Estimation of the Temporal Change in Carbon Stock of Muthupet Mangroves in Tamil Nadu Using Remote Sensing Techniques

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Aim: To study the carbon storage potential of Muthupet mangroves in Tamil Nadu using Remote sensing technoiques.

Study Design:

Place and Duration: The study is carried out in Muthupet Mangroves for the years 2000, 2010 and 2017.

Methodology: In this study the remote sensing images were processed using the ERDAS and ArcGIS software and the NDVI (Normalized Difference Vegetation Index) has also been applied to estimate the quantity of carbon sequestration capability for the Avicennia marina mangrove growing in the Muthupet region for the period 2000-2017. The formula proposed by Lai (2007) was used to calculate the carbon stock using geospatial techniques.

Results: The results show that the mangroves in Muthupet region has NDVI values between -0.671 and 0.398 in 2000, -0.93 and 0.621 in 2010 and -0.66 and 0.398 in 2017. The observation indicates the reliability and validity of the aviation remote sensing with high resolution and with near red spectrum experimented in this research for estimating the the Avicennia marina (Forsk.) mangrove growing in this region. The estimated quantity of carbon di oxide sequestrated by the mangrove was about 1475.642 Mg/Ha in 2000, 3646.312 Mg/Ha in 2010 and 1677. 72 Mg/Ha in 2017.

Conclusion: The capacity of the Avicennia marina growing in Muthupet region to sequestrate carbon show that it has a great potential for development and implementation. The results obtained in this research can be used as a basis for policy makers, conservationists, regional planners, and researchers to deal with future development of cities and their surroundings in regions of highly ecological and environmental sensitivity. Thus the finding shows that wetlands are an important ecological boon as it helps to control the impact of climate change in many different ways.

Keyword: Mangroves, Avicennia marina, Remote Sensing, carbon sequestration, Wetlands

ABSTRACT

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1. INTRODUCTION

An ever-increasing body of scientific evidence suggests that the anthropogenic release of carbon dioxide (CO2) has led to a rise in global temperatures over the past several hundred years (Crowley, 2000; Bradley, 2001; Ni et al., 2012). If this theory holds true, unabated release of greenhouse gases will result in global warming that may lead to significant and potential catastrophic alteration of climate, natural hydrological and carbon cycles globally. In an effort to alleviate the possible impact of atmospheric CO2 on global climate, several strategies are under development to sequester the CO2 released from stationary and mobile sources (Herzog et al., 1997; U.S. Department of Energy, 1999). These carbon management strategies include: (1) increasing the efficiency of energy conversion; (2) using low-carbon or carbon-free energy sources; and (3) capturing and sequestering anthropogenic CO2 emissions from large point sources such as coal-fired thermoelectric generation facilities. The third strategy, termed ‘‘CO2 sequestration”, has gained increased attention in recent years, and would promote continued use of fossil fuels for the generation of electric power by reducing its CO2 footprint.

The mangrove plants fresh, which is mostly located at estuaries, is more difficult than land based forest to be investigated and monitored. Being one of the earliest indicators for climate changes, the mangrove ecological system is easily affected by the changing environmental factors such as increasing atmospheric CO2, average temperature, mean sea level elevation, and salinity. Hence, the influence of climate changes on global distribution of mangrove and regional ecology is becoming an important topic for the various government agencies and environmental protection groups (Bird, 1995; Woodroffe, 1995). The prediction of global climate toward the end of the 21st century based on the average data collected during 1980~1999 as published in the 2007 UN IPCC climate change report indicates that global warming has caused the atmospheric temperature to increase by 0.74℃ for the last 100 years (1906-2005) to cause obviously increasing frequency and extend of meteorological disasters. In recent years, the improvement of various remote sensing technologies and awaking environmental protection cognizance lead to the tendency of applying remote sensing (RS) for investigating and studying mangrove (Ramsey and Jensen, 1996; Green et al., 1997; Kovacs et al., 2004). Tateda et al. (2005) further used the RS technology to estimate the quantity of carbon sequestered by mangrove. Diallo et al (1991) used AVHRR data for monitoring of Savanna primary production in Senegal. Gebreslasie et al (2008) developed an empirical relationship between forest structural attributes and ASTER data. Mathieu et al (2007) used the IKONOS image alone for mapping large-scale vegetation communities in the urban forest. Gitelson et al (2002) investigated the relationship between forest variables and vegetation indices in a Nothofagus pumilio forest. Roy and Shirish (1996) used the Landsat TM images and developed a regional level biomass maps for the Madhav National Park. In their studies they used two different approaches viz. Statistical sampling technique and spectral response modelling. In this research, the multiple spectrum RS technology is used for investigating the NDVI (Normalized Difference Vegetation Index) of mangrove in Muthupet region (Tamil Nadu, India) in order to estimate its carbon sequestration capacity.

