Evaluating the spatio-temporal dynamic urban tree of biodiversity in Ranchi city region using Geoinformatics

By

Shashank Bhaskar

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Under the supervision of

Dr. Amit Kumar

Assistant Professor

Department of Geoinformatics

(School of Natural Resource Management)

Central University of Jharkhand

Ranchi - 835205

INTRODUCTION

- Flora and their diversity in cities have long been a neglected research area instead, more natural environments or environments used for human productions such as forest or rural areas. However, there has been a recent major increase in studies of urban green areas and their importance for species richness.
- Information about the tree species is required for implementing ecosystem management. Forest acts as a carbon sequestration because it stores lot of carbon in the form of biomass So, we need accurate estimation of biomass for the future ecosystem management.
- Aboveground biomass (AGB) estimation is a critical aspect of carbon stock studies and also provides information on deforestation and carbon sequestration on the global carbon balance (Ketterings et al. 2001).
- Remote sensing based AGB estimation is being widely used and are relatively more feasible method to map the urban tree cover and its various components viz., tree heights, diameter and AGB. Urban green space AGB estimation based on remote sensing can be derived from the correlation between field measurements and spectral of vegetation index derived from multispectral, sar and hyperspectral datasets.
- Basically biomass is obtained from field data or through Geoinformatics techniques. Field based techniques are more accurate ways for collecting of biomass data. In any case, these approaches are often time consuming, work concentrated (labour intensive) and difficult to implement especially in remote areas, they cannot provide the spatial distribution of biomass in large areas.
- The advantages of remotely sensed data, as it has the ability to provide the repetitive collection of data, a synoptic view, a digital format that allows fast processing of large quantities of data, and the high correlations between spectral bands and vegetation parameters, make it the primary source for large area AGB estimation, especially in areas of difficult access. Therefore, remote sensing-based AGB estimation has increasingly attracted scientific interest

- Field based biomass is obtained from two methods i.e. destructive and non-destructive methods. The most generally used method for estimating biomass of forest is through allometric equations. Brown et al. developed allometric regression equations to estimate the above-ground biomass of individual trees for tropical forests as a function of diameter at breast height, total height and wood density and Holdridge life zone.
- Several radar-based above ground biomass estimation studies and it exhibit higher sensitivity of the backscatter intensity or coefficient to the biophysical parameters of vegetation in HV polarization as compared to HH polarization (Suzuki et al., 2013; Le et al., 1992; Englhart et al., 2011).
- Various multispectral, SAR, and hyperspectral sensors are available for biomass mapping viz., Sentinel 2, Landsat 8, Envisat, Sentinel 1, ALOS PALSAR, ERS2 SAR, RADARSAT1 &2, AISA. Phased Array Type L-band Synthetic Aperture Radar (PALSAR) L-band (Mitchard et al., 2011; Carreiras et al., 2012) operates in longer wavelength and has a stronger capability to penetrate through the forest canopy and capture more information about the vertical structure of the forests (Hajnsek et al., 2009).
- The term “forest health” is vaguely defined in the literature, making its application to forest management difficult (Kolb et al., 1994). forest health is always a matter of perspective. Social, economic, and ecological perspectives are taken most frequently.

LITERATURE REVIEW

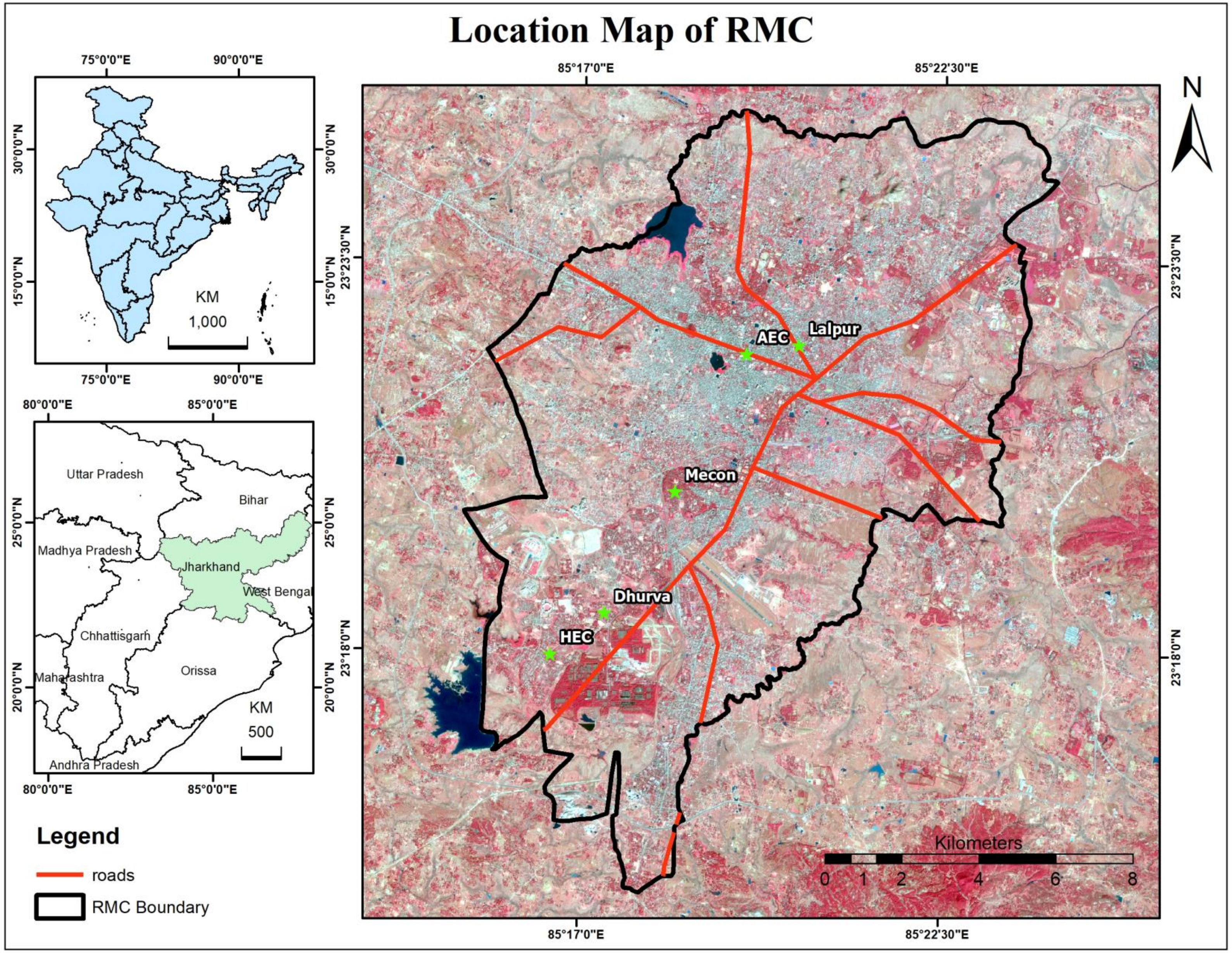
- Today the carbon content in the atmosphere is predominantly increasing due to greenhouse gas emission and deforestation. Forest plays a key role in absorbing carbon dioxide from atmosphere by process of sequestration through photosynthesis and stores in form of wood biomass which contains nearly 70% - 80% of global carbon (K. K. Kumar et al).
- Different forms of biomass in the environment include agricultural products, wood, renewable energy and solid waste. Therefore, it is essential to estimate the biomass content in the environment.
- In olden days, biomass is estimated by forest inventory techniques which consume lot of time and cost.
- The spatial distribution of biomass cannot be obtained by traditional inventory forest techniques so the application of remote sensing in biomass assessment is introduced to solve the problem. Both optical (LANDSAT-8) and synthetic aperture radar (ALOS-2) remote sensing data are used for above ground biomass (AGB) assessment. Biomass that stores in branch and stem of tree is called as above-ground biomass.
- Optical remote sensing calculates the biomass-based on the spectral indices of Soil Adjusted Vegetation Index (SAVI) and Ratio Vegetation Index (RVI) by regression analysis (K. K. Kumar et al).
- Synthetic aperture radar (SAR) is an emerging technique that uses high-frequency wavelengths for biomass estimation. HV backscattering of ALOS-2 shows good relation with field calculated biomass compared to HH utilizes for biomass model generation by linear regression analysis.
- Combination of both optical spectral indices (SAVI, RVI) and HV (ALOS-2) SAR backscattering increases the plantation biomass accuracy to compared to optical and SAR.

