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Assessment of Temporal Change in Terrestrial Carbon Sequestration Capacity With Land Use Land Cover Change Along the Metro Corridor in Kochi, India

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Research Article

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Abstract

Kochi is undergoing drastic environmental changes with the developmental activities. Kochi metro rail project is one among them. The present study focuses on the decrease in carbon sequestration capacity due to clearing of vegetation, especially trees and paddy fields for metro rail. Metro rail corridor extends to a length of 18.22 km with 16 stations. Total extent of the study area is 777.7 ha covering 200 m buffer zone on both sides of metro corridor. This study integrates analysis of satellite images using GIS along with carbon inventory data from field surveys. IRS P6 LISS IV satellite sensor images of 26th February 2013 and 5th February 2017 are used for the study. Ground-truthing is done for 25 sampling plots. The study showed a total reduction of 35.8 ha of vegetation area which is converted into built-up area. The total carbon content is reduced by 6877 tons in an area of 777.7 ha ie: 8.84t/ha on an average. Maximum reduction has occurred along the metro rail and station zones, where maximum numbers of gown up trees were removed.

Keywords/Phrase: Carbon Sequestration, Carbon Content, NDVI, GIS, Ground Truthing, Metro Rail

Introduction

Increasing carbon emission is one of today's major concerns, which is well addressed in Kyoto Protocol. Carbon sequestration and Green House Gas (GHG) emission reduction have been one of the priority research subjects after 1997's Kyoto Protocol. Since then, many countries have initiated programs to assess the quantity of GHG emissions, quantity of sequestrated carbon, carbon budgeting and so on. One of the ways to reduce GHGs is through maintaining a green cover over the earth's landmass. Development of sustainable green cities is the need of today's fast urbanizing world. The ever-growing urbanization contributes to increased carbon emission due to higher consumption of goods and services. Hence it is crucial that the balance be maintained between the carbon emission and carbon sequestration to achieve sustainability.

Carbon sequestration is the long-term storage of carbon in plants, soils, geologic formations and ocean. Carbon sequestration occurs naturally and refers to the storage of carbon that has immediate potential to become carbon dioxide gas. The carbon sequestration capacity is usually measured in terms of carbon content of the tree. The role of trees in carbon sequestration is well known and enhancing carbon sequestration through different land use options to mitigate global warming is being undertaken in a big way in many countries. Optimal use of natural resources and land for sustainable management to create carbon sinks is the only way to achieve this goal. Geographic Information System (GIS) based spatial approach will help in facing the challenges to map spatial pattern of vegetation distribution and their carbon values. The GIS tool will integrate the vegetation inventory data to quantify and map the carbon sink and stock values [1].

While perusing the literature, it was found that in India the carbon balance studies are very scanty. Most of the studies on carbon sequestration are based on forest area [2,3]. A national-level carbon databank is envisaged for all types of forest in India to study the temporal change and carbon sequestration potential for better management of forests. Indian State of Forest Report is one such series of reports published by Forest Survey of India (FSI) which provides state/ district wise forest cover changes with respect to previous assessment. This report was prepared by analyzing satellite data of IRS-P6-LISS III and IRS Resourcesat-2 LISS III with ground truthing by using enough sample plots inside and outside forest regions. Salon et. al (2010) proposed a climate policy instrument that provides a durable framework for local governments to reduce greenhouse gas emissions) [4]. Estimates of carbon dioxide were done by Edward and Matthew, (2008) across metropolitan areas and between central cities and suburbs within metropolitan areas and found a considerable heterogeneity across metropolitan areas. In this context, Climafor approach is another tool used for testing and applying a regional baseline for carbon emissions from land-use change [5]. Using this approach expected emissions from continued land-use change were estimated by applying the risk matrices to the current land cover. The modeling approach to estimate the deforestation pattern is based on readily available cartographic and census data. Ground truthing is vital to understand the role of urban trees to quantify the carbon content. Another method of analysing carbon sequestration is by using remote sensing which saves time, money and also helps in regional mapping. Similarly tree structure can be studied by using another method of remote sensing called LIDAR (Light Detection and Ranging) [6-11]. Correlation of satellite imagery with field based carbon estimates were used to develop regression equation [12]. This equation predicts the carbon content in urban trees using Normalized Difference Vegetation Index (NDVI) computed from Landsat satellite data. Thereby the carbon stored in urban trees over time can be analysed. Ankhit, et. al. (2017) did a comparative analysis of carbon content in three selected dominant tree species namely, Azadirachta indica, acacia sp. and cassia sp. at Gandhinagar and Mahesana in Gujarat, India [13]. Cartosat - 1 and IRS LISS- IV imagery was used to map tree density based on canopy cover. A non - destructive method of random sample collection with 1km x1 km grid size was executed in which 20 percent sampling fraction was considered to estimate tree count. As a result, Azadirachta indica had maximum carbon content capacity compared with Acacia sp. and Cassia sp. Also, Trees with GBH > 18cm could store more carbon than trees with GBH size 90 to 180 cm and girth class 0 to 90 cm. Steve, et. al. (2014) developed very high resolution map of urban tree biomass distribution across the City of Boston [14]. Aboveground tree carbon content at 1m spatial scale was calculated by integrating remote sensing data (Quickbird imagery) including LiDAR-based tree height estimations and field-based observations and mapped the canopy cover. Correlation between demographic characteristics and biomass distribution was verified using Priority Planting Index values. The above study estimated tree canopy of 25% +/- 1.5% (95 % C.I.) and carbon potential to be 355Gg (28.8 Mg C per ha) for the City of Boston which showed the efficacy of advanced remote sensing to improve the managing of urban vegetation. Nicholas et. al. (2013) at Andaman coast of Thailand, has developed a mangrove forest biomass model with the help of remote sensing data and machine learning methods [15]. High-resolution GeoEye-1 satellite imagery, medium resolution ASTER satellite elevation data, field-based tree measurements, published allometric biomass equations, and a suite of machine learning techniques were used to develop spatial models of mangrove biomass. The study could find fifteen mangrove species with estimated total biomass of 345 +/- 72.5 Mg per ha, high density (1313 trees per ha) along the Kamphuan River. Forest based inventory was done by Suman, et al. (2018) at Bhimdandh wildlife sanctuary in Bihar (India) [16]. Based on which a regression model was developed between AGB measured at plot level and their associated spectral parameters from IRS P6 LISS - III sensor. Texture measures, NDVI and Principal components were calculated from the image. Texture analysis is performed to derive the matrices from LISS III image to perform multiple linear regression (MLR) analysis with the help of field based plot biomass. Performance of best-fit model using different regression models were compared and is used to validate the correlation between observed and estimated biomass.