2. MATERIALS AND METHODOLOGY

2.1 STUDY AREA

Muthupet mangrove wetland of Vedaranyam area is located in the southern most end of the Cauvery delta in the districts of Nagapattinam, Thrivarur and Thanjavur (Figure 1). The total area of the lagoon as estimated from the satellite data LANDSAT ETM image, which is having a resolution of 30 m in space for the period April 2015 is 13.32 km2 and it has a volume of 9.6 x 106 m3 (as estimated for February -March 2015). It is a part of a large coastal wetland called the Great Vedaranyam Marsh. This area has a gentle slope towards Palk Strait of Bay of Bengal. The distributaries of Cauvery viz., Paminiyar, Koraiyar, Kandaparichanar, Kilaithangiyar and Marakkakoraiyar discharge their water into the wetlands and form a large lagoon before reaching the sea. Besides the lagoon, the wetland includes many tidal streams, channels and small bays, bordered by thick mangroves; and a number of artificial canals dug across the mangrove wetlands, particularly in their western part and fished intensively. The lagoon receives inflow of freshwater during northeast monsoon through the above drainage arteries occupied by agricultural soils, mangrove swamps and aquaculture ponds. From February to September, freshwater discharge into the mangrove wetland is insignificant. The soil in the lagoon is clayey silt and towards the landward side it is silty clay due to fresh silt deposits.

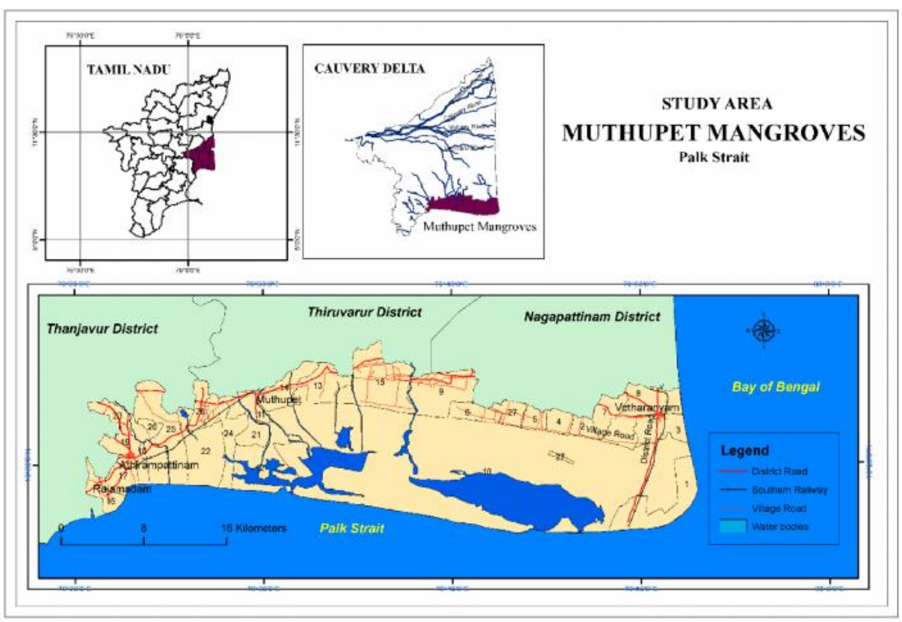

Figure 1: Study area, Muthupet Mangroves

Table 1: Data Sources

S.No	Data and Sensor	Spatial Resolution
1.	Landsat TM 2000	30

2.	**Landsat ETM 2010**	**30**
3.	**Landsat 8 OLI 2017**	**30**

2.2 METHODOLOGY

The objective of this research is to evaluate the feasibility of using the RS technology to evaluate the carbon sequestration capability of mangrove. The satellite data has been taken up from USGS Earth explorer for the years 2000, 2010 and 2017 (Table1). The mangrove growth in the study areas conforms to urban forest that is defined as the grove growing in densely populated regions. Hence, the tree growth is limited and controlled by anthropogenic factors such as land PIF were selected from the imageries were distributed equally in the concrete structures and use so that the artificially planted and natural growing trees form a closely related ecological system. The formula proposed by Lai (2007) for estimating the carbon sequestration is expressed as

$$\textbf{Carbon} = a^*e^{(NDVIb)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where a and b are the normalization coefficients that were obtained on the basis of the PIF (Pseudo Invariant features) selected from the subject and reference images, applying the following formula:

$$a_i = \frac{s\,ri}{s\,si} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$b_i = m_{ri} - ai\ {}^*m_{si} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

(where: sri – standard deviation of the PIF set in the reference image for band (i); ssi – standard deviation of the PIF set in the subject image for band (i); mri – the average value in the reference image for band (i); msi – the average value in the subject image for band(i) (Table 2). NDVI model was run for the 2000, 2010 and 2017 images. (Figure 2). The coefficients were derived from the NDVI images. From these coefficients the formula 1 was used to arrive at the carbon stock values for the Muthupet mangrove region. From the values arrived in the attribute table, the total carbon stock was calculated by summing the values for the period and similarly the total carbon stock for the rest of the years were also derived.

