Research Article

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# Mangrove Forest Cover Change Detection Along the Coastline of Trincomalee District, Sri Lanka Using GIS and Remote Sensing Techniques

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## Abstract
*Mangroves provide valuable services to the coastal community in Trincomalee District despite they distributed in the small area. The objectives of this research are to map out the distribution of the mangroves and to detect the change in mangroves in Trincomalee District during the last 20 years. According to this study the reduction in the extent of mangroves caused by clearance for alternative land use including aquaculture, tourism. The total extent of mangroves in Trincomalee district was estimated using Landsat satellite imageries 1997 and 2017. The medium resolution of Landsat imageries may lead to underestimating relatively small, linear mangroves in coastal line of Trincomalee district. The occurrence of clouds in the coastal area can cause data gaps during analysis. This study estimated total mangroves in Trincomalee district was 20.26km2 and 15.07 km2 in 1997 and 2017 respectively and representing a loss of 5.19 km2 in the 20 years (1997-2017). Mangroves loss in the study area varied both spatially and temporally due to differences in habitat alteration pattern. However, Landsat images adequately aided to detect changes in mangroves in Trincomalee district which shows the rate of decline in mangroves.*

**Keywords:** Change Detection, GIS and Remote Sensing, Satellite Imageries, Mangroves

## Introduction
Mangroves are the group of trees that are dominant along many tropical and sub-tropical coastlines that grow in the estuarine margins of 124 countries and cover around 150,000 km$^2$ to 188,000 km$^2$ around the world [1]. Mangrove forests grow near the big river delta where sedimentation is high [2]. Mangroves cannot grow in areas where waves hit directly. The tangle root system of mangroves establishes sediments which protect the shoreline from the erosion. In addition, it maintains water quality and clarity from the pollutants originating from the land [2]. It is one of the most productive ecosystems that provide the wide range of ecosystem goods and services which are of immense value to the communities [3,4]. It is quite important to understand how human alter and use these ecosystems as so many species including human depend on mangroves forest. The ability to store carbon makes them an important candidate for conservation efforts [1]. Human uses mangrove forest directly and indirectly for several purposes such as building materials, food and medicinal purposes. The Global area of mangrove forest declined by 30-50% between 1980 to 2001 and 16% of species which are in mangroves face extinction [5]. Monitoring mangrove forest is not an easy task as these ecosystems are difficult to access and surveying [6]. Remote sensing data and satellite imageries are the complementary sources of information which are increasingly being used by researches. Most of the studies on mangroves used some sort of remote sensing data [7]. Earth observation satellite is excellent for monitoring mangroves [8]. Therefore, the objectives of this research are to map out the distribution of the mangroves and to detect the change in mangroves in Trincomalee District during the last 20 years (1997 -2017).

## Literature Review
Mangrove flora can be categorized as true mangroves and mangrove associates. True mangrove species grow only in the mangrove environment and do not extend into the terrestrial plant community whereas mangroves associates are found within or in the peripheral areas of mangrove wetlands [9]. Mangroves are predominantly important as habitat for diverse fauna and flora. Especially, it provides breeding grounds for marine species and its communities [3]. Mangroves provide a variety of ecosystem services for human beings. Those services have traditionally collected by the local communities in a sustainable manner [2]. Mangroves protect the coastal area from natural events [10]. Mangrove forests still occur as good existing forest in some regions of the world. However, the loss of mangroves has been significant in recent decades. The health and persistence of mangroves have been threatened by coastal development project and various form of non-renewable exploitations [3].

Rapid urban and industrial development intensify the pressure on many coastal areas [3]. Mangroves have been converted to other forms of land use such as agriculture, aquaculture, urban and industrial development and the road construction. The destruction of mangrove forest is not economically rational for short-term profit in terms of the true economic value of mangroves. The value of mangroves before destruction and after destruction is one of the greatest for all habitats [2]. The threats to mangrove ecosystem should be studied clearly to determine the distribution and rate of change of mangroves accurately [4,11].