- Importance of forested areas in carbon sequestration is already accepted, and well documented (FSI, 1988, and Tiwari and Singh, 1987), however not many attempts have been made to address the potential of trees in carbon sequestration in Urban scenario.
- Carbon sequestration is a phenomenon for the storage of CO_2 or other forms of carbon to mitigate global warming and its one of the important clause of Kyoto Protocol, through biological, chemical or physical processes; CO_2 is captured from the atmosphere.
- Assessment of biomass provides information on the structure and functional attributes of trees. With approximately 50% of dry biomass comprises of carbon biomass assessments illustrate the amount of carbon that may be sequestered by trees.
- Biomass is an important indicator in carbon sequestration therefore estimating the biomass in trees is the first step in carbon accounting. (Lu 2006) mentioned three approaches to biomass assessment. These are field measurement, remote sensing, and GIS-based approach.
- It is an established that the biomass is a function of tree density, height and basal area at any given location. These parameters contribute to the above-ground biomass which differs with site, habitat, forest successional stage, composition of forest, species variability and varying tree density etc. (Brunig 1983; Joshi & Ghose 2014).
- Three primary factors influence the occurrence of treed patches: urban morphology, environment, and vegetation management decisions (Stearns and Montag, 1974; Dorney et al., 1984; Sanders, 1984; Richards et al., 1984; Nowak et al., 1996).
- Sentinel-2 satellite imagery combined with field-measured biomass using RF, a machine learning regression algorithm, to estimate forest AGB in Yok Don National Park, Vietnam. RF regression algorithm was further used to reduce the number of variables in such a way that a minimum number of selected variables can be able to estimate AGB at a satisfactory level (An Thi NgocDang et al, 2019).

OBJECTIVES

1. To map the spatial distribution of tree diversity in Ranchi urban region.
2. To estimate the above ground biomass (AGB) using field based method.
3. To estimate AGB of urban trees using microwave remote sensing.
4. To identify the zones of high and low tree density, and its implication on urban environment.
5. To evaluate the urban tree cover health using various biophysical variables.

STUDY AREA



- The present study was conducted in Ranchi districts of Jharkhand, which occupies total area of 5097 sq. km. Ranchi is the capital of Jharkhand.
- It lies approximately between 85°17′ East longitudes and 23°20′ North latitudes. Ranchi is located at an elevation of 651 m above the sea level. Ranchi is the capital of Jharkhand.
- According to 2011 census of India Ranchi had total population is 29,14,253 (Census of India, 2011).
- Ranchi municipal corporation has a population of 1,126,741 making it the 46th largest urban city in India. Ranchi is highly rich in species diversification but due to increase in human population some species are lost

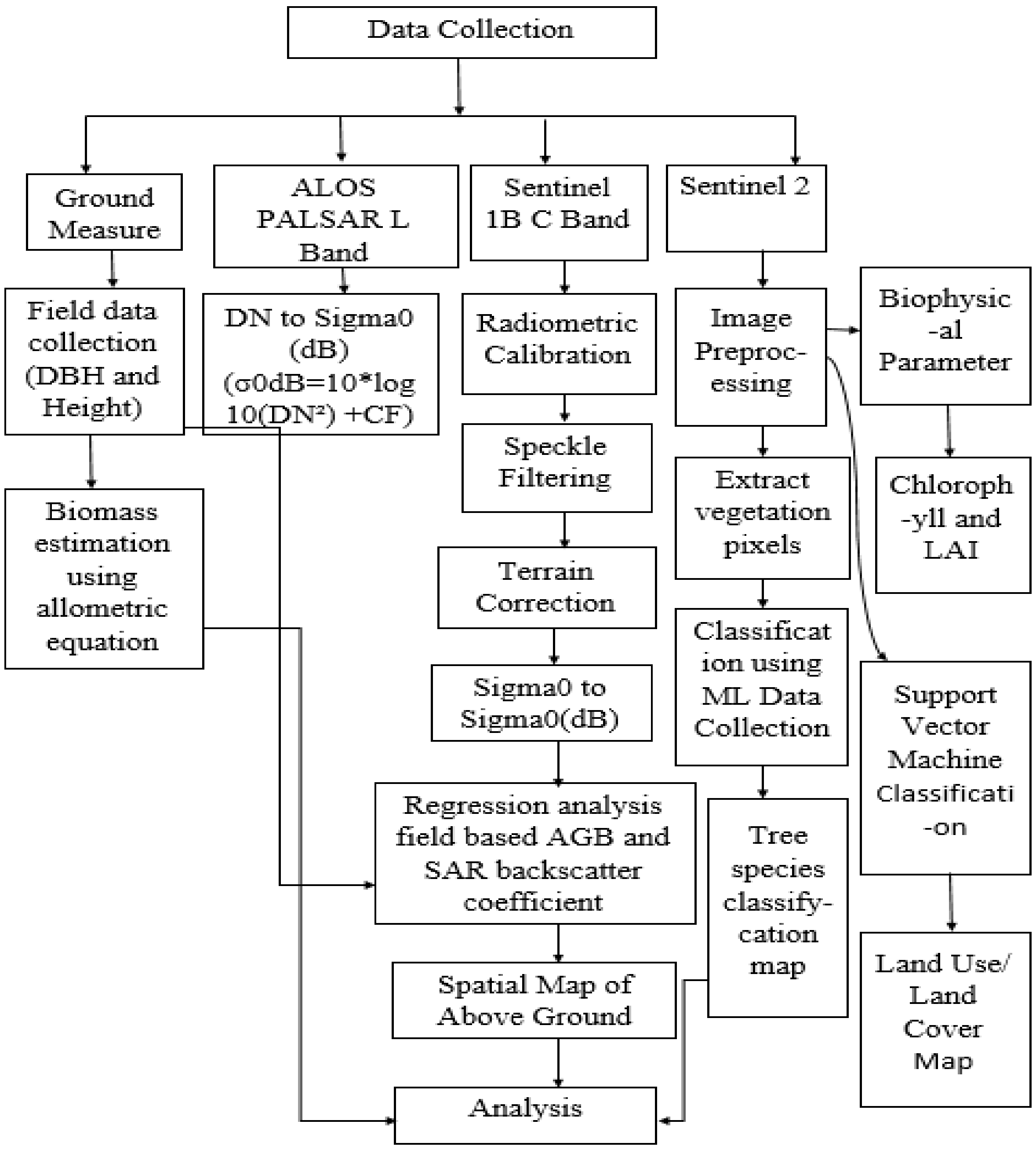
Data And Software Used

In the present study, Google Earth Engine, ENVI 5.3, ArcGIS 10.4, QGIS, SNAP, R Studio, MS Excel have been used for the different objectives.

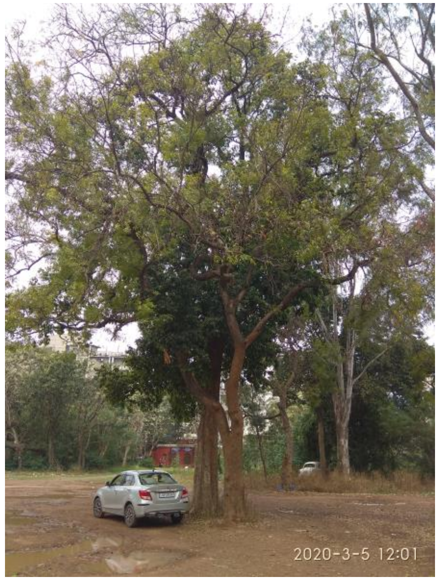
Table containing the details of the data sets used in this study

Data / Sensor	Date-of-acquisition	Spatial & temporal resolution	Source	Use / Description
Sentinel 2 B	22/05/2020 13/01/2020	10 m	USGS Earth explorer	Land Use/ Land Cover Mapping, Tree species classification, Tree health cover monitoring (Chlorophyll, Leaf Area index).
Landsat 8 OLI	27/05/2020	30 m	USGS Earth explorer	Land surface temperature mapping
Sentinel 1	22/01/2020	10 m, VV & VH Polarization	Copernicus hub	SAR based AGB (Above Ground Biomass
ALOS PALSAR	23/07/2008	50 m, HV & HH Polarization	Alaska satellite facility	SAR based AGB (Above Ground Biomass