3. RESULTS AND DISCUSSION

From the above formulae the coefficients derived from the imagery statistics were used in the regression equation for deriving the carbon storage of the mangrove. Radiometric normalization using PIF was developed by Salvaggio, (1993); Schott et al (1988). The objects that have reflectance that doesn't change in different scenes from the same area. These objects don't show variation in the reflectance in different seasons or biological seasons. The other manmade objects that doesn't change over a period of time were also selected. These were taken with reference to the literatures. (Yang et al (2000), Yuan et al (1996), Elvige et al (1995).

$$\text{PIF set} = \{(\text{band } 4 / \text{band } 3) < 1 \text{ and band } 4 > 180\}$$

The coefficients that were derived from the formulae were therein used to arrive at the carbon stick values for the mangroves for the years 2000, 2010 and 2017 by substituting the coefficient values in the formula.

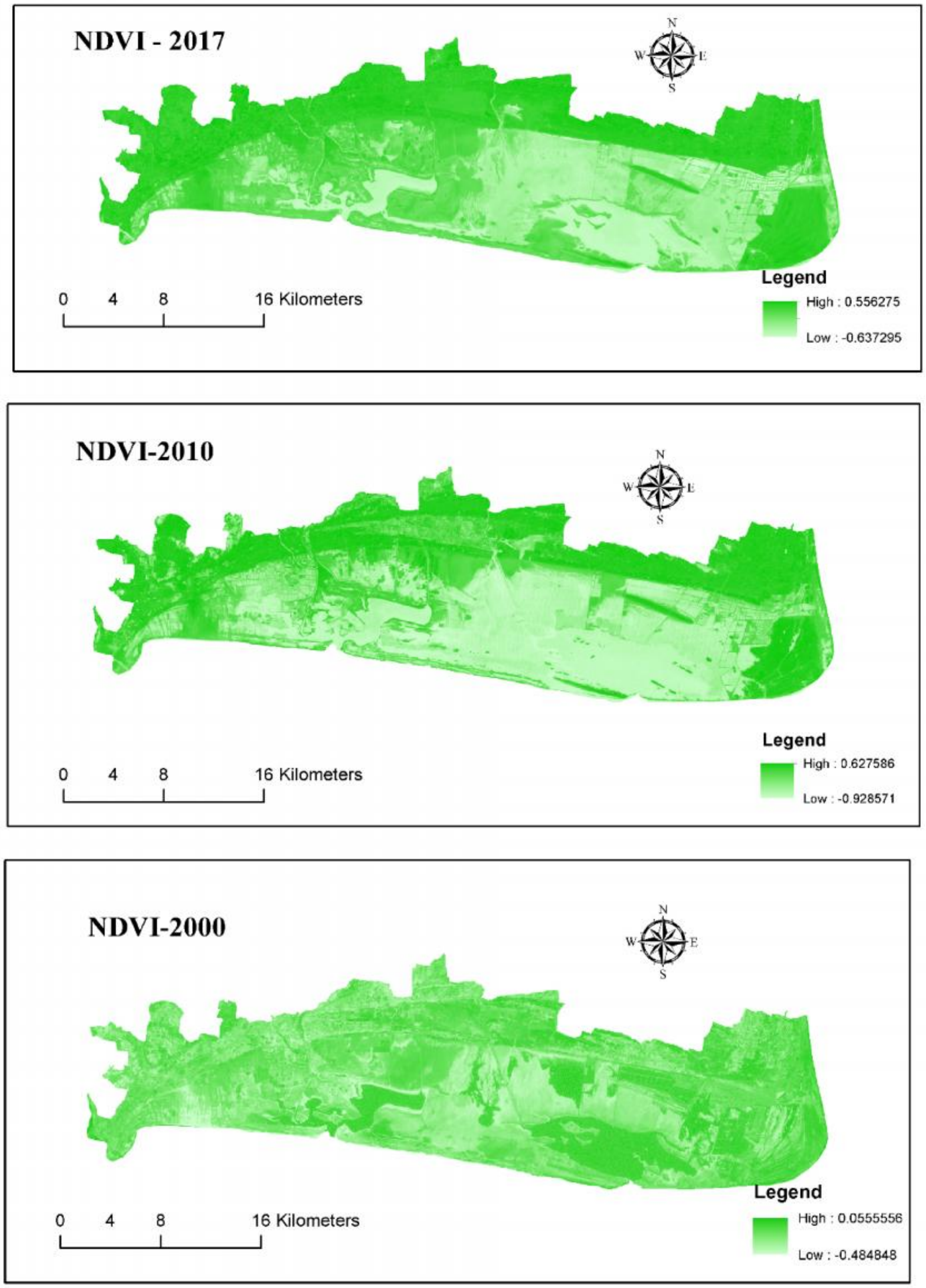

Figure 2: Normalised Difference Vegetation Index 2000, 2010 and 2017

Table 2: The Correlation coefficients derived from Imagery statistics for three different years

Correlation Coefficients			
Year	2000	2010	2017
Coefficient a	0.487	0.738	0.489
Coefficient b	-0.0128	0.382	0.178
Mean	0.4096	-0.264	0.1866
Standard Deviation	0.415	0.274	0.202

3.1 Carbon storage equation for Muthupet Mangroves for three different years

The plot of stored Carbon (Mg /C pixel) vs scaled NDVI were taken for the 10 of the sample area (60 plots) (Myeong et al, 2006). The final regression equation of the carbon storage and the vegetation index is

Carbon = $0.487*e^{(NDVI*0.-0.0128)}$ for the year 2000

Carbon = $0.738*e^{(NDVI*0.382)}$ for the year 2010

Carbon = $0.489*e^{(NDVI*0.178)}$ for the year 2017

Where Carbon is the total Carbon Storage (Mg C/pixel) and NDVI is the Landsat NDVI value. (Table 3)

The value was then calculated for hectare. The Above ground biomass was found out using ERDAS Imagine 2014. The Below Ground Biomass was 26% of the Above Ground Biomass. From the AGB the BGB was calculated. From these the Total Biomass was calculated by adding the AGB and BGB. The biomass value was converted into carbon stock by using the conversion factor with the equation. (Leith, 1963). Biomass values were multiplied by 0.475 to get carbon storage values of the urban trees. (Whittaker et al, 1973). The carbon di oxide sequestered were calculated by multiplying the derived value with 3.67.

3.2 Temporal Change in Total Carbon storage