Accurate mapping techniques may help to effectively monitor and manage mangrove forest. Conventional field surveying method is time-consuming and labour intensive. In addition, it is quite hard to determine mangrove distribution with filed surveying as accessibility of mangrove forest is more difficult. The use of remote sensing helps in monitoring the dynamic structure of mangrove forests as information and observations are performed by satellite sensors which are beyond human ability. Remote sensing is the science of obtaining information about an object, area or phenomenon through the analysis of data obtained from the equipment that is not touching the object [3]. The use of remote sensing technology has made a new era in land cover detection [12]. Further, monitoring mangrove forest could be effectively done through remote sensing technology [13]. Remotely sensed data have been used in many types of research to analyse the relationship between coastal land cover change and mangroves distribution [14,15].

Particularly, medium resolution (30m) multispectral data has been applied to monitor and map mangroves over the large area [13,15-17]. Remotely sensed images have been used to map forest and mangrove forest over the past few decades [4,18,19]. Multi-seasonal satellite images provide life history information on aquatic vegetation that can be effectively used for mapping aquatic vegetation [2,15].

Remotely sensed data on a single tidal date have been widely used to map mangroves in the previous studies. Incoming tides occasionally submerge the mangroves which are located in nearshore coastal wetlands. However, some areas of mangrove forest are likely to be submerged at high tides [20]. Therefore, changes in tides level lead to different mapping result of mangrove forest. As mentioned in the previous studies, result from single-tidal remotely sensed data underestimates the distribution of mangrove forest [3,21,22]. The mapping accuracy of mangrove forest using remotely sensed data may be improved by understanding the unique characteristics of mangroves [23-25]. Vegetation growing status and cover condition are explained using Vegetation Indices (VI) [18,21,23]. Normalized Differenced Vegetation Index (NDVI) is widely used to map and monitor a large area of forest cover [12]. However, NDVI values for mangroves are highly correlated with mangroves canopy cover, biomass and leaf area index [12].

A more efficient tool should be introduced to monitor the temporal change of mangroves in a huge area. Remote sensing technique has widely been used for mapping of coastal habitat. It is believed that remote sensing technique can be a reliable alternative to ground survey methods of mapping in the inaccessible region [26]. Further, remote sensing techniques are applied to mangrove forest for mapping, change detection, measure land cover and for management purposes [26]. Moreover, Landsat imageries are used in various Mangroves change detection studies and identification of mangroves wetlands [27]. The limitations on the distribution of current remote sensing data are discussed by Lee et al., and they recommended the location-based instant satellite image for a new generation of remote sensing [7].

In Sri Lanka, Mangrove forest is scattered along the shoreline, lagoons and the rivers that are influenced by tidal action. The largest tracts of mangrove habitats in Sri Lanka are found in Puttalam Lagoon, Kala Oya basin and Trincomalee [9]. Sri Lanka’s mangroves have high species richness and structure compare mangrove forest elsewhere in the world. This unique ecosystem is home to over 20 true mangrove species of Sri Lanka [9]. The mangrove systems covering an area of 6000-7000 ha are interspersed along the coastline of Sri Lanka. The largest mangrove system is located in Puttalam Lagoon – Dutch Bay – Portugal Bay complex and covers an area of 3385 ha. The other large concentrations are in Batticaloa and Trincomalee districts. The understanding of the importance of mangroves has been improved among the local people. However, the great concern should be given on enforcement and management of mangrove forest. Managing mangrove forest is a challenging task as high responsibility and obligation are attached to mangrove resources. Therefore, remote sensing technique was applied in monitoring and mapping temporal changes of the mangroves. The current status of mangrove forest can be determined by adopting temporal data on the species distribution [28].

## Study Area

Trincomalee District is located between $8^{0}$15’00” north and $9^{0}$00’00” north and from $80^{0}$45’00” east to $81^{0}$15’00” east in the eastern coast of Sri Lanka (Figure 01). The area covers a wide range of vegetation types. Mangroves were a single layer with simple hierarchy. The height of the mangroves in the study area is less than 5m. The study area consists of various geomorphologic habitats including muddy beaches, sandy beaches, and rocky beaches along the coastal line. Different types of mangrove forest occur in the study area that provides healthy habitats for various marine and terrestrial plants and animals.