METHODOLOGY



FIELD PHOTOGRAPHS



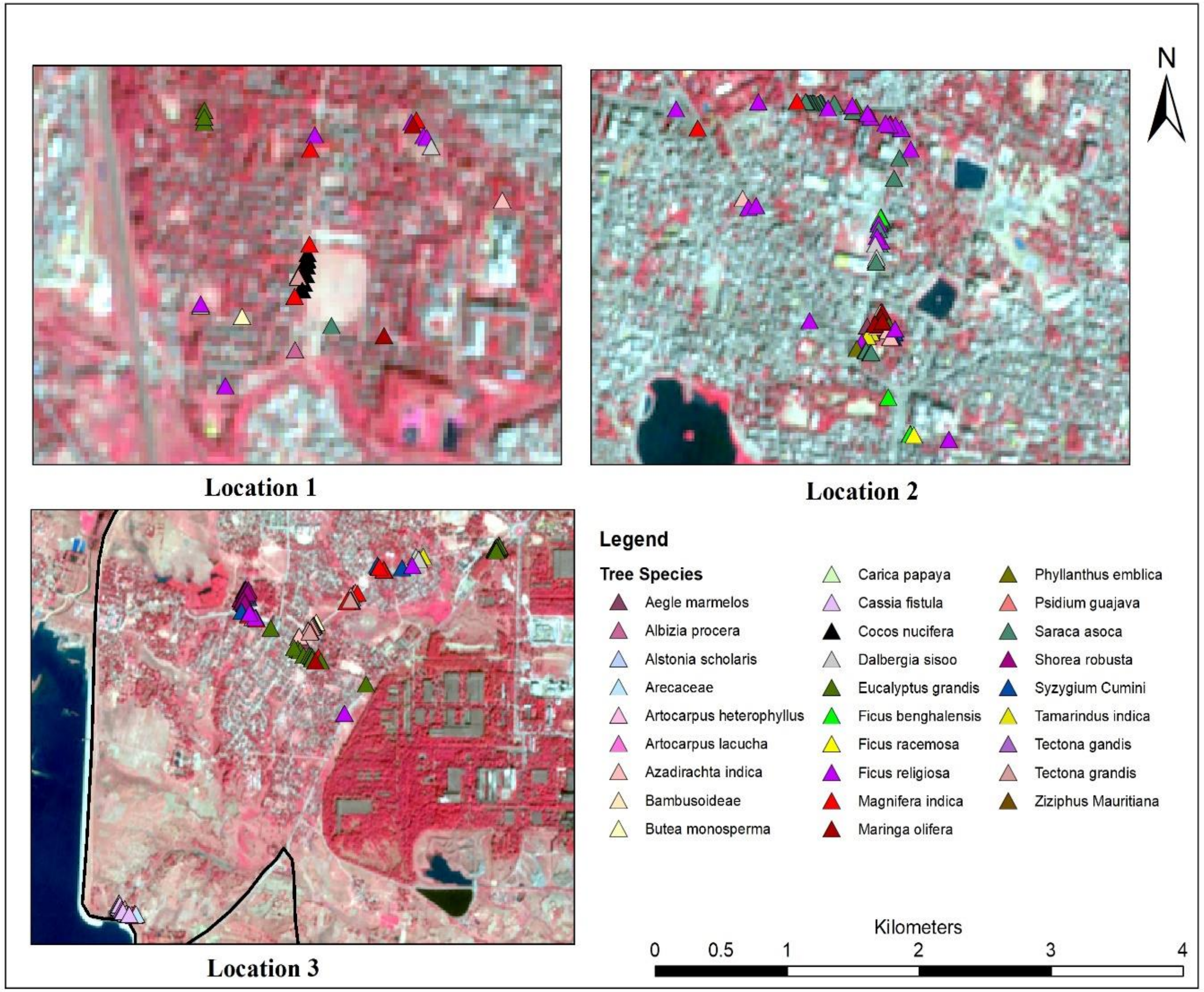
Specific gravity and volume equations of species present in the study area

Species	Specific Gravity	Volume Equations
Phyllanthus Emblica	0.619	V=-0.406+3.540 D-3.231D*D
Saraca asoca	0.59	V= (0.0673*(0.59*D*D*H) ^0.976
Ziziphus Mauritiana	0.597	V = -0.00342/D -0.0922/D+2.28178+9.46641*D
Bambusoideae	0.655	V= (0.0673*(0.59*D*D*H) ^0.976
Ficus benghalensis	0.59	√V= 0.03629+3.95389*D-0.84421*SQRTD
Aegle marmelos	0.754	V= 0.119-1.768*D+9.258*D*D
Cocos nucifera	0.48	V= (0.0673*(0.59*D*D*H) ^0.976
Artocarpus lacucha	0.64	V= (0.0673*(0.59*D*D*H) ^0.976
Ficus racemosa	0.619	V= (0.0673*(0.59*D*D*H) ^0.976
Eucalyptus grandis	0.53	V= 0.02894-0.89284*D+8.72416*D*D
Psidium guajava	1.025	V= (0.0673*(0.59*D*D*H) ^0.976
Tamarindus indica	1.28	V= 0.046883-0.894379*D+7.220441*D*D
Syzygium Cumini	0.647	V = 0.2736-3.377*D+12.959*D*D
Artocarpus heterophyllus	0.46	V= 0.076-1.319*D+11.37*D*D
Magnifera indica	0.68	V = -0.00092-0.55547*D+7.3446*D*D
Azadirachta indica	0.7275	V =-0.00342/D*D -0.0922/D+2.28178+9.46641*D
Butea monosperma	0.44	√V= 0.24276+2.95525*D
Arecaceae	0.64	V= 0.007602/D*2 -0.033037/D + 1.868567 +4.483454*D*D
Carica papaya	1.03	V= (0.0673*(0.59*D*D*H) ^0.976
Ficus religiosa	0.385	√V= 0.03629+3.95389 *D-0.84421*SQRTD
Maringa olifera	0.262	V= (0.0673*(0.59*D*D*H) ^0.976
Shorea robusta	0.73	V= 0.05823-1.22994*D+10.51982*D*D
Dalbergia sisoo	0.669	V/D*D =0.00331/D*D+0.000636
Alstonia scholaris	0.36	V= (0.0673*(0.59*D*D*H) ^0.976
Albizia procera	0.64	V= -0.043832+3.262852* D
Tectona grandis	0.577	V/D*D= 0.045181/D*D-0.91863/D+8.18261+1.95661*D
Cassia fistula	0.812	V= 0.066+0.287*D*D*H

Source: FSI (1996), FRI (1996), Salunkhe et al. (2001), FSI (2015), FSI (2019)

Grids generation and vegetation sampling

- The topographic sheet (1:50,000) of Ranchi district had been collected and used for identifying the major elements such as built up, agriculture, forest, wastelands, water body or any other such elements.
- Vegetation sampling was done using field transect method in the February 2020–March 2020 and transects were laid in each grid in the representative areas of the total vegetation of that grid.
- The whole study area is divided into 204 grids with a size of 500 m * 500 m. Vegetation indices used for identifying the vegetation in the Ranchi municipal corporation.
- The vegetation sampling is done randomly along the roads of Ranchi city and also where the vegetation was high. The latitude and longitude of individual tree species had been recorded by GPS and DBH were collected by using measuring tape. Specimen of each trees were collected during study and species were photographed during field visit.
- The identification of recorded species was done with the help of flora found in Jharkhand. The scientific name of the species was identified on the basis of some journals and as well as from the BSI (Botanical survey of India). The latitude and longitude points were used for preparing the location and distribution map of plant species.