The study we have undertaken is in Kochi, which is a fast developing city in Kerala, India with rapid and unplanned urbanization, enhanced potential for industrialization, uncontrolled growth of construction activities and rapid increase in the number of vehicles. A no care attitude and gross negligence coupled with ever increasing needs and demands over the years have lead to environmental degradation. Mega projects such as Smart city, Infopark, Vallarpadam Container Terminal and Metro rail project raises many environmental concerns. Rapid urbanization and intense commercial developments in the recent past have resulted in steep rise in travel demand, putting Kochi's transport infrastructure to stress. It is in this context that need for a metro rail project has come up. Metro rail is expected to reduce the carbon load of the atmosphere through decreased number of vehicles. It is expected that number of commuters would shift from road transport to metro which will lead to reduced fuel consumption and reduction in the associated emissions [17]. But implementation of such projects cause a sizeable reduction of urban trees which would reduce the carbon sequestration capacity of the area and could offset the carbon benefits of reduced number of vehicles. The present work analyzed such a scenario for a metro rail project in Kochi. The study analysed the spatio-temporal changes occurred in urban vegetation cover due to the metro rail project in Kochi during the years 2013 to 2017 and made an assessment on the loss of carbon sequestration potential of vegetation around the metro rail corridor using IRS-P6 LISS IV (Linear Imaging and Self-Scanning Sensor) data and GIS applications. This study provides an insight into the ill effects of urbanisation on the society and environment due to developmental activities unless it is suitably restored by planting trees and retaining vegetations to increase the carbon sequestration potential of the region under stress.

Study area

Kochi, located on the southwest coast of India, lies between 76°9′–76°24′ E and 9°47′–10°10′ N. The area is warm and humid, with two monsoon periods annually namely the southwest (SW) monsoon spanning from June to Sep and northeast (NE) monsoon (from Oct to Nov). The annual rainfall ranges from 3233mm to 3456mm at different places of the district, most of which falls in months from June to

September during SW and NE monsoon seasons [18]. The months from February to May are the hottest (summer season in Kerala). December to January months are the coldest. Kochi's maximum temperatures range from 28.9 °C to 32.7 °C and minimum temperatures range from 22.1 °C to 25.4 °C (KMRL, 2014b). The average elevation of the city is about 1.5m, crisscrossed by water bodies called the back waters. It is a city of about 6lakhs people, with 2lakhs within the metropolitan area [19]. Apart from this, there is a major contribution of floating population. This city is fast developing with increased industrial activities, road traffic and other human activities which lead to degradation of the environment, with changes in both emission scenario and land use pattern.

The present study focuses on decrease in carbon sequestration capacity due to clearing of vegetation for metro rail project. This is measured in terms of carbon content of vegetation. The total extent of study area is 777.7ha, covering 200m buffer zone on both sides of metro corridor (Fig. 1).

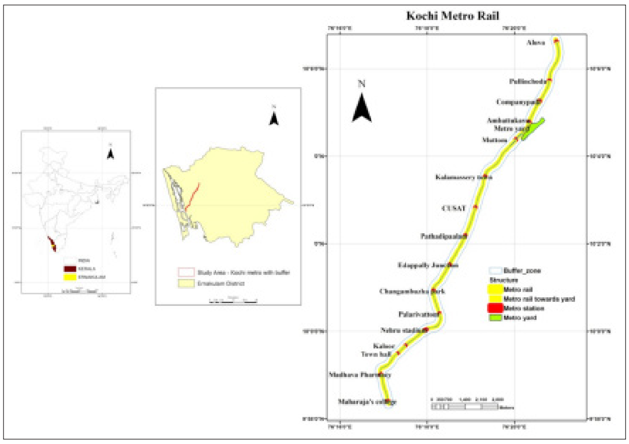


Figure1: Study area

It includes 19.9ha of metro rail and stations, 23.3ha metro maintenance yard and 734.5ha buffer zone. The buffer zone along the metro corridor is taken as 200m on both sides of metro center line and metro yard is considered separately. It is observed that the change in vegetation beyond 200m is not entirely due to metro, but is also contributed by other developmental activities. Kochi metro rail project corridor extends to a length of 18.22km with 16 stations. The major vegetation types of the study area are mixed trees, rain trees, coconut trees, Floating vegetation, Grassland and fallow paddy.

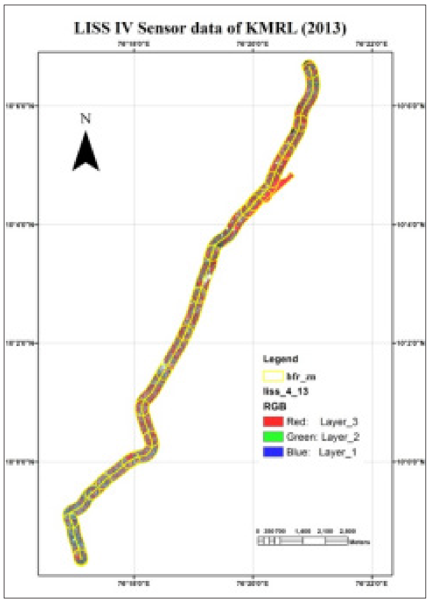
Data and Methodology

Primary Data

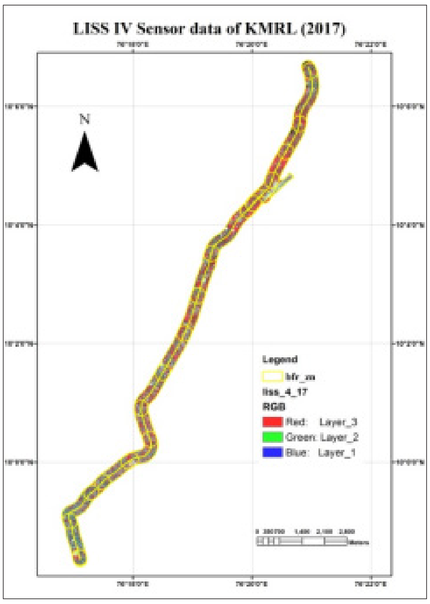
The study integrates field inventory data collected during the period 2013-2017 from different locations in the study region with the satellite images. Analysis involves four major steps, namely, (2.1.a.) Image processing, (2.1.b) derivation of vegetation indices using satellite imagery (2.1.c) collection of field inventory data and ground truthing through field verification and (2.1.d) calculation of change in carbon sequestration capacity of the study area. Primary source of data is LISS IV satellite data from the Indian Space Research Organisation's (ISRO) Resourcesat-2 which was launched in 2011. The two satellite scenes each of 26th February 2013 and 5thFebruary 2017 were collected from https://uops.nrsc.gov.in as cloud free images to study the change in carbon sequestration capacity of the area. Since both are acquired during same month, it provides greater degree of accuracy in comparison.

