ISSN : 0974 - 7451 Volume 6 Issue 5

Trade Science Inc.

Environmental Science
An Indian Journal

Current Research Paper

ESAIJ, 6(5), 2011 [229-238]

# Carbon sequestration potential of forest: A case study in Neyyar wild life sanctuary

J.Firmin Linus[1*], P.V.Karunakaran[2], G.Devi[1]

[1]Anna University of Technology, Tirunelveli- 627 007, Tamil Nadu, (INDIA)

[2]Centre for Environment and Development, Thiruvananthapuram, Kerela, (INDIA)

E-mail : firmin.linus@gmail.com

*Received: 27th June, 2011 ; Accepted: 27th July, 2011*

## ABSTRACT

Global Warming is becoming a huge problem for society due to Green House Gas emission in the wake of modernization and urbanization. The process by which carbon sinks remove carbon dioxide ($CO_2$) from the atmosphere is known as carbon sequestration. With the help of remote sensing and geographic information system (GIS) biomass and corresponding carbon sequestration potential of the forest of Neyyar Wildlife Sanctuary is estimated in this study. At a large scale, forests offer better carbon sequestration than any other terrestrial landuse. Satellite data can be used to estimate ground biomass, seasonal productivity and carbon sequestration. This study provides a methodology to assess the biomass and carbon sequestration potential with quick turnaround time. In this study with the acquired information about the presence of different types of forests and their corresponding capacity to store carbon in the Neyyar Wildlife Sanctuary have been classified. Neyyar Wildlife Sanctuary, forming the catchments of the Neyyar reservoir it is of 30 Kms east of Trivandram, the capital of Kerala. Classified image and NDVI imaged of the study area are used to find out the biomass for various vegetation classes. As a result it is found that carbon sequestration capacity of evergreen forests is most followed by semi-evergreen and deciduous forests. © 2011 Trade Science Inc. - INDIA

## KEYWORDS

Remote Sensing;
GIS;
Biomass;
NDVI image;
ArcGIS;
EARADAS.

## INTRODUCTION

### General

Green House Gases (GHGs) is one of the most discussing events of today in national and international levels. It is believed that anthropogenic increase in GHGs will result in temperature rise by 1.4 to 5.8°C during next century. A 1°C rise in temperature will displace the limits of tolerance of land species some 125 km towards the poles. $CO_2$ is among the most important anthropogenic GHG and now the enrichment of the atmosphere with this at concentrations slightly above 370 p.p.m., is unquestioned. Because forests play an important role in the carbon cycle, radiation budget, and in maintaining climatic balance, variation in biomass quantity can be a good indicator of changes in these processes. Moreover, since the Kyoto protocol on greenhouse gas emission reduction, forests have been targeted for reducing carbon emissions because they store great quantities of carbon and exchange it with the atmosphere through photosynthesis and respiration. Around 3000 B.C, nearly 80% of India was forested, but in 1999 it was critically reduce to 19.4%. To overcome this critical situation, study of present carbon budget and concluding some enhancing measures of our native forest is highly significant.

## Carbon sequestration

Carbon sequestration is a hot research field that owes its latest popularity to the upswing in global attention directed towards global warming. The phrase "carbon sequestration" refers to efforts to capture excess carbon dioxide from the atmosphere, condense it, and store it in some benign way. Carbon capture and storage (CCSD) technologies are implemented in some limited way in many fossil fuel power plants. The technology for capturing is ahead of the technology for storing, which is just starting to be explored seriously. Carbon sequestration could be an important part of the fight against greenhouse gases.

The most primitive form of carbon sequestration would be to simply plant more trees. Plants naturally take $CO_2$ from the atmosphere and output oxygen. Much of the carbon from the $CO_2$ is integrated into their biomass and released safely into the soil upon their deaths. A more sophisticated version of carbon sequestration would be the pursuit of artificial photosynthesis. If the principles of photosynthesis could be reliably instantiated in solar cell-like devices, they would both generate power and remove excess carbon dioxide from the atmosphere, probably at rates substantially superior to that of plants, which are limited to a certain palette of chemical reactions and approaches.

## GIS and remote sensing

A Geographic Information System integrates hardware, software, and data for capturing, managing, analysing and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, reports, and charts.

Remote Sensing is the science and art of acquiring information about material objects, areas, or phenomena from remote. Specifically remote sensing is the process of earth system observation from air or space using sensors mounted on aircrafts or satellites. The sensors detect and record the electromagnetic radiation (EMR) reflected or emitted by the earth objects.