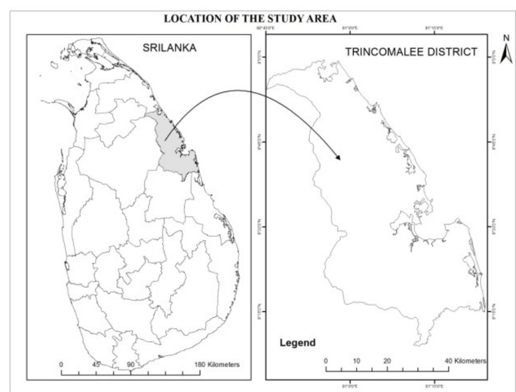



**Figure 1:** Map of Study Area

## Methodology

Digital image processing software ERDAS IMAGINE 15 and Arc GIS 10.4.1 were used to process, analyze, and integrate spatial data to reach the objectives of the research. Both Multi-temporal satellite data of Landsat and topographic map scale 1:50.000 were used in this research. Landsat TM at a resolution of 30 m of 1997 and 2017 was used for identifying mangroves distribution and for change detection. The Landsat images covering entire Trincomalee District acquired from US Geological Survey (USGS). The data were projected to Universal Transverse Mercator (UTM) coordinate system; Datum WGS 1984, zone 44 N. These data sets were imported in satellite image processing software (ERDAS Imagine version 15) to create a false colour composite (FCC) of the Trincomalee District Mangrove Forest. It was generated with the band combinations of 5, 4, and

3 which are near-infrared, red edge, and red band respectively. Other bands were not used to avoid introduction of atmospheric artefacts that could cause classification errors. FCC for the study area was generated using the layer stack option in ERDAS imagine 15. The study area was extracted from both images through subsetting of satellite images by taking Geo-referenced outline boundary of Trincomalee District as AOI (Area of Interest).

For land cover classification, supervised classification with maximum likelihood algorithm was applied in the ERDAS Imagine 15. Maximum likelihood algorithm (MLC) is one of the most popular supervised classification methods used with remote sensing image data. Minimum clouds cover images used for analysis. Change detection was evaluated by using the pixel-by-pixel comparison of the images. Classified images of 1997 and 2017 were overlaid to generate the change detection map. The misclassified areas were corrected using recode option in ERDAS Imagine. Google earth data provided opportunities to access classification accuracy. To evaluate the accuracy of the map, the accuracy assessment was implemented using Kappa coefficient calculation through the ERDAS Imagine 15.

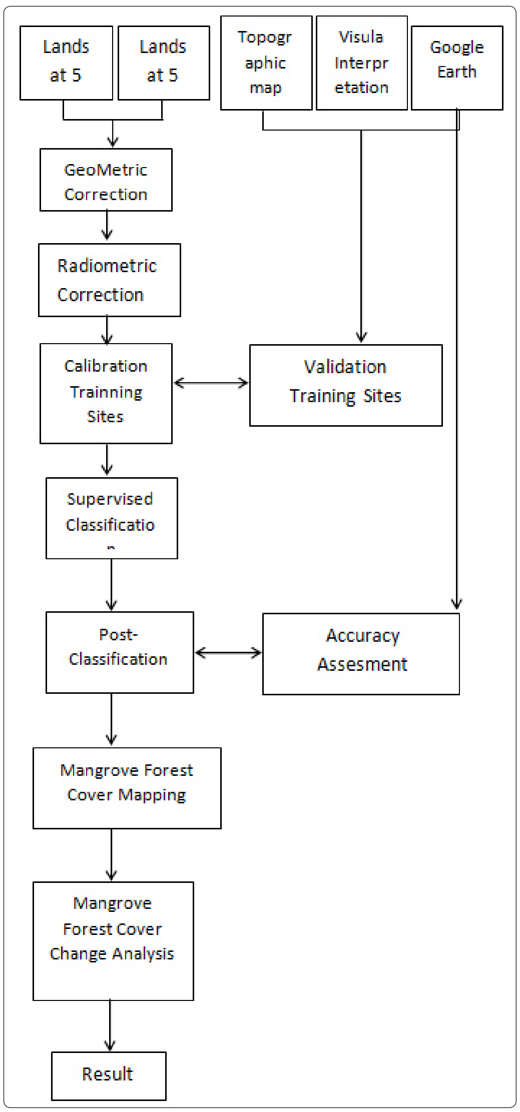



**Figure 2:** Flowchart of Methodology for Mangrove Change Detection

## Result and Discussion

The mangroves change detection process produced relatively accurate information with overall accuracies of 70% and 78.75% and Kappa coefficients of 0.6250 and 0.7031 in 1997 and 2017 respectively. Therefore, it was assumed to have performed adequately for the purpose of detecting changes in mangroves extent in Trincomalee District, Sri Lanka.