Image Processing

Multi-spectral IRS1D LISS IV MX images, with a resolution of 5.8m X 5.8m, is selected. Generally, information about vegetation is collected at Red and NIR spectral regions of LISS IV. LISS IV sensor data consist of three band information separately in different layers (Fig.2).



2013



2017

Figure 2: Study area boundary overlaid over LISS IV satellite data

Using ERDAS IMAGINE 9.2, these layers were stacked and given standard False Color Composite (FCC) for better vegetation analysis. These two stacked satellite images were stitched together and the study area is trimmed out using ArcGIS 10.2. The area boundary is digitized using boundary location points.

Satellite image is generally delivered as an image of raw Digital Number (DN) values. The DN values do not provide the required information. Therefore, we have to prepare the data for analysis by converting the DN values into these reflective values i.e. Radiance. The general equation to convert DN to radiance is:

$$L^{*}= ((L_{max}- L_{min})\, Q_{cal}) / Q_{calmax} + L_{min} \quad \text{Srinivas(2006)} \quad (1)$$

Where

L* - Spectral radiance at sensors apertureW.sr.m^{-2},

Qcal - Calibrated Digital Number

Qcalmax - Maximum possible DN value

Derivation of Normalized Difference Vegetation Index (NDVI)

The Vegetation Indices an estimate the biomass of vegetation from remote sensing images and the most appropriate one is with the Normalized Difference Vegetation Index (NDVI) [20]. The NDVI is based on absorption in the red (R) spectrum and very strong reflectance in the near infrared spectrum (NIR).

$$NDVI = (NIR – R) / (NIR + R) \quad \text{Rouse, et al. (1974)} \quad (2)$$

Where NIR = near infrared spectrum and R = red spectrum

Since accuracy for digital classification of vegetation types is low, the study area is classified into different vegetation categories through manual classification of the digital image. Although labor-intensive, this modification improves accuracy, limiting the possibility of using statistical outliers. The vegetation pattern along the metro corridor of Kochi is delineated from satellite imagery based on NDVI values and validated through field observations.

Collection of inventory data and Ground truthing through Field verification

Since identification of vegetation type requires more site specific information, accuracy assessment of classified image is done through field verification, ie. ground truthing,. To ground truth every pixel of a classified image is not always practical. So, a set of reference pixels are used. Reference pixels are selected as those for which actual data are known and they are randomly selected [21]. Initially the area was divided into different vegetation types and based on NDVI values, five main vegetation types are identified in the area. Based on the classification, a total number of 25 plots for different vegetation types were taken for ground truth sampling during the period 2013-2017 so that enough number of sampling is done for different types of vegetation (fig.3 a &b). Ground truthing involves calculation of biomass using volumetric equation for trees and dry weight calculation for shrubs, herbs and grass. Through ground truthing, maximum accuracy is attained.

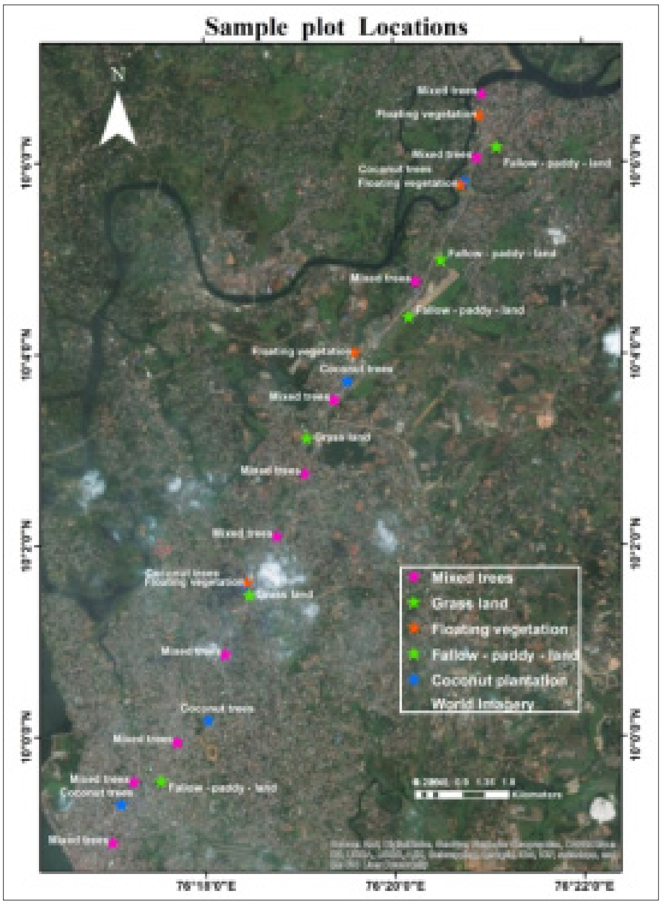
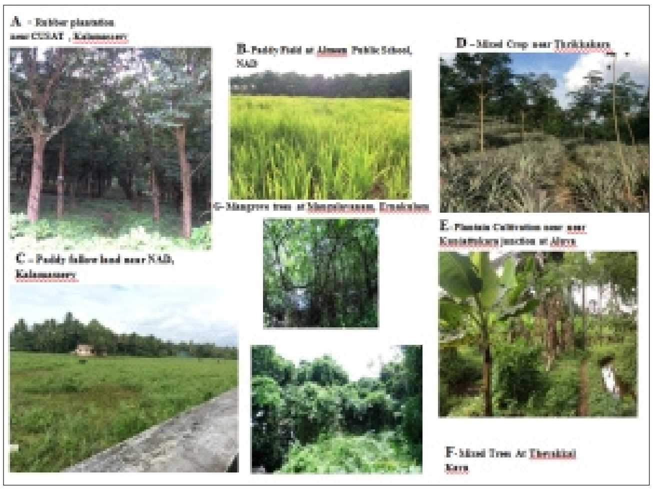


Figure 3: (a) The sample plot locations.