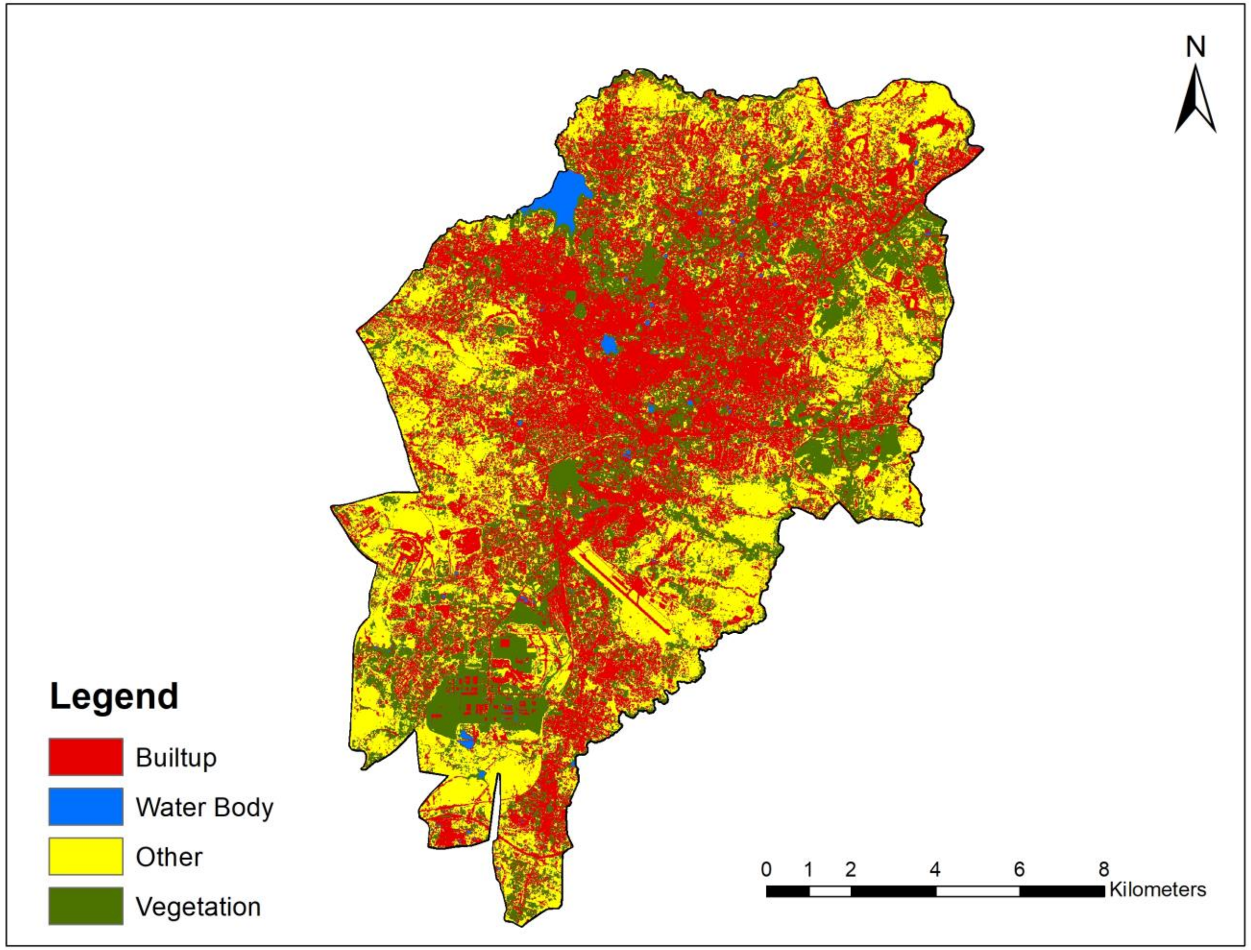


This figure representing the tree species wise map of the Ranchi municipal corporation

RESULTS AND DISCUSSION

Land Use/ Land Cover

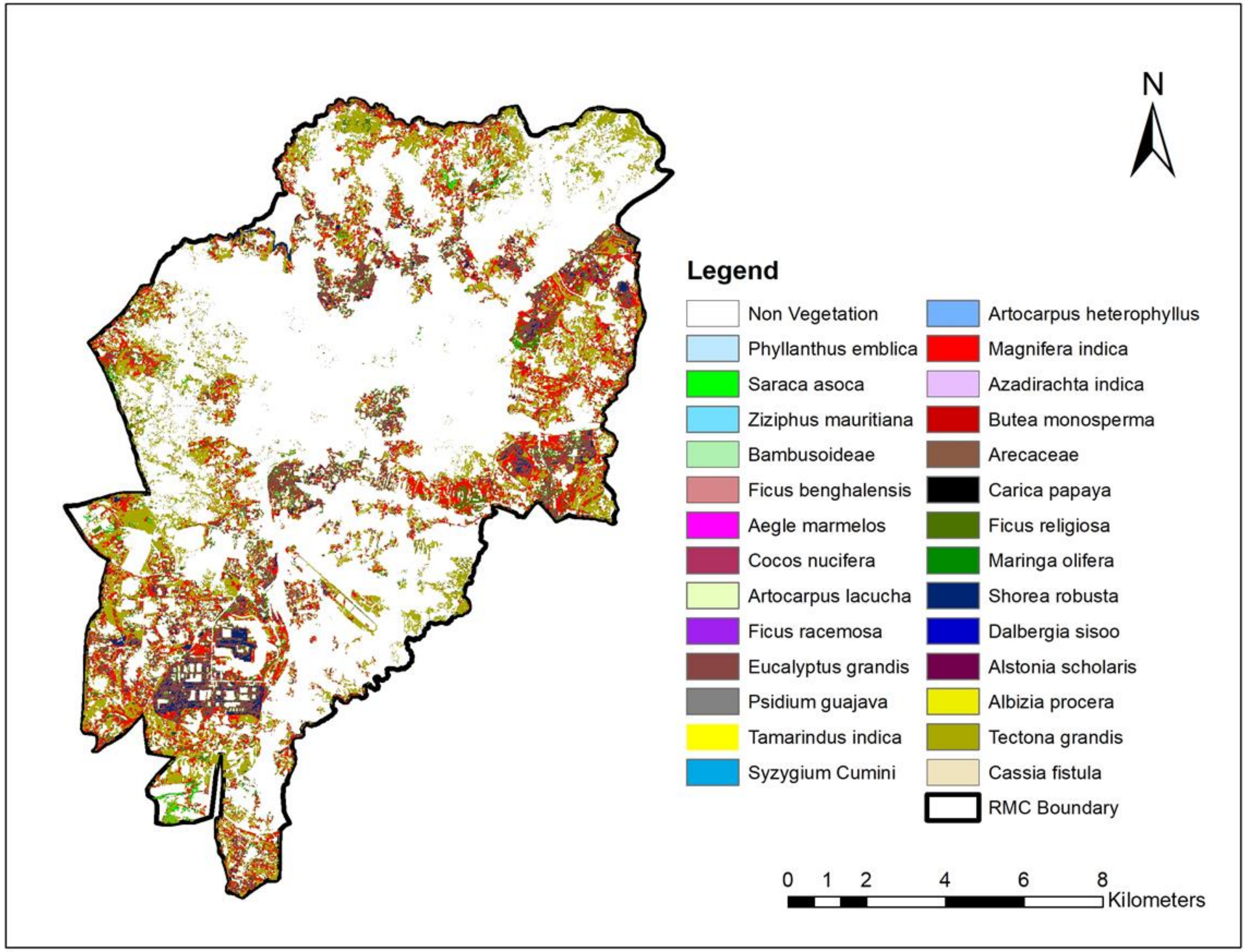
- The calibrated Sentinel 2 was used to prepare the land use land cover map.
- Support vector machine techniques was implemented for the classification of an image. Support vector machine classification technique uses training sites to classify the satellite images and also used google earth for the reference.
- The image is classified into four classes Built up, Water Body, Vegetation and Other classes. From the support vector machine technique built up has an area of 86.55 sq km, water body 26.20 sq km), vegetation (16.76 sq km) and other classes has 45.61 sq km.
- Accuracy assessment of classification resulted an overall accuracy for classification was 98.15 % and kappa coefficient is 0.975.



Land use/ Land cover map of study area for year 2020

TREE SPECIES CLASSIFICATION USING MACHINE LEARNING

- During field surveys, 276 individual trees were recorded from 27 species was used for the classification. Of these, six species were considered to be common.
- The most common dominant tree species found are Eucalyptus grandis and followed by Ficus religiosa, Saraca asoca, Magnifera indica, Shorea robusta and Tectona grandis. These six species are quite different in size, canopy area and in appearance.
- Accuracy assessment of classification resulted an overall accuracy for classification was 87.50 % and kappa coefficient is 0.924.

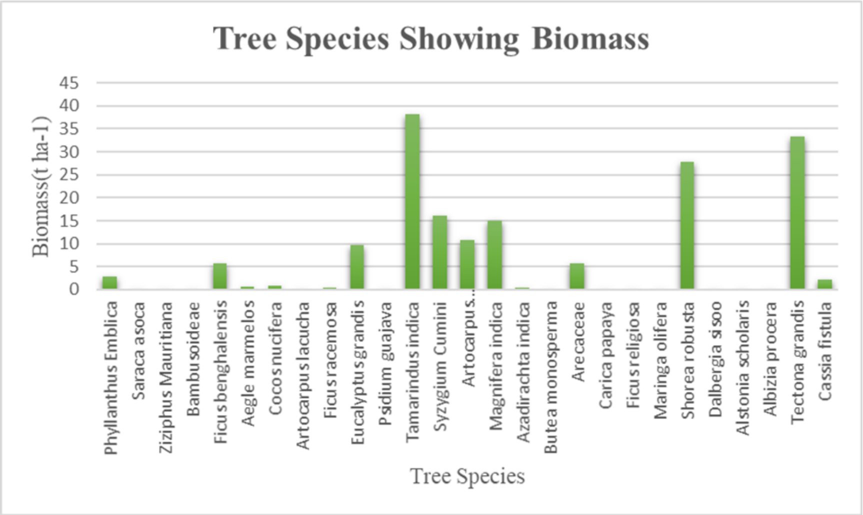


The above map is classified by using ML Methods i.e. Support vector Machine for RMC (Ranchi Municipal Corporation).