From the above equations, the research estimates that the total amount of carbon storage for the 3 different years.

Table 3: Carbon stock estimation of Muthupet Mangroves for 3 different time periods

YEAR	AGB ($Mg\ ha^{-1}$)	BGB ($Mg\ ha^{-1}$)	TGB ($Mg\ ha^{-1}$)	CS ($Mg\ ha^{-1}$)
2000	693.724	180.368	874.092	402.082
2010	771.942	200.705	972.648	457.145
2017	1714.192	445.689	2159.881	993.545

The carbon stored in the Muthupet mangroves is found to increase gradually from 2000 to 2010. After the disastrous effect of the tsunami in 2004, many awareness programmes have been conducted to conserve and regenerate the mangrove forests. Hence many people including government administrative bodies and non-governmental organisations have taken immense effort to conserve the mangroves and replanted the mangroves as a conservation measure. Hence the vegetation has increased reasonably in the region.

4. CONCLUSION

- The aforementioned discussion reveals that if an adequate resolution is selected, and complete visible and near infrared light spectra are covered, the RS method is feasible to obtain reliable results on evaluating the Avicennia marina mangrove.
- For addressing the unique characteristics of the Avicennia marina mangrove growing in the Muthupet region such as bushy growth in a long and narrow clustering area, RS images with high resolution, e.g. those obtained using aviation RS or the ISONOS or QUICKBIRD satellites launched after September 1999 will be appropriate.
- Additionally, the RS should cover visible light (especially red and green light spectra) and near infrared spectra.
- This RS research was carried out during the 17-year period from 2000 till 2017. Hence, the estimated quantity of carbon sequestration based on RS information collected during the wet season is lower than the actual carbon sequestration capacity of the mangrove in the study areas.
- Although the Avicennia marina mangrove trees are often cut down, they grow prolifically near Muthupet seashore indicating that the plant has adapted to the local environment.
- In future, the government may have the policy to encourage private sectors to plant the Avicennia marina mangrove in Muthupet and abandoned fish farms along the seashore for achieving carbon sequestration, end-of-the-pipe treatment of wastewater, and environmental beautification in addition to providing educational function, promoting tourism, and accumulating assets for economic benefits from carbon exchange.

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