## Biomass estimation

Carbon sinks removes $CO_2$ from atmosphere through absorption. There should be a precise, accurate and cost effective method for measuring the quantity of carbon sequestration. There are many conventional methods for quantification of sequestrated carbon. Many of these methods are complicated, expensive and limited in their coverage. Such limitations impede sound quantification and monitoring of carbon. Remote Sensing can provide answers against such measurement and monitoring limitations.

## Conventional methods of biomass estimation

Several methods have been used to estimate forest biomass. Some of the commonly employed techniques are (i) the harvest of average size trees either for stand or within given size classes, (ii) the harvest of all materials in an unit area, and (iii) the harvest of individuals over a wide range in size and establishing the relationship between biomass and easily measureable plant parameters, such as, diameter and/or height. The height-diameter at breast height (h-dbh) relationship to biomass in forest stand is well formulated.

## Biomass estimation - a remote sensing approach

It is possible to use remote sensing canopy reflectance models for estimating foliage, woody biomass and productive potential. Biomass distribution in forest ecosystem is a function of vegetation type, its structure and site condition. Ground based sampling in functional homogenous vegetation categories is an approach which has found acceptability in the recent past. Earlier studies have investigated the relationship of spectral vegetation indices derived from satellite data to surface vegetation parameters using correlation or regression analysis. The present study aims to quantify biomass distribution using satellite data in tropical forest of Western Ghats. These forests are characterized by heterogeneity, temporal variations due to change in penology and background reflectance.

### Rationale of the study

Traditional methods of estimating forest biomass at the tree level use allometric equations, by measuring tree wood density, height and diameter at breast height (DBH). These methods are destructive, time consuming, expensive, and feasible to small areas only. Satellite images are good source for plant productivity measurement through biomass and carbon content measurements of vegetation. Healthy vegetation absorbs blue- and red-light energy to fuel photosynthesis and reflect near infrared wavelengths. A plant with more chlorophyll will reflect more near-infrared energy than an unhealthy plant. Thus, analyzing the spectrum of both absorption (R) and reflection (NIR) of plants can provide productivity and finally the carbon content. Vegetation index (VI) is a measure of the ratio between the radiance values in R and NIR wave bands. A more specific representation of the vegetation index is the Normalized Difference Vegetation Index (NDVI) which is a normalized ratio of the NIR and R bands.

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{R}) / (\mathrm{NIR} + \mathrm{R}) \quad (1)$$

### Research objectives

### General objectives

The main objective of the study is to estimate the carbon sequestration potential and the present carbon budget of the study area. To achieve this objective, the following tasks are carried out:

### Specific objectives

- Generation of NDVI map of the area
- Forest type map using digital classification of satellite data
- Calculation of areas of different natural forest types
- Comparison of the present biomass of unit areas of different forest types.
- To estimate the present carbon budget in the study area.

## EXPERIMENTAL

### General

The Neyyar Wildlife Sanctuary is situated about 32 km from the city of Thiruvananthapuram, the capital city of Kerala. The Neyyar Wildlife Sanctuary is also a part of the beautiful Neyyar Reservoir, which is an excellent tourist destination and the place offers excellent conditions for boating. The scenic Agasthyakoodam Peak, rising to a height of about 1890 meters above the sea level, is located in close proximity to this wildlife sanctuary.

### Study area

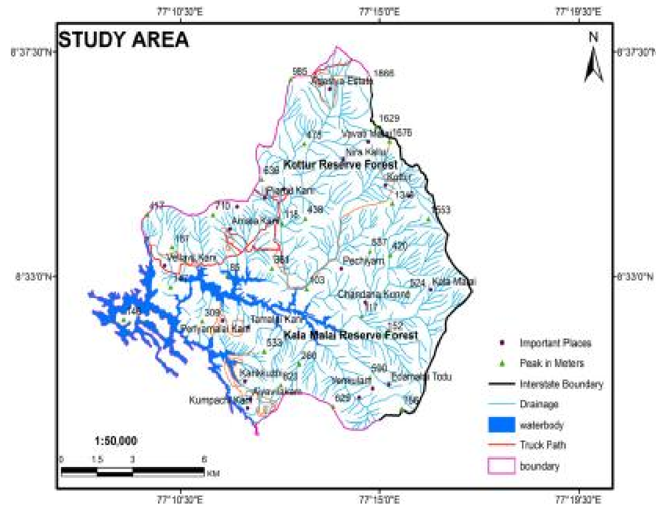


**Figure 1 : Neyyar wild life sanctuary, the Southern most protected area of Western Ghats.**

The area selected for the study is the Neyyar river basin constituting the catchment area of Neyyar reservoir. It includes the drainage basins of its tributaries, Mullayar and Kallar and forms part of the Neyyar Wildlife Sanctuary in Thiruvananthapuram district. It is spread over the southeast corner of the Western Ghats, and covers a total area of 128 sq km. It is located between 77°8' and 77°17' E longitudes and between 8°29' and 8°37' N latitudes.