FIELD BASED AGB DERIVED FROM THE ALLOMETRIC EQUATION

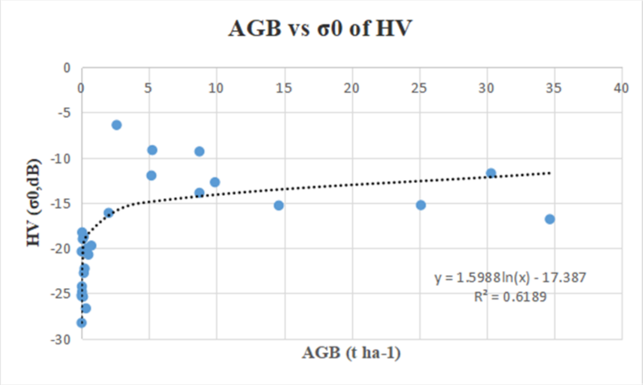
S. No.	Species	Scientific Name	No of trees	Mean DBH (Cm)	Mean Height	Mean biomass (t ha-1)
1	Amla	Phyllanthus Emblica	1	29.29	7.31	2.86
2	Ashoka	Saraca asoca	29	23.15	10.20	0.12
3	Bair	Ziziphus Mauritiana	2	39.49	9.44	0.24
4	Bamboo	Bambusoideae	12	12.02	9.01	0.02
5	Banyan	Ficus benghalensis	4	83.12	12.95	5.77
6	Bel	Aegle marmelos	8	26.75	8.34	0.56
7	Coconut	Cocos nucifera	7	55.14	15.97	0.79
8	Dahu	Artocarpus lacucha	3	23.67	6.70	0.09
9	Dumar	Ficus racemosa	1	52.22	7.92	0.46
10	Eucalyptus	Eucalyptus grandis	43	41.71	16.68	9.61
11	Guava	Psidium guajava	4	24.12	8.45	0.18
12	Imli	Tamarindus indica	6	57.16	12.03	38.21
13	Jamun	Syzygium Cumini	14	40.30	11.62	16.09
14	Jackfruit	Artocarpus heterophyllus	6	42.62	10.21	10.88
15	Mango	Magnifera indica	26	48.62	9.44	14.94
16	Neem	Azadirachta indica	5	46.81	11.09	0.35
17	Palash	Butea monosperma	3	54.14	15.03	0.006
18	Palm	Arecaceae	2	41.24	8.22	5.69
19	Papaya	Carica papaya	1	7.00	9.62	0.018
20	Peepal	Ficus religiosa	36	76.97	12.02	0.007
21	Sahjan	Maringa olifera	8	42.11	9.44	0.182
22	Sal	Shorea robusta	24	55.10	13.28	27.691
23	Seesum	Dalbergia sisoo	6	49.15	9.49	0.001
24	Sinderia	Alstonia scholaris	2	21.49	6.40	0.041
25	Shirish	Albizia procera	1	22.29	15.84	0.051
26	Teak	Tectona grandis	15	24.92	6.15	33.41
27	Wakin	Cassia fistula	4	32.48	7.61	2.21

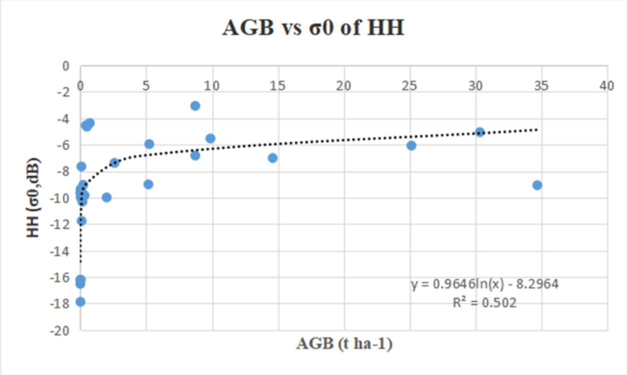
Species comprises with their above ground biomass (t ha-1)

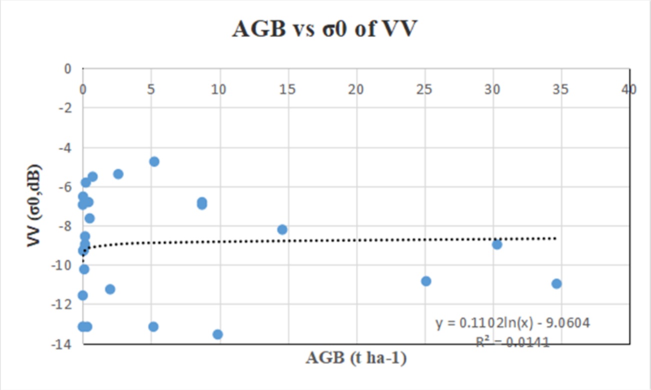


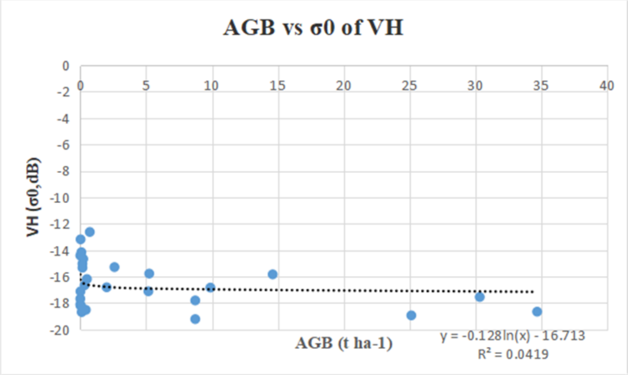
AGB ESTIMATION USING SAR (SYNTHETIC APERTURE RADAR)

- A total of 27 randomly selected tree species were taken at different parts of Ranchi municipal corporation area. In this research, a total 170.57 t ha-1 above ground biomass was recorded.
- The highest biomass is contributed by *Tamarindus indica* (38.21 t ha−1) and followed by *Tectona grandis* (33.41 t ha−1), *Shorea robusta* (23.14 t ha−1), *Syzygium Cumini* (16.09 t ha-1) and *Magnifera indica* (14.94 t ha -1).
- The logistic regression analysis has been done for the comparison between above ground biomass (AGB) and backscattering coefficient retrieved from HH polarisation, HV polarisation of ALOS PALSR. From this regression analysis, it is observed that highest correlation of AGB and backscattering coefficient has been seen in HV (R^2 = 0.61) polarisation as compared with HH (R^2 = 0.502) polarisation.
- The regression analysis between field based AGB and backscatter coefficient retrieved in VV and VH polarizations of Sentinel 1B exhibited insignificant correlation with VH (R^2 = 0.0149) as compared to VV (R^2 = 0.0141). The higher R^2 value may be due to higher sensitive and higher penetration level of L band as compared to C band.