. **Figure 3:** (b) Different types of vegetation sample lots

Biomass estimation using volumetric equation

Representative plots for different vegetative types were selected from the classified image for ground truthing and measurements were taken for tree height and breadth. Biomass is calculated using volumetric equation based on shape of tree.

$$V= s*h*f \quad (3)$$

Where V - Volume of tree, s – basal area of the tree, h – height of the tree and f – form factor

The calculated tree volumes are multiplied with respective species wise specific gravity to obtain tree biomass [22]. The value of form factor 'f' for trees having different shapes and specific gravity for different species of plants in the area is given in table 1.The form factor range from 0.62 to 0.9 for more branched to cylindrical respectively. For example 'f' is 0.9 for coconut tree which is almost cylindrical and for a much branched plant like Chandada it is taken as 0.62. The specific gravity ranges from 0.38 to 0.72 for different species. Table 1gives specific gravity and form factor values for different type of vegetation based on Forest Survey of India 1996 report.

No	Name	Species	Specific gravity	Form factor
1	Coconut tree	Cocos nucifera	0.413	0.9
2	Rubber tree	Hevea brasiliensis	0.599	0.65
3	Mahagony	Swietenia mahogany	0.639	0.65
4	Nutmeg	Mystrica fragrans	0.426	0.65
5	Arecanut	Areca catechu	0.548	0.9
6	Jack tree	Artocarpus heterophyllus	0.505	0.65
7	Mango	Mangifera indica	0.584	0.65
8	Acacia	Acacia auriculiformis	0.719	0.65
9	Teak	Tectona grandis	0.5757	0.75
10	Chandada	Macaranga peltata	0.378	0.62
11	Wild jack tree	Artocarpus hirsutus	0.516	0.65
12	Rain tree	samanea saman	0.639	0.65

Table1: specific gravity and form factor

Biomass estimation from Dry weight

Samples were collected to obtain dry weight for shrubs, herbs and grass. Dry weight is taken for shrub and herb type vegetation. In case of shrubs, cut out one mature plant as sample and have taken count of it that covers the plot (31.62 m x 31.62 m). In the case of herbs, 30 cm x 30 cm mini plot is considered inside the main plot and extrapolated to the covered area, Fig.4.

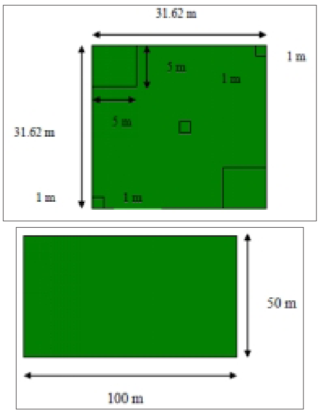


Figure 4: Size of sampling plots

Calculation of carbon sequestration capacity from NDVI

Carbon sequestration capacity is calculated in terms of carbon content of the tree. This study uses NDVI values of satellite image to quantify carbon content. From the imagery, a regression equation is developed using NDVI as the independent variable and carbon content (kg C/pixel) as dependent variable. Carbon content values in each plot were standardized to kg C/pixel (30m X 30m) and registered to the image pixel at the plot location. The regression equation developed by Soojeong Myeong (2006) is used for this calculation [12].

$$\text{Carbon} = a * e^{(NDVI*b)} \quad (4)$$

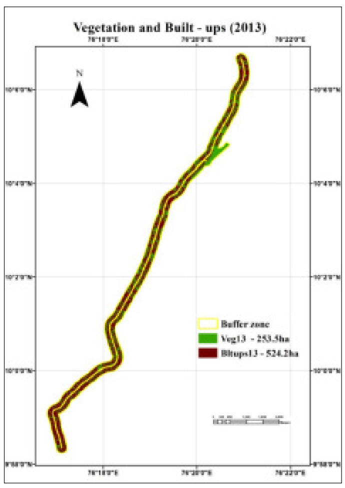
'a' and 'b' are constants determined from the nonlinear regression equation. The assessment of various linear and nonlinear equations confirmed that a nonlinear regression equation provide the best estimate of carbon content for the NDVI data. Regression equation obtained using carbon inventory data and NDVI will give values of constants 'a' and 'b' for each type of vegetation.

Results

The Kochi Metro construction work was started in June 2013, and was opened to public in June 2017. Majority of the vegetation along the metro rail premises were cleared for this purpose. This study analyses the temporal change in carbon sequestration potential of vegetation between 2013 and 2017. We expect the changes exclusively by metro rail activities along the metro corridor. Since the rail is constructed right above the existing roads, comparatively less number of trees were removed along the rail. But cutting down of trees in the stations premises were comparatively on a larger scale and many of the aged trees with high carbon content were removed. The associated construction works was not limited to rail but extended to both sides of the rail and hence we have considered a buffer zone of 200m on both sides along this corridor. For setting the metro yard site, the vegetation was completely cleaned up in the area. The impact of clearing of vegetation for the metro construction is scientifically analysed in this study and discussed here.

Change in vegetation area

The geometry details of the study area are calculated using geospatial tools. The rail stretch is having a length of 18.2km, covering 9.9 ha area. Considering the buffer of 200m, the study area covers 777.7 ha. On analysing the vegetation coverage in this area during the years 2013 and 2017, there observed a significant reduction in vegetation area and an increase in built up area for the construction of metro infrastructure. In 2013, the total vegetation area in this zone was 253.5 ha which is reduced to 217.7 ha in 2017. The built up area has increased from 524.2 ha in 2013 to 560 ha in 2017. There is a total reduction of 35.8 ha of vegetation area which is converted to built up area (fig.5).



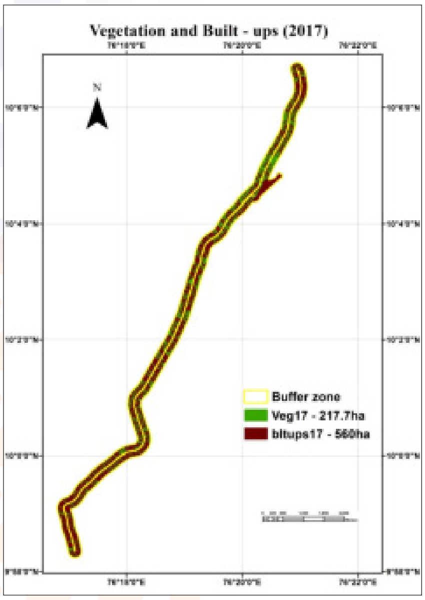
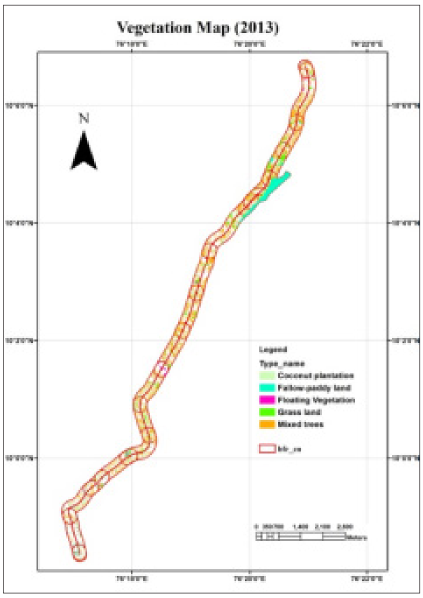


Figure 5: Change in the vegetation and built-ups between (a) 2013 and (b) 2017.