### Data used

- Satellite Image - IRS P6 LISS 4 Image of the year 2007.
- Toposheet of the study area of the year 1998.
- Forest Division Boundary map given by the Forest Department of Kerala Government.
- Field data.

### Satellite data

The LISS-IV image is a multispectral high resolution image with a spatial resolution of 5.8m at nadir. This image can be obtained in two modes based on the operating mode of the camera: i) Mono-spectral and ii) Multi-spectral. In multi-spectral mode, data are collected in three spectral bands, 0.52 to 0.59 microns (Band 2-Green)

0.62 to 0.68 microns (Band 3-Red)

0.76 to 0.86 microns (Band 4-NIR)

In the multispectral mode, the sensor provides data corresponding to pre-selected 4096 contiguous pixels, corresponding to 23.9km swath.

In Mono mode, the data of full 12K pixels of any one selected band, corresponding to a swath of 70 km can be transmitted. Normally, Band-3 data are transmitted in this mode.

## Orbit parameters

The LISS IV have an altitude of 817km and inclination of 98.96 degree. The specification of LISS IV is shown in TABLE 1.

**TABLE 1 : Orbit Parameters**

| Orbits/cycle | 341 |
|---|---|
| Semi major axis | 7195.11 km |
| Altitude | 817 km |
| Inclination | 98.69 deg |
| Eccentricity | 0.001 |
| Number of orbits/day | 14 |
| Orbital period | 101.35 minutes |
| Repetivity | 24 days |
| Distance between adjacent paths | 117.5 km |
| Distance between successive ground tracks | 2820 km |
| Ground trace velocity | 6.65 km/sec |
| Equatorial crossing time | 10.30 A.M |

## Resolutions

The spatial resolution of IRS LISS 4 image is 5.8m, and in the Multi-spectral mode, data are collected in three spectral bands,

B2: 0.52—0.59, (green); B3: 0.62—0.68, (red); B4: 0.77—0.86 (NIR)

**TABLE 2 : Spectral Resolution**

| Band | Wavelength Region (µm) | Resolution (m) |
|---|---|---|
| 1 | 0.52 - 0.59 (green) | 6 |
| 2 | 0.62 - 0.68 (red) | 6 |
| 3 | 0.77 - 0.86 (near-IR) | 6 |
| 4 | 1.55 - 1.70 (mid-IR) | 6 |
| pan | 0.62-0.68 (red) | 6 |

## LISS-IV Specifications

The LISS-IV image has the additional feature of off-nadir viewing capability by tilting the camera by +/- 26 degree. This way it can provide a revisit of 5 days for any given ground area and its specification are given below in TABLE 3

**TABLE 3 : Specification of Liss iv image.**

| | |
|---|---|
| IGFOV (Across Track) | 5.8 m |
| Ground sampling distance | 5.8 m |
| Spectral Bands | B2, B3, B4 |
| Swath width | 23.9 km(multispectral mode)<br>70 km(mono-spectral mode) |
| Saturation radiance | B2=55<br>B3=47<br>B4=31.5 |
| Integration time | 0.877714 msec |
| Quantization | 10 bits |

## Software Used

Following software have been used for satellite image analysis, and for the generation of biomass map through NDVI Analysis.

- ArcGIS 9.3
- Eradas Imagine 9

## ArcGIS an overview

ArcGIS provides a scalable framework for implementing GIS for a single user or many users on desktops, in servers, over the Web, and in the field. ArcGIS is an integrated family of GIS software products for building a complete GIS. It consists of several primary frameworks for deploying GIS:

- ArcGIS Desktop - An integrated suite of professional GIS applications.
- Server GIS - ArcIMS, ArcGIS Server, and ArcGIS Image Server.
- Mobile GIS - ArcPad and ArcGIS Mobile for field computing.

ArcGIS Desktop gives you an overview of the ArcGIS Desktop system and shows that how to access the basic functions of the software. The main application in ArcGIS is ArcMap, which is used for all mapping and editing tasks as well as for map-based query and analysis. ArcMap represents geographic information as a collection of layers and other elements in a map view. There are two primary map display panels in ArcMap: the data frame and the layout view. The