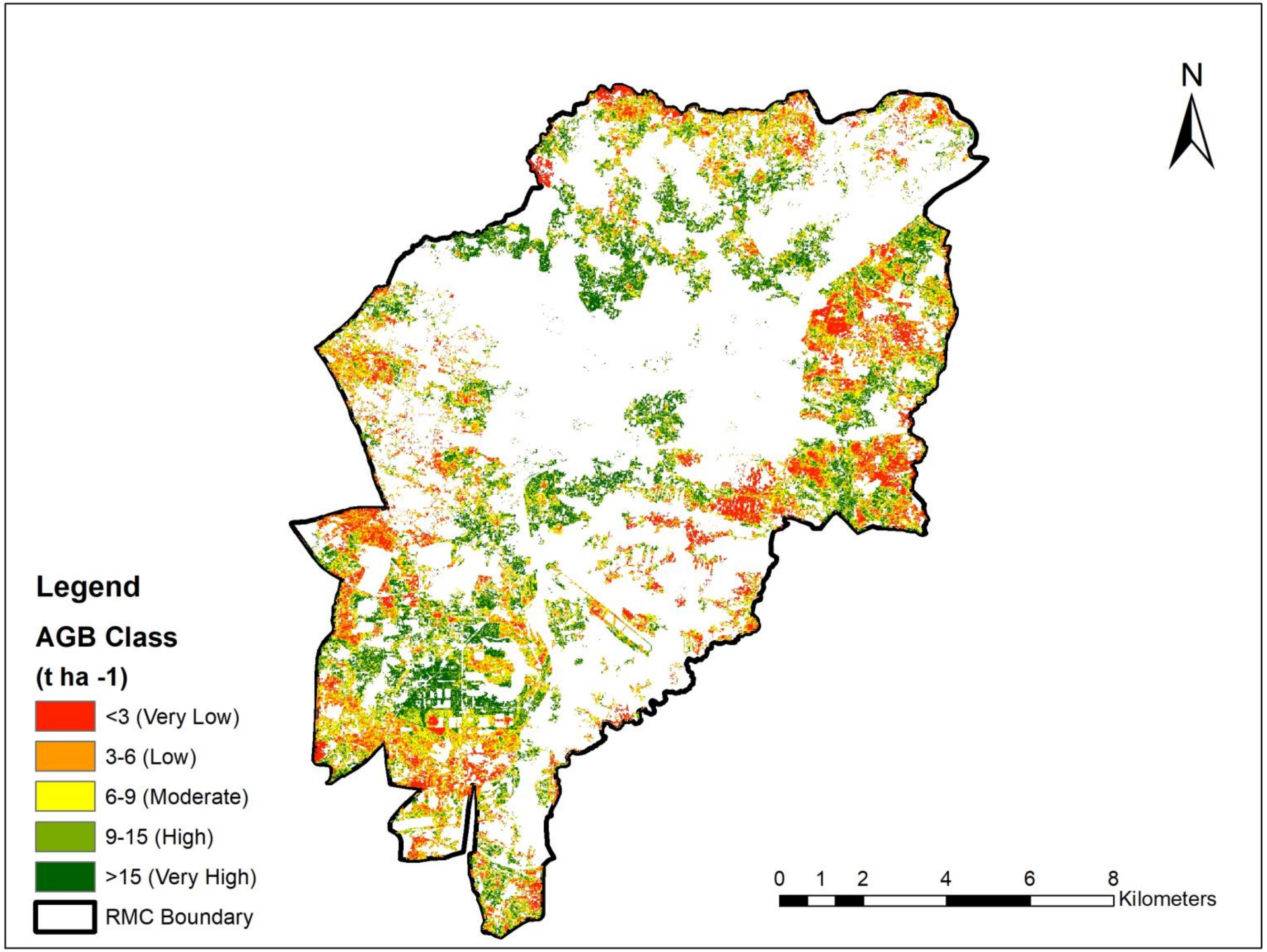






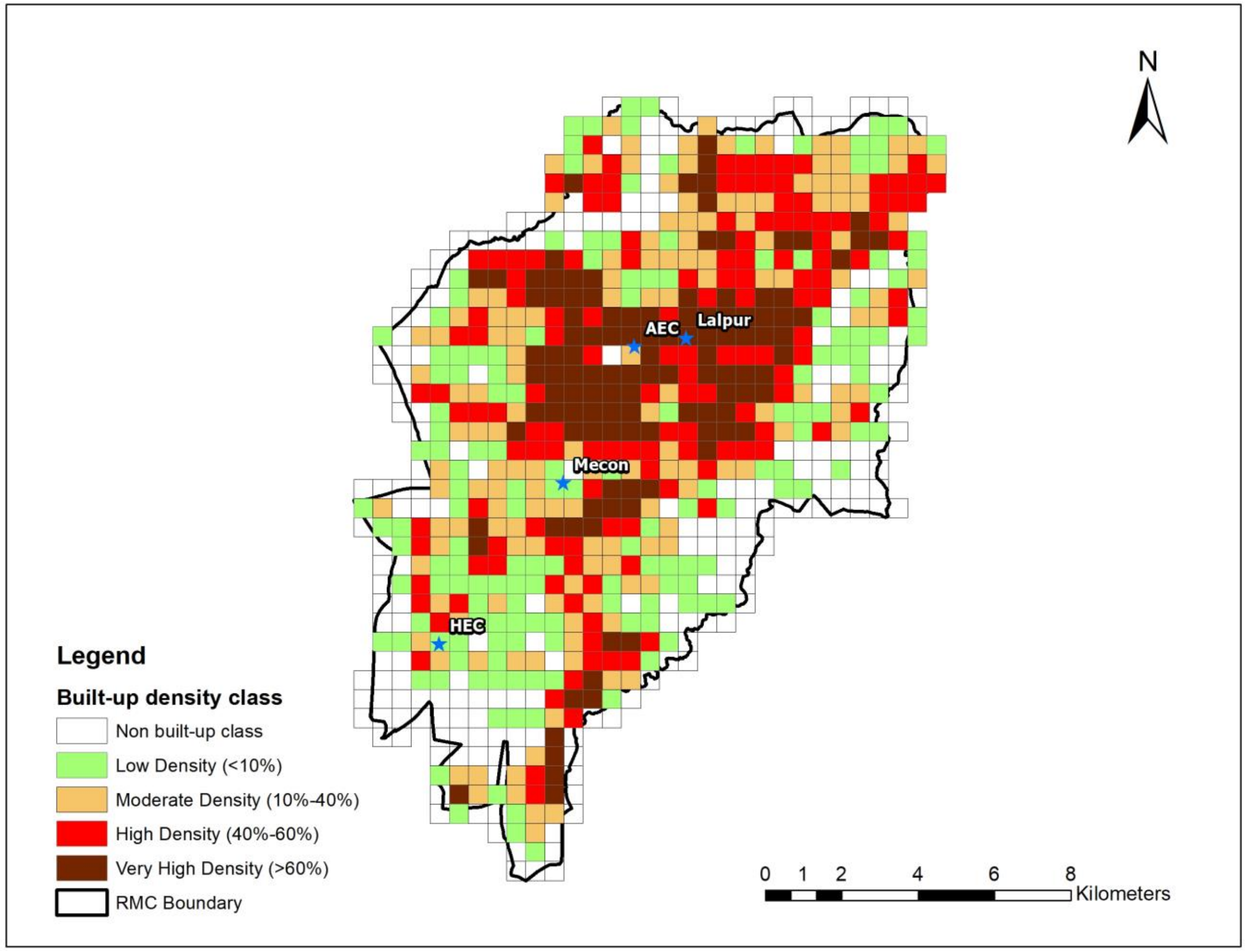


Estimated above ground biomass (AGB) map prepared using backscattering coefficients of HV polarization of ALOS PALSAR



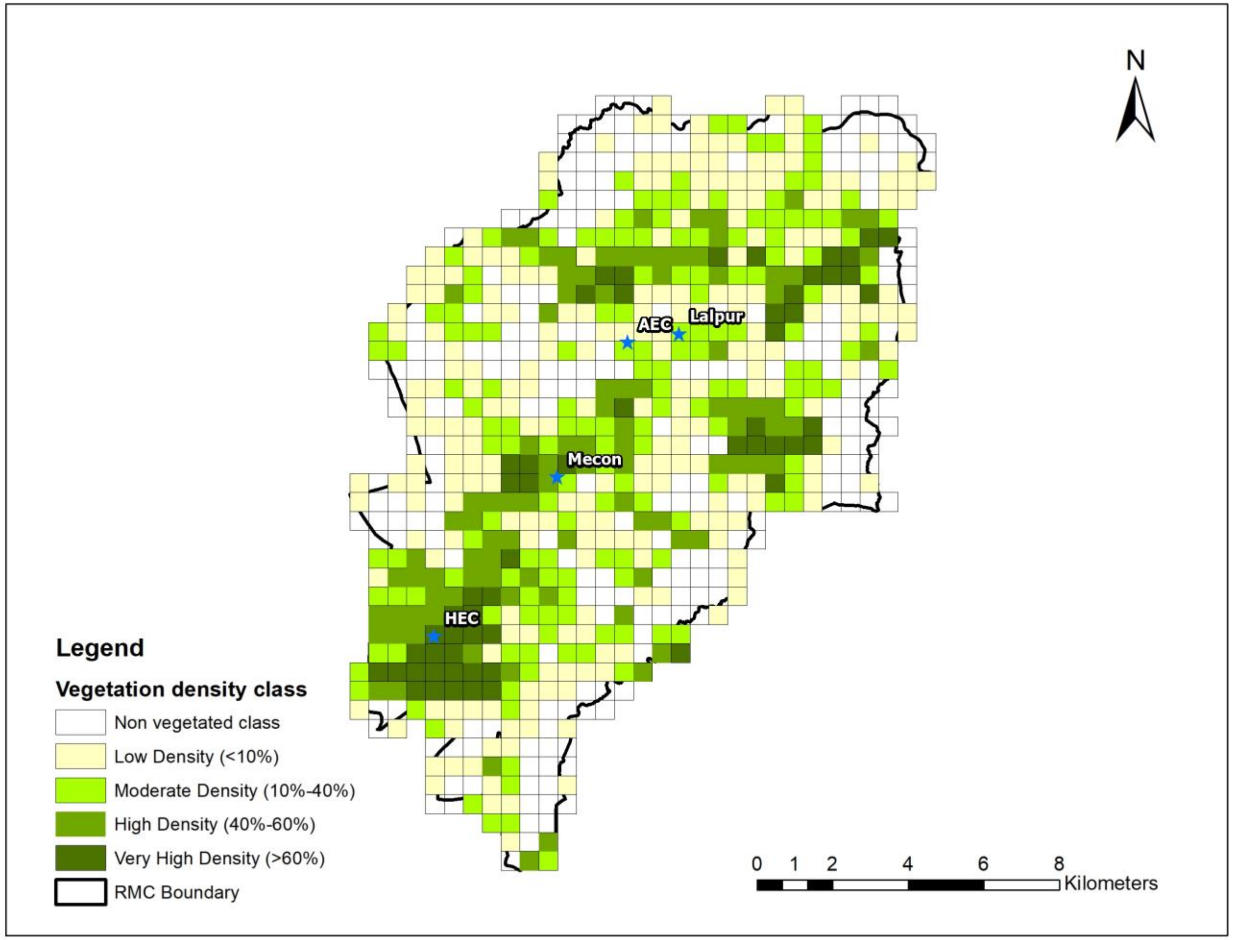
Spatial distribution of built-up density and vegetation density in Ranchi municipal corporation

- Built-up density and vegetation density are the total areas of the built-up and vegetation per unit area, respectively. The grid-based technique was utilized to perform built-up density and vegetation density classification using Sentinel 2 of Ranchi municipal corporation.
- This represents that the 15.6% area was characterized as very high built-up density, whereas 32.14% area as high density built-up area, which are mostly observed in central and western part of city. Few fragmented high built-up density land were also observed in southern parts and north-eastern parts. Low built-up density was observed in major parts 67.14% primarily near rural–urban fringe, followed by moderate built-up density 48% in the Ranchi municipal corporation.