**Table 1: Summary of accuracy (%) and kappa statistics for 1997**

| **Mangroves in 1997** | | | | | |
|---|---|---|---|---|---|
| Class Name | Reference Totals | Classified Totals | Number Correct | Producers Accuracy | Users Accuracy |
| Mangroves | 20 | 20 | 16 | 71.66% | 60% |
| Overall Classification Accuracy = 70.00% | | | | | |
| Overall Kappa Statistics = 0.6250 | | | | | |

**Table 2: Summary of accuracy (%) and kappa statistics for 2017**

| **Mangroves in 2017** | | | | | |
|---|---|---|---|---|---|
| Class Name | Reference Totals | Classified Totals | Number Correct | Producers Accuracy | Users Accuracy |
| Mangroves | 20 | 20 | 18 | 80.61% | 67.49% |
| Overall Classification Accuracy = 78.75% | | | | | |
| Overall Kappa Statistics = 0.7031 | | | | | |

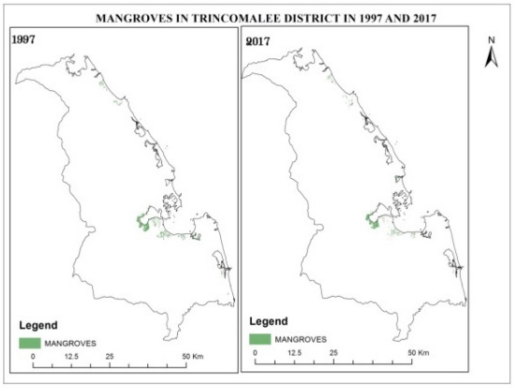
Details of change of mangroves in the study area are given in the following table 3 and figure 3-6. This study shows that mangrove forests were extensively distributed within 2 km from the coast of the study area. The total area of mangrove forests was declined and fragmentation was apparent. In some areas, mangroves are well protected

**Table 3: Mangrove Forest Change**

| **Change of Mangrove forest** | | | | | |
|---|---|---|---|---|---|
| | 1997 | 2017 | Change | Change % | Loss of mangroves per year |
| Mangrove | 20.26km$^2$ | 15.07km$^2$ | 5.19 km$^2$ | 25.61% | 0.26km$^2$ |

Temporal and spatial changes in mangrove forest extent in Trincomalee District are shown in figure 3-6. The total area of mangrove forest in Trincomalee District has declined continuously since 1997.

Mangrove forest cover along the coastline of Trincomalee District experienced a net reduction from 20.26km$^2$ in 1997 to 15.07km$^2$ in 2017, a decline of 5.19 km$^2$ or 25.61%. An average loss of mangrove forest is 0.26km$^2$ over the period of 20 years (1997-2017). The Rate of mangroves loss differs from area to area and over time. The highest rate of mangroves changes has seen in Kinniya DS division in the period between 1997 and 2017. The larger areas of mangroves in Tambalakamam, Kinniya, Seruwila DS divisions also showed the high rate of loss. The main drivers of mangrove forest loss at the local level have been identified as habitat alteration and development activities in the coastal area.



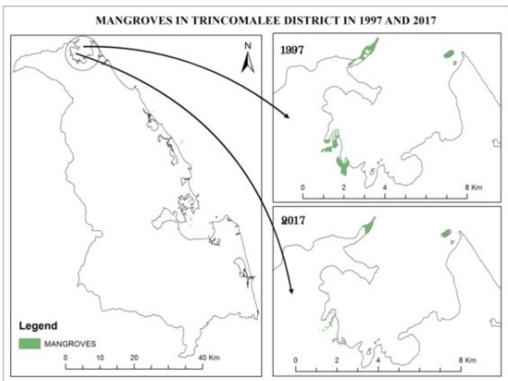
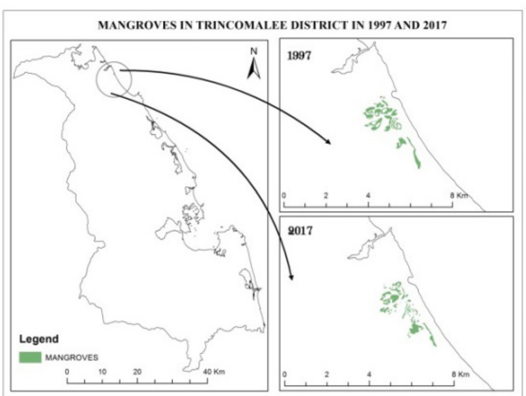




