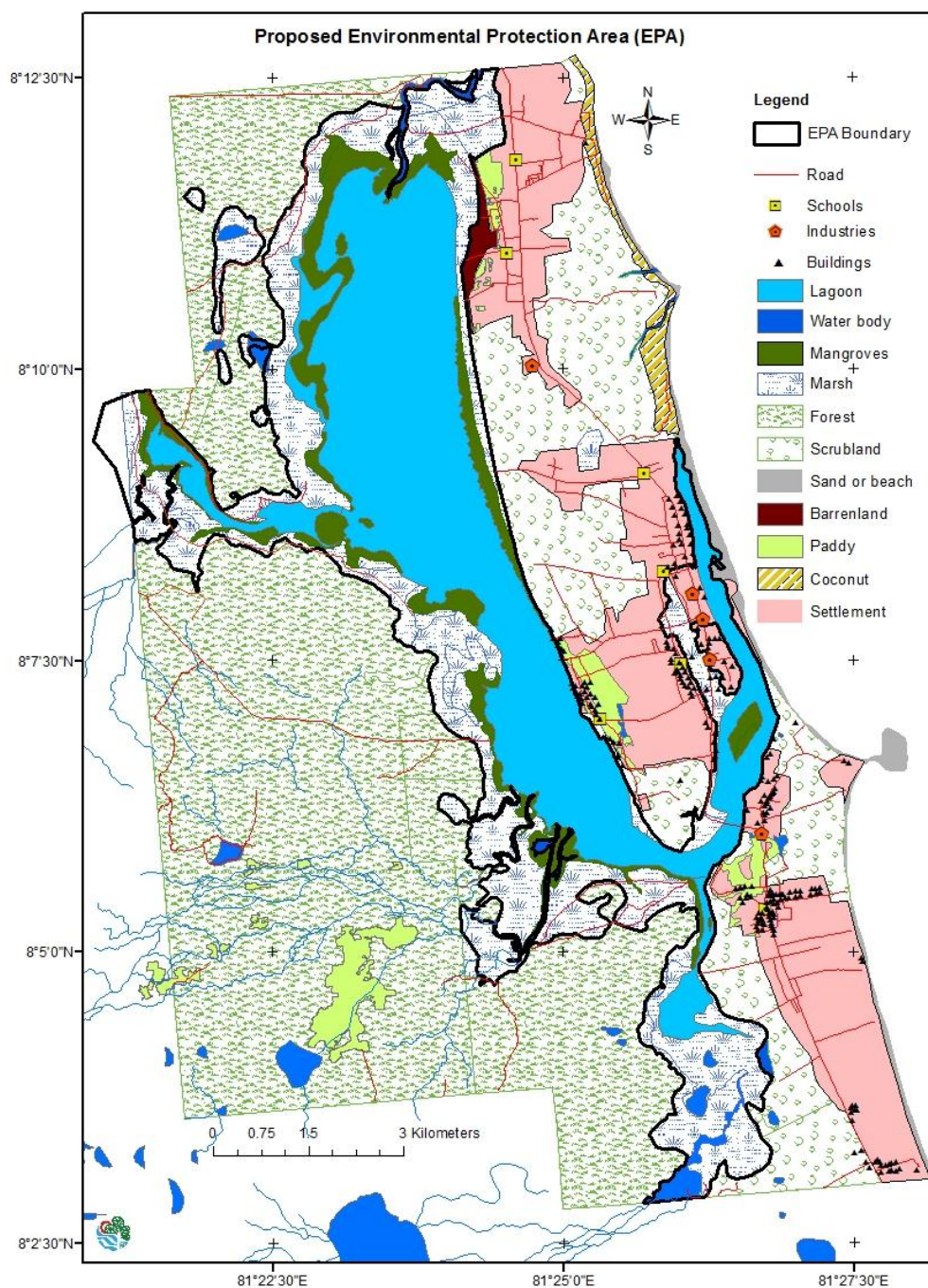
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**Figure 4.** Land development around the *Panichchankerni* Lagoon over the past 6 years and it is one of the key threats to destruction of mangroves.

**Table2.** Parameters considered on wetlands valuation.

Attributes	
1	Biological Diversity
2	Historical and Cultural Value
3	Scientific Value
4	Uniqueness
Function	
5	Water Quantity Regulation
6	Water Quality Regulation
7	Habitat for Fish
8	Habitat for Wildlife
Uses	
9	Plant production
10	Animal
11	Mineral
12	Water Storage Supply / energy
13	Truism Recreation
14	Research Education
15	Waste Water Disposal
16	Land Development





**Figure 5.** Proposed EPA for *Panichchankerni* Lagoon which is rich in mangroves and biological diversity.

## 5. Conclusion

There have been identified forty two (42) important wetland ecosystems during the field visits in the study area. The collected information through the questionnaire survey have been considered to identification of the most vital and threatened wetlands in the South eastern river basin. The selected seven wetlands are then analyzed using Landsat ETM+, AVNIR2 and PALSAR data and it has been revealed that the Landsat ETM+ is more eligible to spot out wetland eco systems and to avoid the

atmospheric disturbances ALOS - PALSAR have been used and it has been revealed that the polarized data are more suitable in delineation of forest and vegetative cover while AVNIR2 is moderately suitable in this methodology.