Spatial distribution of built-up density in Ranchi municipal corporation

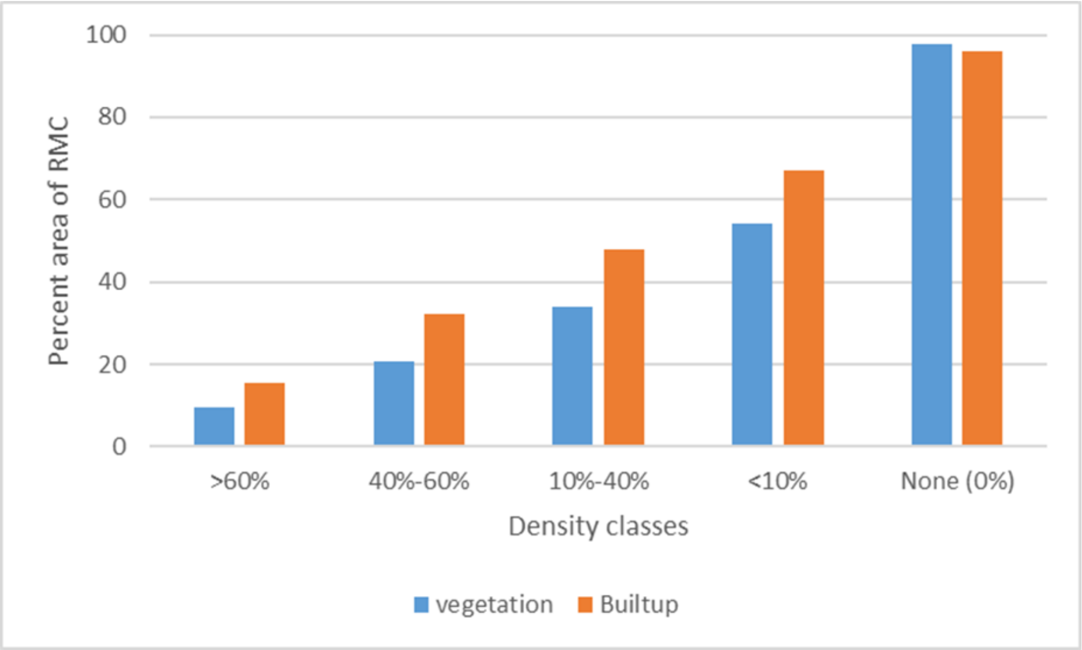
- The vegetation density exhibits that the only 9.7% and 20.8% area were categorized under very high density and high density vegetation respectively, which are located in the southern (industrial area) and northern and eastern parts of Ranchi municipal corporation. The moderate density vegetation covers major parts 33.87% of the Ranchi municipal corporation followed by low density vegetation 54.31% mainly associated with built-up land.
- The main objective of Built-up density and vegetation density extraction was to show the high and low tree diversity zones and its implication on urban dwellers.



Spatial distribution of vegetation density in Ranchi municipal corporation

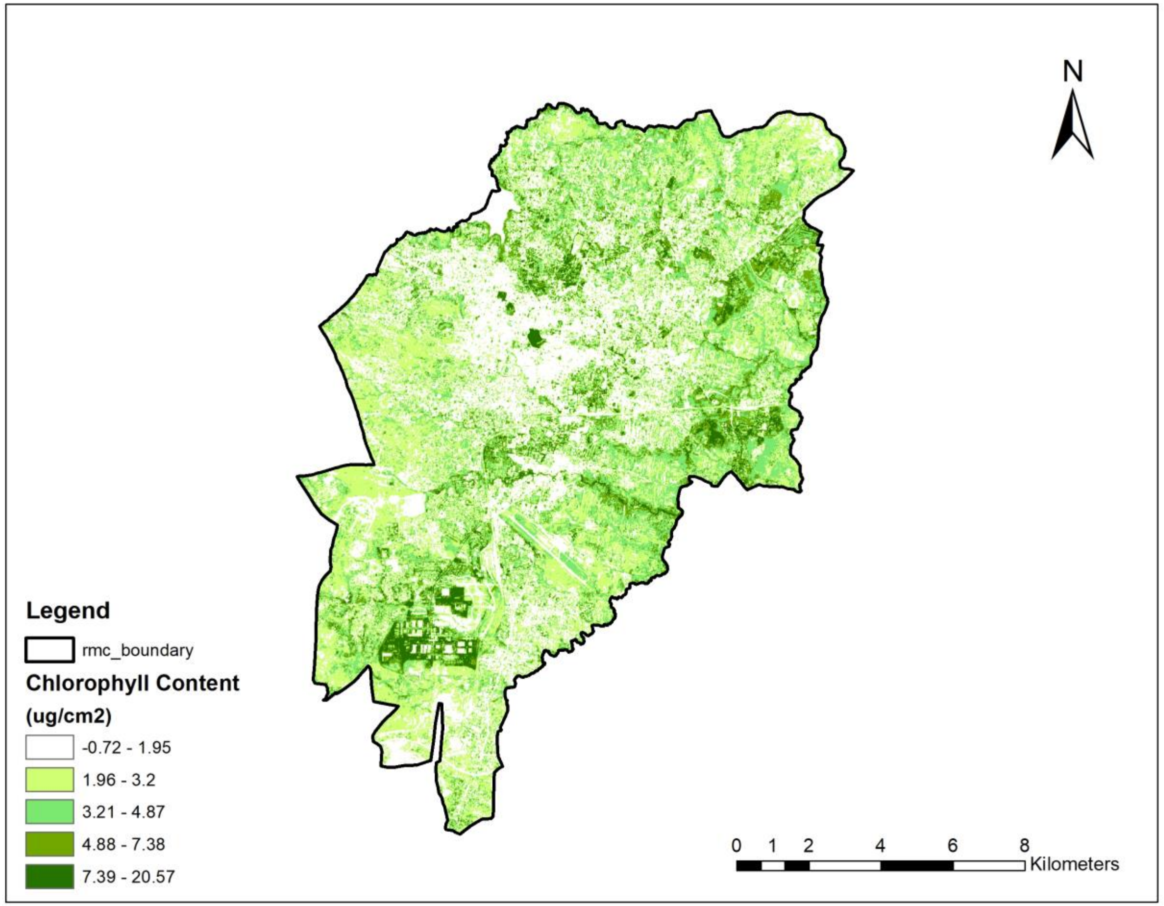
Percentage area under different built-up density and vegetation density classes obtained through Support vector machine classification technique.

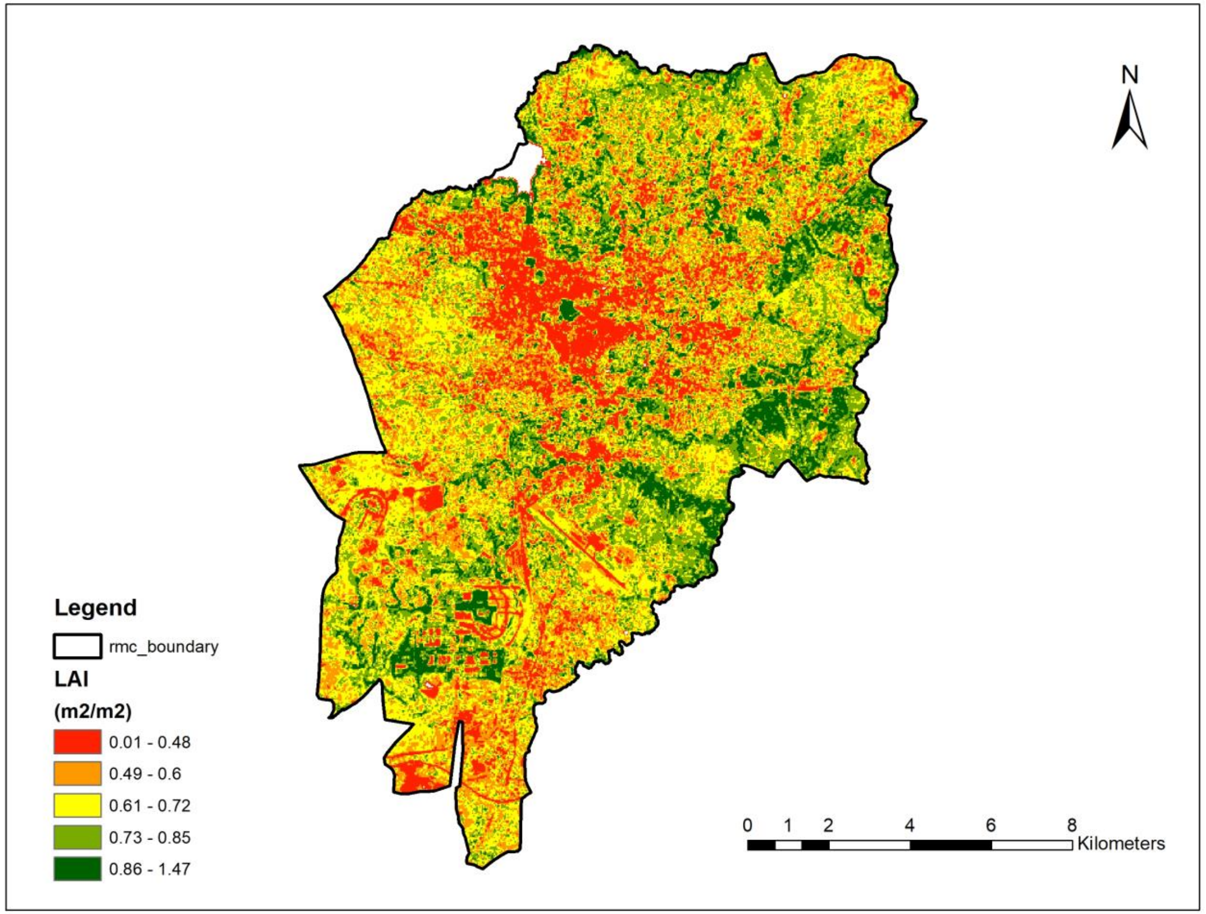
	Built-up density	Vegetation density
	(Based on Support Vector Machine classification)	
Density class		
Very high (>60%)	15.6	9.7
High (40–60%)	32.14	20.8
Moderate (10–40%)	48.00	33.87
Low (<10%)	67.14	54.31
None	96.04	97.34