**Figure 3:** Mangroves in Trincomalee District in 1997 and 2017



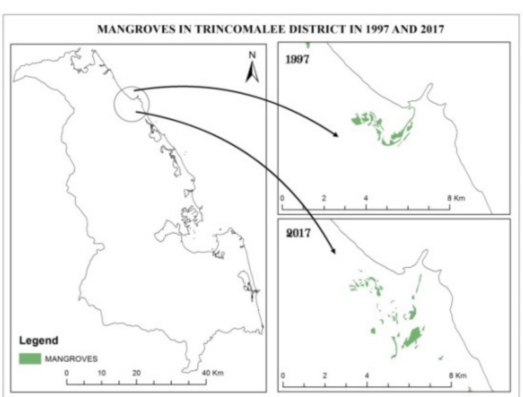
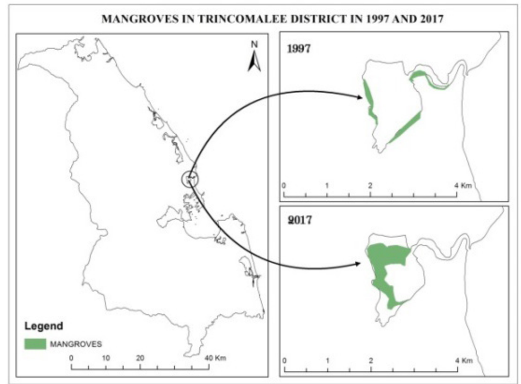




**Figure 4:** Mangroves in Trincomalee District in 1997 and 2017



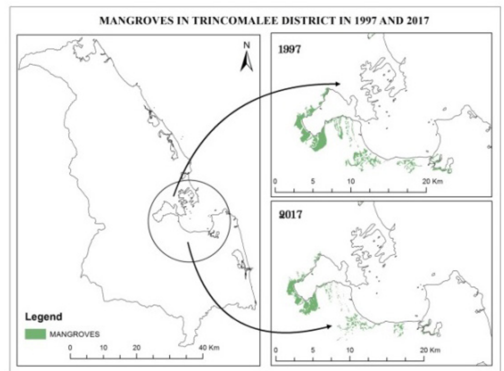




**Figure 5:** Mangroves in Trincomalee District in 1997 and 2017

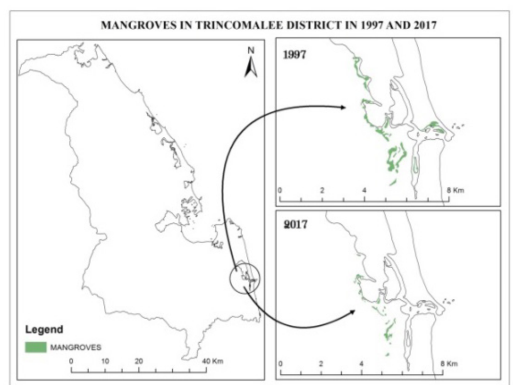



**Figure 6:** Mangroves in Trincomalee District in 1997 and 2017

## Conclusion

In conclusion, monitoring using remote sensing and GIS could detect mangrove forests cover changes in the coastal area. The given information on current status and rate of change of mangroves in Trincomalee District will be of value to many stakeholders in a number of ways. The findings of this research have contributed to understanding the special distribution and rate of decline of mangrove forest in Trincomalee District.

The conservation and restoration of mangrove forests demand accurate data on the rates of loss and current extent of mangrove forest in Trincomalee District. High-resolution satellite images can be used to map mangrove forests in future that could go well beyond the present estimate of mangrove coverage in the coast of Trincomalee District. Further, species distribution and degradation can also be detected using high-resolution satellite images. A precise classification would be adapted in order to species-specific monitoring for the benefit of managing and sustaining the productive forest for supporting the ecological function of the mangrove system.

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