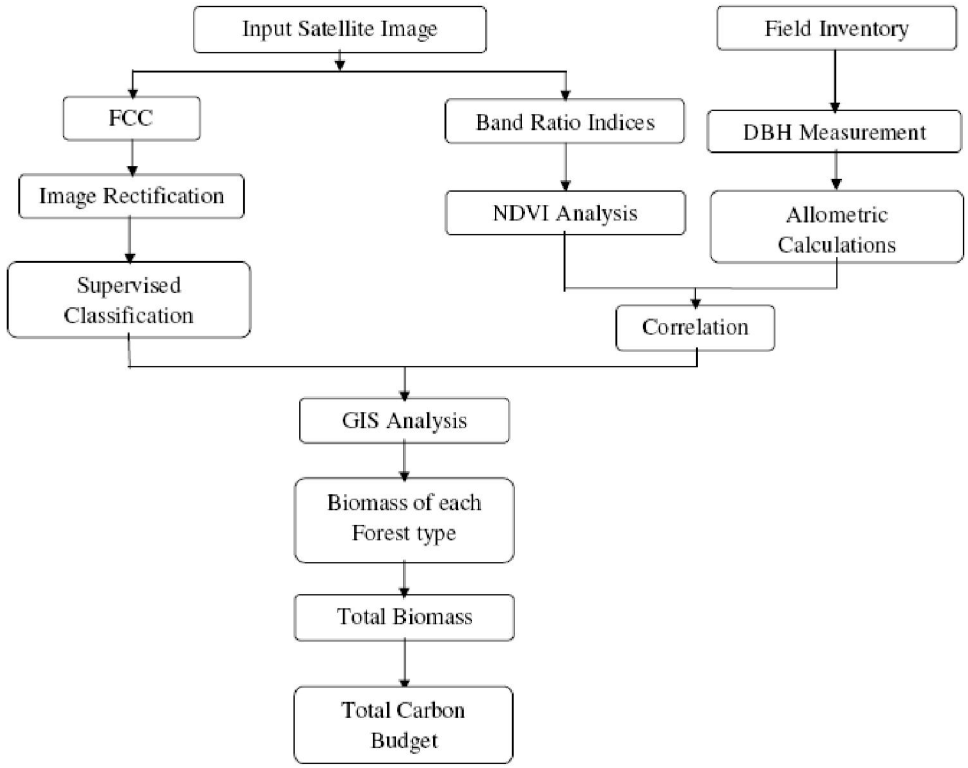


**Figure 2 : Methodology Flowchart**

data frame provides a geographic "window", or map frame, in which you can display and work with geographic information as a series of map layers. When the maps are created in ArcMap, it will automatically append a file extension (.mxd) to your map document name. All the maps you compose in ArcMap are saved to an ArcMap document file named with a .mxd extension. Map document files are managed in file system folders.

## ERDAS an overview

ERDAS IMAGINE, the geographic imaging software favored by remote sensing professionals, only gets better with each new release. ERDAS IMAGINE 9.2 adds advanced image handling tools through the IMAGINE Geospatial Light TABLE™ interface, superior mosaicking functions, more import and export utilities, as well as advanced 3D visualization and scene creation capabilities.

ERDAS IMAGINE is the world's leading geospatial data authoring software. Important Features of ERDAS IMAGINE are,

- Easy to learn
- Increase productivity
- Accuracy
- Unparalleled flexibility
- It's from ERDAS, the inventor of commercial remote sensing software

ERDAS IMAGINE performs the advanced remote sensing analysis and spatial modeling to create new information. In addition, with ERDAS IMAGINE, results in 2D, 3D, movies are visualized, and on cartographic quality map compositions are also formed.

## Methodology

The methodology for the estimation of carbon sequestration potential of forest comprise of both the allomatric calculation and the satellite image calculation using NDVI analysis, the combined workflow of both method is shown in Figure-2.

In this proposed study, initially, map of different forest types is prepared from satellite images. Images are processed using GIS software technique as visually interpreted on screen and classified based on the interpretation key prepared by ground observations for a set of sample points (ground truthing) and attributed to the corresponding vegetation types. These maps are finalized after thorough field study.

The biomass are estimated using NDVI values corrected with field data. NDVI are calculated from satellite images using GIS software and the field estimation of above ground biomass using allometric equations[12]. Below ground biomass are estimated using a default conversion factor of 0.26 of above ground biomass. Carbon estimation from the biomass can be calculated based on Koch (1989) and the minimum value of 0.43 are adopted as the conversion

**The methodology involved the following steps,**

- Geometric corrections.
- Supervised classification.
- NDVI analysis.
- Field inventory.
- Allometric calculations.

## Geometric corrections

Raster data is commonly obtained by scanning maps or collecting aerial photographs and satellite images. In order to use these types of raster data in conjunction with other spatial data, it is often needed to georeference to a map coordinate system. When the georeference or orthorectify raster, it is defined how the data is situated in the map coordinates. This process includes assigning a coordinate system that associates the data with a specific location on earth. This transformation of raster data allows it to be viewed queried and analyzed with other geographic data. Geometric correction includes the following steps,

- Choosing map coordinate systems.
- Transforming the raster with a geometric model.
- Resampling the raster.