Initially, visual interpretation and verification through field visit was conducted, to assist manual digitization. Mainly five types of vegetation viz: coconut trees, mixed trees and crops, fallow paddy, floating vegetation and grass land were identified in the area (Fig 6.a & 6.b). Among the vegetation types, mixed trees and fallow paddy land shows decrease in area of 18.4 ha and 26.1 ha respectively, while coconut, floating vegetation and grass land shows slight increase in area of 0.36 ha, 0.29 ha and 8.1 ha respectively. Comparing the area of vegetation cover in the year 2013 with 2017, there is 44.5 ha of decrease in vegetation area. It is compensated by an increase of 8.7 ha in the year 2017 with afforestation activities by KMRL in selected barren lands available as per 2013 image. Considering all these changes there is a net decrease in the vegetation area of 35.8 ha in the year 2017. This analysis was done using vegetation map (fig.6a&b)



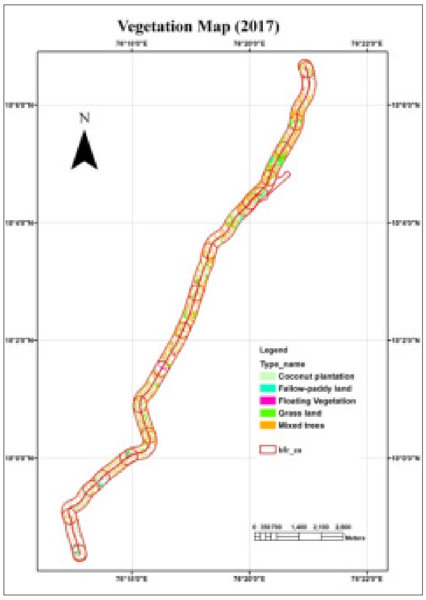


Figure 6: Vegetation cover (a) before starting the metro construction (2013): (b) after the construction activities (2017)

To quantify this decrease in vegetation, NDVI map of the area was also analyzed. Fig.7 shows the area under different NDVI ranges. It is categorized under low, medium and high categories based on NDVI values. The NDVI values in 2013 shows range from -0.207 to 0.7254 per pixel, where as in 2017 this is changed to -0.128 to 0.679 which confirms the fact that there is decrease in vegetation area. There is decrease in area for high and medium NDVI category, whereas there is increase in area for low NDVI category in the year 2017. The high category showed a decrease in area of 54.5 ha and medium showed a decrease of 4.7 ha. Low category showed an increase of 23.5 ha. Even though grass land and fallow paddy fields with low NDVI were cleared for metro construction there were planting of saplings by KMRL as part of their green initiative. It can be one of the reasons for increased area in low NDVI category. Net decrease in vegetation area using NDVI map is 35.7 ha. There is a negligible mismatch in area between the values obtained from the vegetation maps and NDVI map. When the NDVI (grid system) is layered over geometrical area (x,y coordinate system), the geometry doesn't match exactly. So a slight difference can be expected.

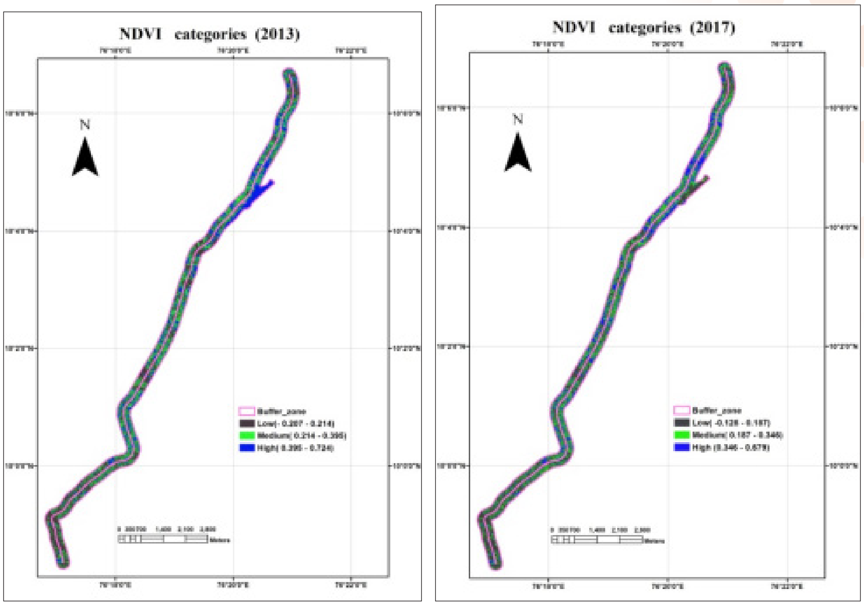


Figure 7: Change in NDVI values between 2013 and 2017

Change in carbon sequestration capacity

Change in carbon sequestration capacity is measured in terms of carbon content of the vegetation type. Ground truthing for different types of vegetation was done for greater accuracy in calculating the carbon content from NDVI values. For this a total of twenty five sampling plots were selected (fig.3). Tree dimension measurements and dry weight were taken as per the type of vegetation. Carbon content for these plots was calculated using volumetric equation explained under data and methodology 2.1.c.1 above. From the calculated carbon content for the plots and the corresponding NDVI values, a non-linear regression equation was fitted. The constants 'a' and 'b' (eqn.4) were estimated with high r2 values of 0.5 to 0.9 for different vegetation types. Mainly four types of identical vegetation are grouped in the area viz: coconut trees, mixed trees & mixed crop, floating vegetation, grassland & fallow-paddy. Table 2 gives values of 'a' and 'b' and r2 for these vegetation types. Carbon content for the whole area was calculated by applying these constants for appropriate vegetation types.