Finally, it has been done a statistical analysis to rank the identified wetlands according to the importance. At the final stage a SWOT analysis has been initiated to prepare guidelines in order to implement the areas as Environmental Protection Areas as per the National Environmental Act of Sri Lanka. Monitoring has been conducted by the CEA from time to time in order to prevent the violations of the act and further environmental implementations.

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**Annexure 1:** Internal and external strategy factors

	Weight	Rate	Scoring
<b>Strengths</b>			
1. Low population density	0.3	2	0.6
2. Less urbanization	0.2	1	0.2
3. Difficult to access some wetlands by community	0.3	2	0.6
4. Some areas are administrate under the security forces	0.4	4	1.6
5. Government and NGO support	0.4	3	1.2
6. Community support	0.5	4	2.0
7. Pollution control activities	0.4	4	1.6
<b>Weaknesses</b>			
1. Some important wetlands are privately owned	0.2	3	0.6
2. Exiting polluting Industries	0.3	2	0.6
3. Attitudes changing not easy	0.4	2	0.8
4. Lack of coordination	0.1	3	0.3
5. Not aware community well	0.2	3	0.6
6. Political influences	0.4	3	1.2
Total			11.9
<b>Opportunities</b>			
1. CEA implementation and WSC support	0.4	5	2.0
2. Other stakeholder support	0.3	4	1.2
3. Most of the wetlands are state owned	0.2	3	0.6
4. Allow Traditional fishing	0.1	4	0.4
5. Allow ecotourism	0.2	4	0.8
<b>Threats</b>			
1. Land filling	0.2	2	0.4
2. Encroachments	0.3	5	1.5
3. Waste disposal	0.2	5	1.0
4. Deforestation	0.2	2	0.4
5. Shrimp farming	0.4	2	0.8
6. Invasive species distribution	0.3	3	0.9
Total			10.0
Grand Total			22.1

**Annexure 2: Proximity matrix of SWOT analysis**

Proximity Matrix- Strength							
Case	Squared Euclidean Distance						
	Low population	Less urbanization	Difficult to access	Security Control	Government and NGO	Community support	Pollution Control
Low population	0.00	1.17	0.00	5.00	1.40	6.00	5.00
Less urbanization	1.17	0.00	1.20	11.00	5.00	12.30	11.00
Difficult to access	0.00	1.17	0.00	5.00	1.40	6.00	5.00
Security Control	5.01	11.00	5.00	0.00	1.20	0.17	0.00
Government &NGO	1.37	5.04	1.40	1.20	0.00	1.65	1.20
Community support	6.00	12.30	6.00	0.20	1.70	0.00	0.20
Pollution Control	5.01	11.00	5.00	0.00	1.20	0.17	0.00
Proximity Matrix - Weakness							
Case	Squared Euclidean Distance						
	Ownership	Polluting Industries	Attitudes	Lack of coordination	Not aware community	Political influences	
Ownership	0.00	1.00	1.10	0.10	0.00	0.40	
Polluting Industries	1.00	0.00	0.10	1.10	1.00	1.40	
Attitudes	1.10	0.10	0.00	1.30	1.10	1.20	
Lack of coordination	0.10	1.10	1.30	0.00	0.10	0.90	
Not aware community	0.00	1.00	1.10	0.10	0.00	0.40	
Proximity Matrix -Threats							
Case	Squared Euclidean Distance						
	Land filling	Encroachments	Waste disposal	Deforestation	Shrimp farming	Invasive species	
Land filling	0.00	10.22	9.36	0.00	0.20	1.26	
Encroachments	10.22	0.00	0.26	10.22	9.50	4.36	
Waste disposal	9.36	0.26	0.00	9.36	9.08	4.02	
Deforestation	0.00	10.22	9.36	0.00	0.20	1.26	
Shrimp farming	0.20	9.50	9.08	0.20	0.00	1.02	
Invasive species	1.26	4.36	4.02	1.26	1.02	0.00	
Political influences	0.40	1.40	1.20	0.90	0.40	0.00	
Proximity Matrix							
Case	Squared Euclidean Distance						
	CEA/WSC Support	Stakeholders Support	State ownership	Traditional Fishing	Eco-tourism		
CEA/WSC Support	0.00	1.65	6.00	3.65	2.48		
Stakeholders Support	1.65	0.00	1.37	0.68	0.17		
State ownership	6.00	1.37	0.00	1.05	1.04		
Eco-tourism	3.65	0.68	1.05	0.00	0.17		
Eco-tourism	2.48	0.17	1.04	0.17	0.00		