## Supervised classification

With supervised classification, are identify information classes (i.e., land cover type) of interest in the image. These are called "training sites". The image processing software system is then used to develop a statistical characterization of the reflectance for each information class. This stage is often called as "signature analysis" and involve developing a characterization as simple as the mean or the range of reflectance on each bands or as complex as detailed analysis of the mean, variance and covariance over all bands.

## Mosaicing

This is the process of assembling adjacent areas aerial or space photographs or images whose edges have been matched to form a continuous pictorial representation of a portion of the earth surface.

## Masking

The principle behinds the mask technique is to multiply the source image by the mask image that contains two values, one for preserved values and zero for undesired areas.

## NDVI analysis

The Normalized Difference Vegetation Index (NDVI) data provides a numerical value to the relative amount of live green vegetation. Through the ENVI Program, we created the NDVI Image with bands 3 and 4 (Red and IR) from the ERTS Satellite of the Landsat Program images by using the formula of (NIR-Red/NIR+Red).

Below the NDVI Sub-set images, a density slice study of the respective sub-sets provides color differentiated digital data. The data is enhanced through density slicing and is more easily interpreted through the slicing of the NDVI bands into ranges. In our model, green indicates area's of the highest NDVI produced density of vegetative growth, followed by red, and finally yellow containing the least relative vegetation.

With the advent of satellite remote sensing it has become possible to understand the green leaf concentration or chlorophyll status of vegetation for a large area of the earth surface with the help of a single digital image. Out of the numerous Digital Image Processing techniques (like TNDVI, VI etc.) used; NDVI (or Normalized Difference Vegetation Index) happens to be the most widely used technique to help understand the vegetation health status. This technique not only highlights the vegetated areas of an image but also gives an idea regarding as to how healthy the plants are.

The basic equation behind this operation can be expressed as:

$$\mathrm{NDVI} = (\mathrm{NIR} - \mathrm{R}) / (\mathrm{NIR} + \mathrm{R}) \qquad (2)$$

where, NIR = Near Infrared Band value, R = Red Band value, recorded by the satellite sensor.

## Field inventory

### Ground validation

Verification of the classified image has been done by the field data collected at different sites using GPS with an accuracy of 9 feet.

### DBH measurement

Diameter at breast height, or DBH, is a standard method of expressing the diameter of the trunk or bole of a standing tree. DBH is one of the most common dendrometric measurements.

On sloping ground, the "above ground" reference point is usually taken as the highest point on the ground touching the trunk, but some use the average between the highest and lowest points of ground. If the DBH point falls on a swelling in the trunk it is customary to measure the girth below the swelling at the point where the diameter is smallest.

The two most common instruments used to measure DBH are a girthing (or diameter) tape and callipers.

A girthing tape actually measures the girth (circumference) of the tree; the girthing tape is calibrated in divisions of π centimetres (3.14159 cm), thus giving a directly converted reading of the diameter. Callipers consist of two parallel arms one of which is fixed and the other able to slide along a scale. Callipers are held at right-angles to the trunk with the arms on either side of the trunk. Electronic callipers are also available enabling highly accurate measurements to be taken and stored for further analysis.

### Collection of soil samples

An analysis based on the Walkley-Black method is a rapid and effective means for determining the organic carbon, elemental carbon and total organic carbon content of urban aerosol samples collected on glass fibre and teflon-backed glass fibre filters. The estimated accuracy of the method is + 18%, ?33% and ?8% for OC, EC and TOC, respectively, the precision is ±7%, ±21% and ±4%, and the detection limit 0.33 $\mu g\ m^{-3}$, 0.54 $\mu g\ m^{-3}$ and 0.29 $\mu g\ m^{-3}$.

Soils and sediments contain a large variety of organic materials ranging from simple sugars and carbohydrates to the more complex proteins, fats, waxes, and organic acids. Important characteristics of the organic matter include their ability to form water-soluble and water insoluble complexes with metal ions and hydrous oxides interact with clay minerals and bind particles together; sorb and desorb both naturally-occurring and anthropogenically-introduced organic compounds; absorb and release plant nutrients; and hold water in the soil environment.

Soil and sediment total organic carbon (TOC) determinations are typically requested with contaminant analyses as part of an ecological risk assessment data package. TOC contents may be used qualitatively to assess the nature of the sampling location (e.g., was a depositional area) or may be used to normalize portions of the analytical chemistry data set (e.g., equilibrium partitioning).

### Allometric equations

The allometric Equations used for the calculation of carbon sequestration potential of different forest types using DBH measurement is given below[12].