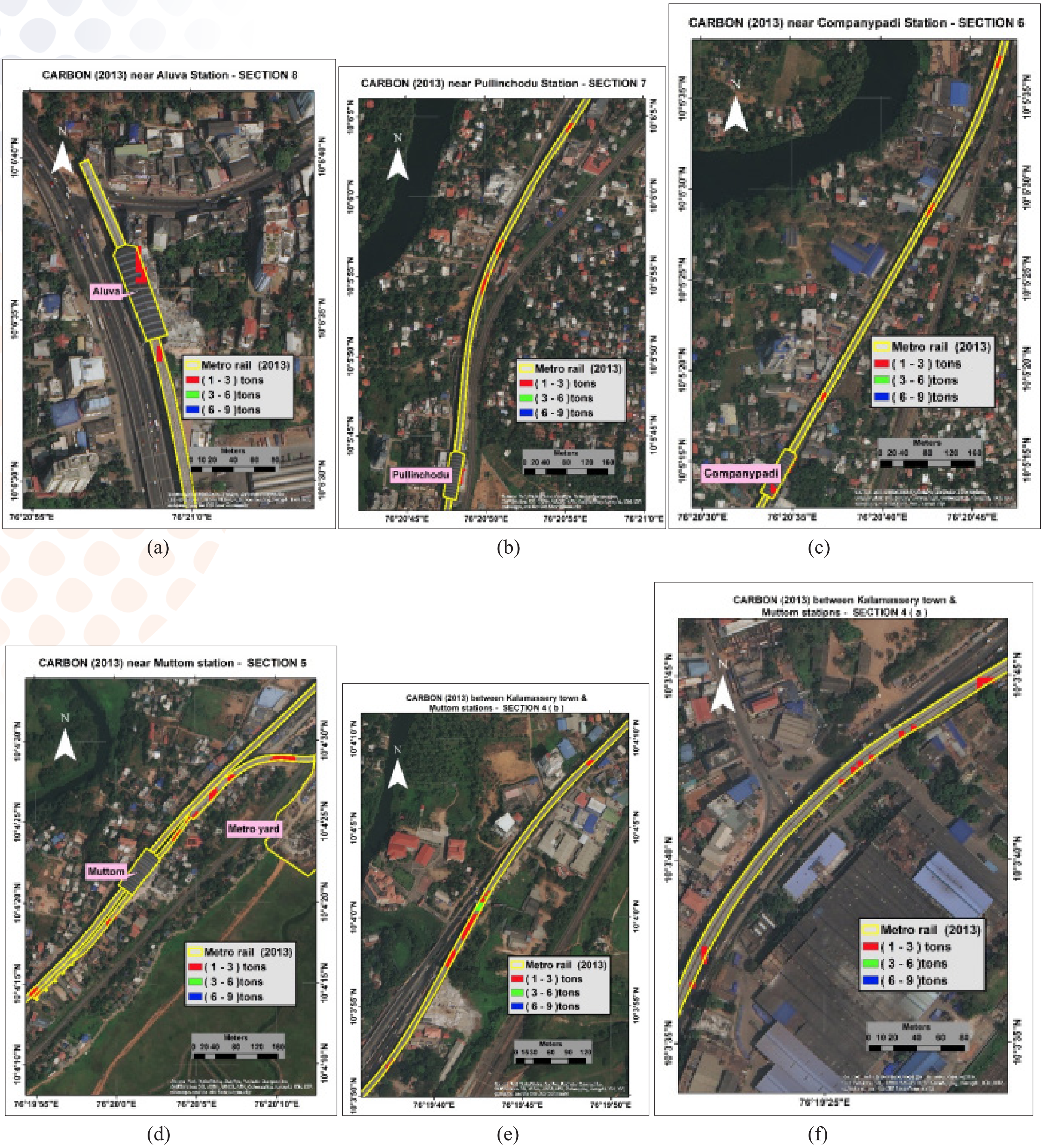
S.No	Type	2013			2017		
1	Coconut trees	a	b	r^2	a	b	r^2
2	Mixed trees & Mixed crop	1.4022	0.0427	0.4963	1.034	0.0647	0.5259
3	Floating Vegetation	2E - 06	28.039	0.7995	1E - 06	12.947	0.6375
4	Grassland & paddy - fallow land	0.2206	6.3528	0.8614	0.5301	4.2718	0.6993

Table 2: Constants 'a' and 'b' obtained from the regression equation calculated for each vegetation types.

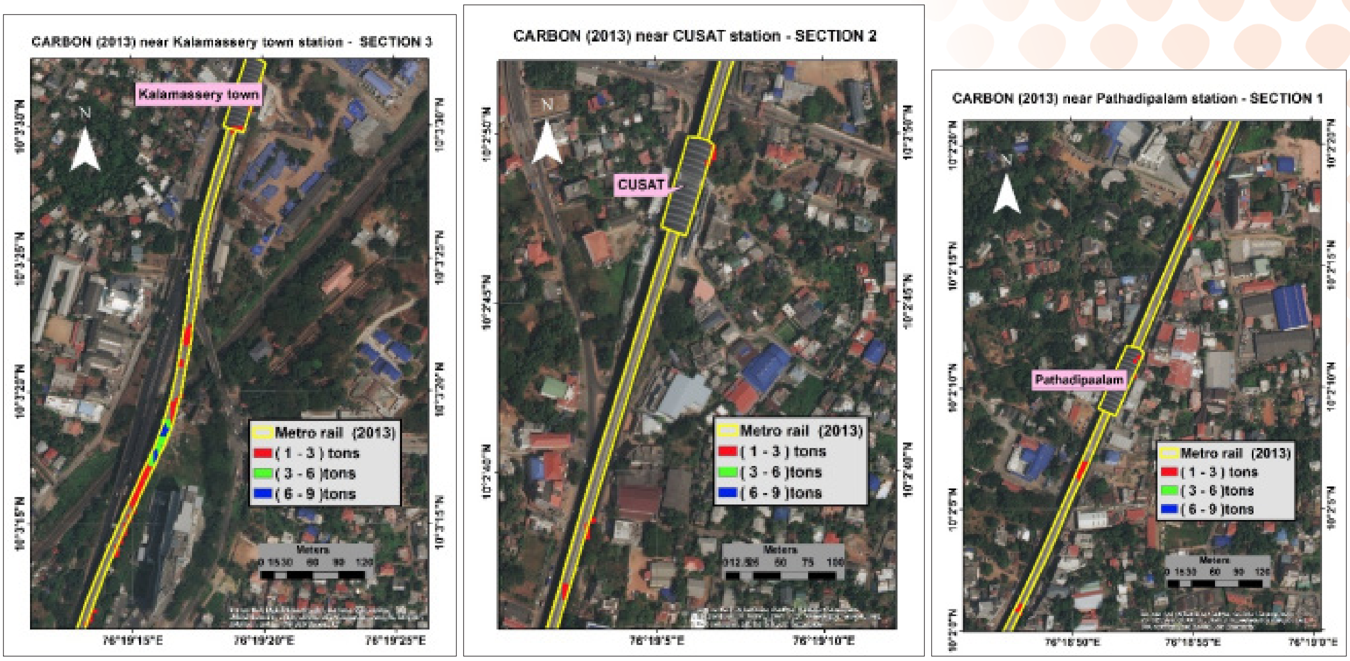
Fig.8-10 gives the carbon content of the study area. It is divided into three zones viz:

1. Rail & stations,
2. Metro yard and
3. Buffer zone.

Fig.8 (a-i) gives the range of carbon content in rail and station zone. This is a long stretch with rail width <10cm and station width <20cm in the image, we have made it into different sections to highlight the major areas of change. There is no vegetation occurring in this area in 2017. The carbon content in different sections ranges from 1-9 tons/pixel. In this area of 19.9ha there is a total decrease of 416.2tons of carbon. Here the main type of vegetation that is cleared includes mature trees with high NDVI and grass land with low NDVI. Maximum cutting of mature trees occurred in this area for setting the stations which resulted in this drastic decrease of carbon content. There have been massive clearing of vegetation on both sides of metro corridor. Considering this, we have taken 200m buffer zone on both sides.



CARBON (2013) near Aluva Station - SECTION 8
Aluva
Metro rail (2013)
(1 - 3) tons
(3 - 6)tons
(6 - 9)tons
Meters
(a)
CARBON (2013) near Pullinchodu Station - SECTION 7
Pullinchodu
Metro rail (2013)
(1 - 3) tons
(3 - 6)tons
(6 - 9)tons
Meters
(b)
CARBON (2013) near Companypadi Station - SECTION 6
Companypadi
Metro rail (2013)
(1 - 3) tons
(3 - 6)tons
(6 - 9)tons
Meters
(c)
CARBON (2013) near Muttom station - SECTION 5
Muttom
Metro yard
Metro rail (2013)
(1 - 3) tons
(3 - 6)tons
(6 - 9)tons
Meters
(d)
CARBON (2013) between Kalamassery town & Muttom stations - SECTION 4 (b)
Metro rail (2013)
(1 - 3) tons
(3 - 6)tons
(6 - 9)tons
Meters
(e)
CARBON (2013) between Kalamassery town & Muttom stations - SECTION 4 (a)
Metro rail (2013)
(1 - 3) tons
(3 - 6)tons
(6 - 9)tons
Meters
(f)



(g) (h) (i)

Figure 8 (a - i): The major areas of change in carbon contents along metro rail given as different sections.

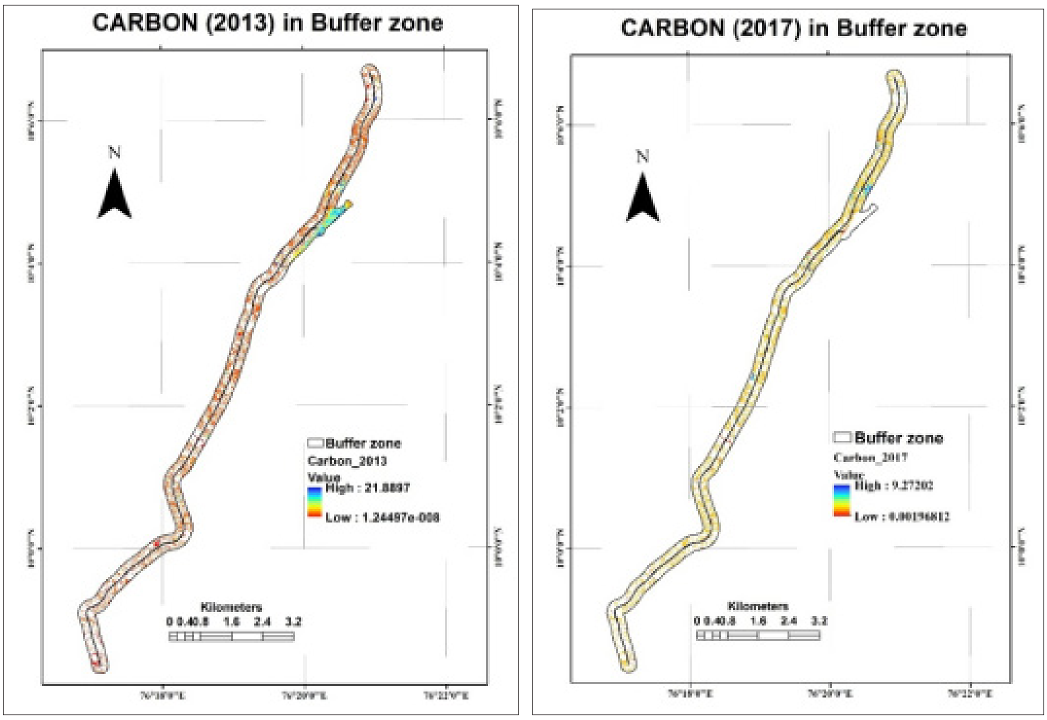


Figure 9: Change in carbon content in the buffer zone between (a) 2013 &(b)2017.

Figure 9 gives the change of carbon content in the buffer zone between 2013 and 2017 respectively. It has decreased from 0-21.9 tons/pixel in 2013 to 0-9.3 tons/pixel in 2017. Within this area of 734.5 ha the change is 6390.3 tons of carbon. The main types of vegetation occurring in this area are mixed trees, coconut trees, Fallow paddy, floating vegetation, grass land. The major decrease in carbon content is contributed by mixed trees, 5968tons, followed by coconut, 384.7tons.

Figure 10 (a &b) gives the change of carbon content in the metro yard area between 2013 and 2017 respectively. It is decreased from 1-17 tons/pixel in 2013 to 0.5-3.9 tons/pixel in 2017. In this area of 23.3ha the carbon content is reduced by 70.679tons. Here it is mainly fallow paddy which was cleared for setting up the metro yard.

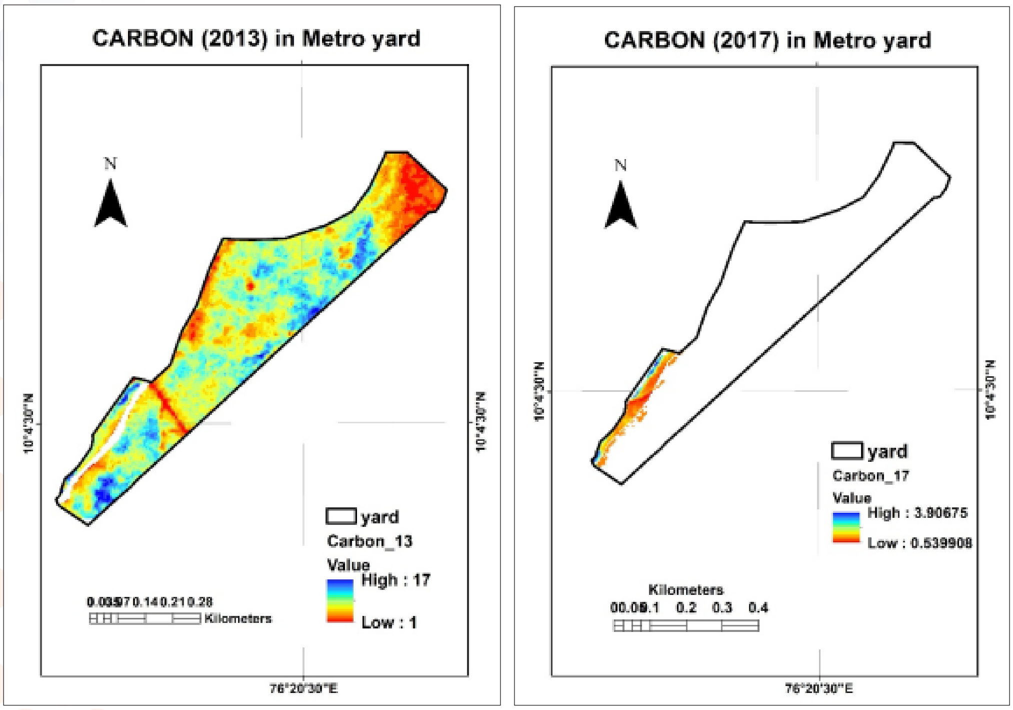


Figure 10: Change in carbon content in metro yard between (a) 2013 & (b) 2017.

Comparing the area and type of vegetation, maximum change occurred in the rail and station area with a reduction of 20.92 tons/ha followed by 8.7 tons/ha in the buffer area. The reduced carbon content is lowest in the metro yard with 3.03 tons/ha. Here even though the complete area is cleared, the vegetation type being grass land and fallow paddy is having low NDVI. In totality within an area of 777.7 ha, the total carbon content is reduced by 6877 tons i.e.: 8.84 tons/ha on an average.

Discussion

As per the tree survey carried out along the proposed alignment by Kochi Metro Rail Limited (KMRL) the following information were collected. The trees that could be affected by the implementation of the project were enumerated within 10m (5m on either side from the center of the alignment). The tree volume and biomass were determined according to the standard methods of forest mensuration. The trees along the sides of the proposed alignment are mostly planted for shade purpose and a few are fruit bearing trees and coconut trees. There are very few trees which falls under the definition of The Kerala Preservation of Trees Act, 1986 (http://extwprlegs1.fao.org/docs/pdf/ind80121.pdf). About 477 trees existed on the proposed alignment. The estimated biomass loss of 477 trees was 97tons and ten times the number of trees were planned to be planted by KMRL. But this estimate is much low compared with the results obtained from this study. According to their calculation about 4770 plants are required to be planted in the project area in an area of 2 ha. A green belt for the Muttom Dock Yard was also in the plan as a compensatory afforestation work. According to the report, the recommended plant species for afforestation include Alstonia scholaris, Polyalthia longifolia, Pongamia glabra, Mimusops elengi, Sweitenia mahogany, Hydnocarpus laurifolia, Hopea parviflora, Strychnos nuxvomica, Cassia fistula and Casuarina equisetifolia.

It is observed that majority of the trees planted on the sides are cut. Most of the trees have girth greater than 70cm, which are mature trees with high carbon content. As per the latest reports from different sources, 6937 trees are claimed to be planted in different areas, along the metro and other public places and institutions, by KMRL to compensate for the loss. Though KMRL promoted afforestation programs at various places within city, it has to be noted that the trees being cut are larger and older having greater sequestration potential in comparison to newly planted trees [23,24]. So it may take years to compensate for the loss. And one more fact is that survival of plants, planted in the area is subject to uncertainty.

Conclusion

This is an attempt to study the change in carbon sequestration potential of Kochi with the introduction of metro rail. Spatial information on the distribution, composition and status of vegetation at appropriate scale was provided by a combination of satellite imagery and field observation. The study estimates the change in carbon sequestration capacity before and after the commissioning of metro rail project ie; between 2013 and 2017. The clearing activities exclusively for the metro rail construction were analysed. The study area covers a total of 777.7 ha along the metro corridor which was divided into different zones for the study purpose. It includes 19.9 ha of metro rail and stations, 23.3 ha metro maintenance yard and 734.5 ha buffer zone. The buffer zone up to 200m on both sides were selected, since vegetation pattern change beyond that may be contributed by other activities. The vegetation change in the area shows a net reduction of 35.8 ha between 2013 and 2017 which is converted into built-up area. This is also reflected in the NDVI map which shows a decrease in the high NDVI area. The carbon content was calculated using volumetric equations derived through ground truthing measurements. In totality within an area of 777.7 ha, the total carbon content is reduced by 6877 tons i.e; 8.84 tons/ha. Comparing the area and type of vegetation, maximum change occurred in the rail and station area with a reduction of 20.92tons/ha ie; 416.2 tons in 19.9ha being the main type of vegetation cleared include mature trees. In the buffer area the reduction is 8.7tons/ha ie; 6390.3tons in 734.5ha. The reduced carbon content is lowest in the metro yard with 3.03 tons/ha ie; 70.68 tons in 23.3ha. Here even though the complete area is cleared, the vegetation type being grass land and fallow paddy is having low NDVI. Even though area cleared is more in buffer zone the carbon content reduction is more in rail and station zone which was having more mature trees in 2013 and were cleared for the construction activities. The compensating afforestation activities by KMRL couldn't contribute much at present with low NDVI vegetation. A detailed analysis of carbon sequestration capacity of different vegetation types present along the metro corridor is done here. The results confirms the fact that mature trees contribute more in increasing the carbon sequestration capacity of the area. Based on the results with the changing environmental scenario this research work would help in planning for the sustainable management of urbanization and associated land use changes by generating baseline data with respect to carbon sequestration capacity of similar cities of emerging economies elsewhere [25,26].

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