**For gbh 30–50 cm (r2 = 0.79); Equation = –0.191 + 0.004936 * GBH +0.01222 * length** (3)

**For gbh 51–100 cm (r2 = 0.83); Equation = –0.609 + 0.008246 * GBH + 0.0409 * length** (4)

**For gbh 101–150 cm (r2 = 0.80); Equation = –2.328 + 0.01902 * GBH + 0.103 * length** (5)

**For gbh 151–200 cm (r2 = 0.83); Equation = – 4.771 + 0.02683 * GBH + 0.211 * length** (6)

**For gbh > 201 cm (r2 = 0.96); Equation = –13.194 + 0.05515 * GBH + 0.368 * length** (7)

The allometric Equations used for the calculation of carbon sequestration potential of different forest types using NDVI values,

$$T_1(x) = 0.8 + 0.02 * Topt(x) - 0.0005 * [Topt,(x)]^2 \quad (8)$$

$$T_2(x,t)=C*\{1/[1+exp[0.2*(Topt(x)-10-T(x,t)] ]\bullet 1/\{1 + exp\ [0.3*(- Topt(x)-lO+T(x,t)]\} \quad (9)$$

$T_1$,$T_2$ – suitability of Temperature

C- constant = 1.19

T(x,t) - mean monthly temperature = $32^0$c

Topt- mean Temperature during the month of maximum NDVI = $30^0$c.

$$W(x,t) = 0.5 + EET(x,t) / PET(x,t), \quad (10)$$

W – Scalars representing the availability of water.

EET – Estimated Evapotranspiration = 128.1.

PET – Potential Evapotranspiration = 106.1.

The valuves of EET & PET is given by Penman Monteith equations using the present climatic conditions.

$$E = \varepsilon^{|} T_1 T_2 W\ (gMJ^{-1}) \quad (11)$$

ε – The light efficiency

$\varepsilon^{|}$ - Typical maximum conversion factor for above ground Biomass = 2.5

$$Biomass = \varepsilon * NDVI * PAR \quad (12)$$

PAR = 0.51 for Tropical Forest.

**Carbon Sequestration Potential = Biomass * 0.43** (13)

Thus the Carbon Sequestration Potential of different Natural Forest type was calculated by the conversion factor 0.43.

Here

NPP=net primary production

APAR = Absorbed Photo-synthetically Active Radiation

LUE = Light Use Efficiency factor

PAR = Photo-synthetically Active Radiation

## Mathematical representation of the algorithms used

A theoretical summary of the steps involved in the calculation of biomass from remote sensing data is as outlined below:

**NDVI = *f*(Band 4, Band 3) Ref.** (14)

**Biomass = *f(APAR)* (W/m2)** (15)

**FPAR = *f(NDVI)*** (16)

**PAR = *f (K?) (W/m2)* for clear sky and Tropical countries PAR is 0.51** (17)

**Biomass = *APAR*ε(g/MJ)*** (18)

Where ε = light use efficiency

**$\varepsilon = \varepsilon^{\circ} * T1 * T2 * W$ *(g/MJ)*** (19)

Where $\varepsilon^{\circ}$ = globally uniform maximum (2.5g/MJ) and *T1* and *T2* relate to plant growth regulation (acclimation) by temperature

Where T2=1.185*{1+exp (0.2Topt-10-Tmon)}-1*{1+exp **(-0.3Topt-10+Tmon)}-1.** (20)

## RESULTS ANS DISCUSSIONS

The present study is carried out with a new methodology for the estimation of Carbon Sequestration Potential of different Natural forest types using both the DBH measurements and the NDVI analysis of satellite imagery through the allometric equations. In this present study, a classified image is created using LISS IV image. The classified image is distributed mainly among four vegetation classes namely Evergreen, Semi-Evergreen, Deciduous forests and Grasslands. Semi-Evergreen forest was found to be the most prominent type of forest with an area of 5624 hectares followed by Evergreen and Deciduous forest with areas 1472 and 3547 hectares respectively. The classified image was validated using field data collected at different sites.

Different types of forest have different biomass. Theoretically the order should be, Evergreen > Semi-Evergreen > Deciduous > Grassland.

## Carbon sequestration map of evergreen forest

The Carbon Sequestration map of Evergreen Forest in Neyyar wild life sanctuary is given below in Figure 3

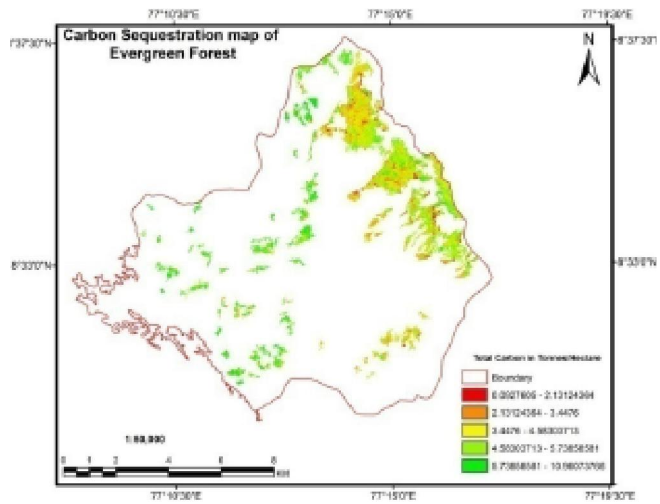


**Figure 3 : Carbon Sequestration Map of Evergreen Forest**

## Carbon sequestration map of semi-evergreen forest

The Carbon Sequestration map of Semi-Evergreen Forest in Neyyar wild life sanctuary is given below in Figure 4,

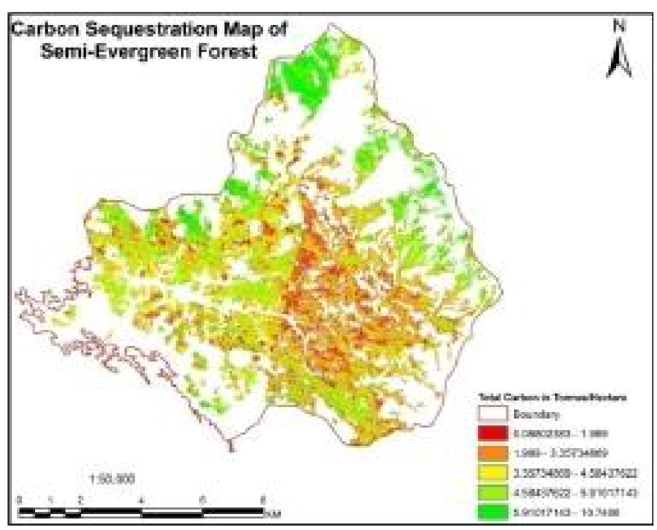


**Figure 4 : Carbon Sequestration Map of Semi-Evergreen Forest**

## Carbon sequestration map of decidous forest

The Carbon Sequestration map of Decidous Forest in Neyyar wild life sanctuary is given below in Figure 5,

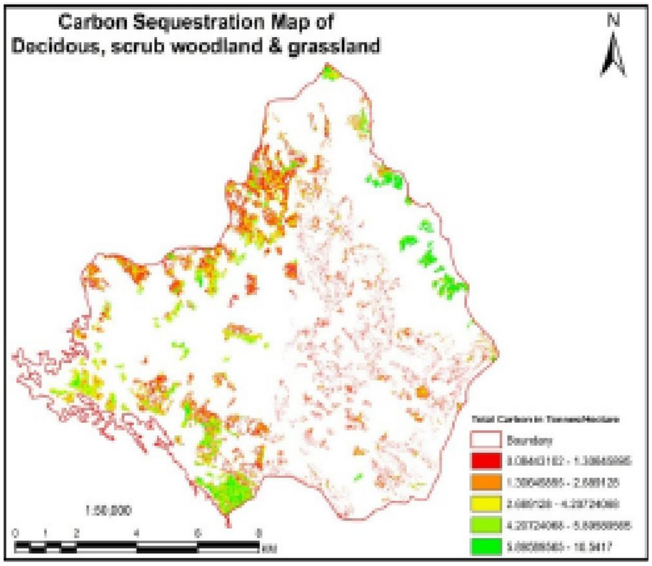


**Figure 5 : Carbon Sequestration Map of Deciduous, Scrub Woodland & Grassland.**

Carbon sequestration potential using conventional methods

The Carbon Sequestration Potential of different Natural Forest types using DBH measurement and Allometric calculations is given below,

## Carbon sequestration potential using remote sensing method

The number of pixels in Evergreen, Semi-Evergreen and Deciduous forests was found to be as 229769, 844922, 201291 respectively. The biomass of grasslands hasn't been considered as they emanated negative values for NDVI map. This may have happened due to the presence of rocky terrain and other exposed areas.

The Carbon Sequestration Potential of different Natural Forest types using NDVI analysis and Allometric calculations is given below,

## Soil organic carbon

The percentage of Soil Organic Carbon Present in different natural forest types is given below, (walkley and Black method)

- Evergreen Forest = 19.53%
- Semi-Evergreen Forest = 16.43%

**TABLE 4 : Conventional methods.**

| Forest Types | Area(Hectares) | Total Carbon(tones/hectare) |
|---|---|---|
| Evergreen Forest | 1472 | 7448.32 |
| Semi-Evergreen Forest | 5624 | 4336.11 |
| Grassland, Scrub Woodland & Decidous Forest | 3547 | 2419.54 |

**TABLE 5 : Remote Sensing Method.**

| Forest Types | Area(Hectares) | Total Carbon(tones/hectare) |
|---|---|---|
| Evergreen Forest | 1472 | 9682.44 |
| Semi-Evergreen Forest | 5624 | 3887.49 |
| Grassland, Scrub Woodland & Decidous Forest | 3547 | 908.83 |

- Decidous Forest = 15.43%

## CONCLUSIONS

The carbon sequestration potential of different natural forest types in Neyyar Wildlife Sanctuary is obtained. From that obtained values in tones/ hectare, we can calculate the present carbon budget in the neyyar wildlife sanctuary are calculated. Thus the present carbon budget for entire study area has been found as, 14478.76 tones /hectare with the advent of remote sensing techniques. Remotely sensed data high performance processing of software could help to get the carbon budget from the Western Ghats region. From this we concluded that this technology could be useful to estimate the carbon budget for entire Western Ghats and forest in india.

## REFERENCES

**[1]** Anu Rani Sharma, K.V.S.Badarinath, P.S.Roy; Corrections for Atmospheric and Adjacency Effects on High Resolution Sensor Data -A Case Study Using IRS-P6 LISS-IV Data., The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing **(2008)**.

**[2]** A.B.Frank, J.F.Karn; Journal of Range Management, **56(4)**, **(2003)**.

**[3]** Freek Van Der Meer, Wim Bakker, Klaas Scholte, Andrew Skidmore, Steven De Jong, Jan Clevers, Gerrit Epema; Vegetation Indices, Above Ground Biomass Estimates and the Red Edge from Meris., International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam **(2000)**.

**[4]** Jawad T.Al-Bakri, Mahfouz M.Abu-Zanat; correlating vegetation cover and biomass of a managed range reserve with NDVI of SPOT-5 HRV., Jordan Journal of Agricultural Sciences, Volume 3, No.1, **(2007)**.

**[5]** Jean-Yves Pontailler, Graham J.Hymus, Bert G.Drake, J.Can; Remote Sensing, **29(3)**, 381-387 **(2003)**.

**[6]** M.Lal, Roma Singh; Journal of Environmental Monitoring and Assessment, **60**, 315-327 **(2000)**.

**[7]** S.Mani, N.Parthasarathy; Journal of Biomass and Bio energy **31**, 284-290 **(2007)**.

**[8]** Martin F.Garbulsky, Josep Penuelas, Dario Papalez, Iolanda Filella; Global Change Biology, **14**, 2860-2867 **(2008)**.

**[9]** Meenakshi Kaul, G.M.J.Mohren, V.K.Dadhwal; Mitig.Adapt.Strateg.Glob.Change, **15**, 489-510 **(2010)**.

**[10]** Nathalie Pettorelli, Jon Olav Vik, Atle Mysterud, Jean-Michel Gaillard, Compton J.Tucker, Nils Chr.Stenseth; Trends in Ecology and Evolution, **05(11)**, **(2005)**.

**[11]** Nisha Wani, A.Velmurugan, V.K.Dadhwal; International Society for Tropical Ecology, **51(1)**, 11-19 **(2010)**.

**[12]** A.Ramachandran, S.Jayakumar, R.M.Haroon, A.Bhaskaran, D.I.Arockiasamy; Journal of Current Science, **92(3)**, **(2007)**.

**[13]** Rodel D.Lasco; International Journal of Science, **45**, **(2002)**.

**[14]** P.S.Roy, Shirish A.Ravan; Journal of Bio-Science, **21(4)**, 535-561 **(1996)**.

**[15]** Suruchi Bhadwal, Roma Singh; Journal of Current Science, **83(11)**, **(2002)**.

**[16]** J.Terakunpisut, N.Gajaseni, N.Ruankawe; Journal of Applied Ecology and Environmental Research, **5(2)**, 93-102 **(2007)**.

**[17]** S.W.Todd, R.M.Hoffer, D.G.Milchunas; Int.J.Remote Sensing, **19(3)**, 427-438 **(1998)**.

**[18]** K.J.Wessels, S.D.Prince, N.Zambatis, S.Macfadyen, P.E.Frost, D.Van Zyl; International Journal of Remote Sensing, **27(5)**, 951-973 **(2006)**.

**[19]** Yetrie Ludang1 Herry Palangka Jaya; Journal of Applied Sciences in Environmental Sanitation, **2(1)**, 7-12 **(2007)**.