Distribution of built-up density and vegetation density in percentage area of Ranchi municipal corporation (RMC)

Map representing Chlorophyll Content estimated and LAI from Sentinel 2B Imagery for Ranchi municipal corporation (RMC)

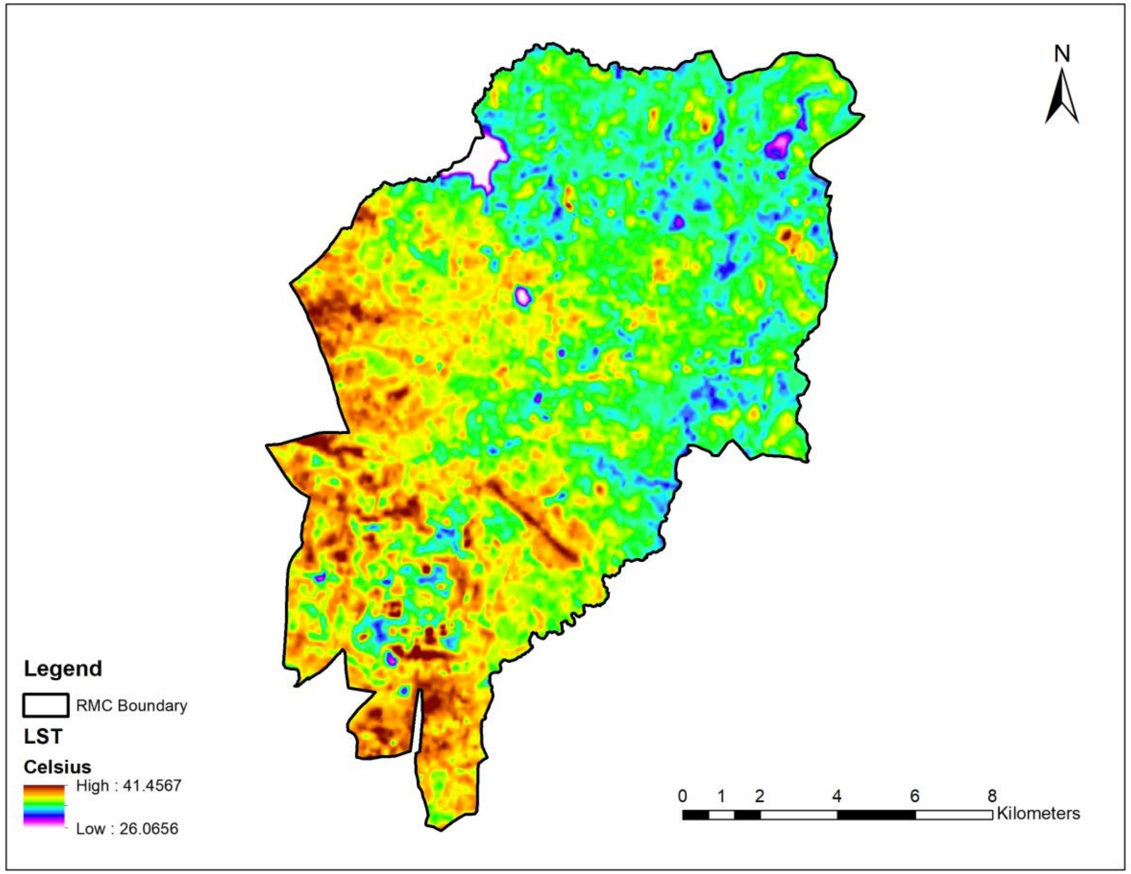


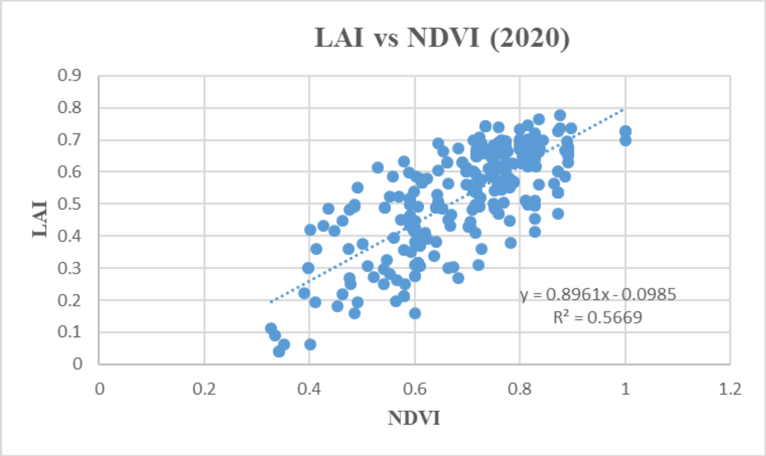


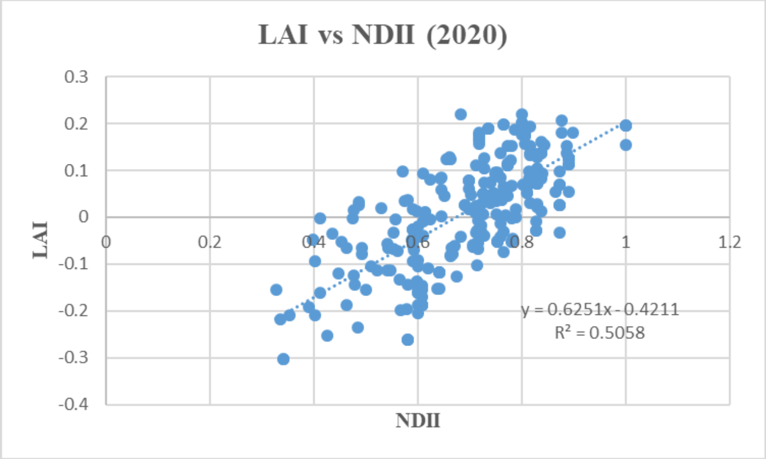
- The chlorophyll content value for ranged from -0.72µg/cm² to 20.57µg/cm².
- The negative values and values near to 0 shows features like water-body, fallow-land, built-up etc. and all the other features except vegetation. The darker shade of green shows the high content of chlorophyll in the zone and vice-versa.

The leaf area index content shown in the map for 2020 ranged from 0.01m²/m²to 1.47m²/m²

Map representing land surface temperature estimated from Landsat 8 OLI Imagery for Ranchi municipal corporation (RMC)







- Land surface temperature of any area is increasing due to the urbanization which results to the population rise, deforestation, air quality degradation, etc.
- The land surface temperature for 2020 ranged from 26.06 Celsius to 41.45 Celsius.

The relationship between vegetation indices and measured LAI in the full-sample obtained from Sentinel 2B imagery

CONCLUSION

- This study concludes that the most dominant tree species found in Ranchi Municipal corporation viz. *Eucalyptus grandis*, *Ficus religiosa*, *Magnifera Indica*, *Saraca asoca, Shorea robusta*, and *Tectona grandis* The highest level of overall classification accuracy (87.50%) for the tree species classification using Support vector machine classification was achieved using all bands of Sentinel 2B.
- The present study also exhibited high correlation between radar backscatter and field based AGB in ALOS PALSAR as compared to Sentinel 1B SAR. This may be attributed due to higher sensitivity to backscatter values and higher penetration level of L band ALOS PALSAR as compared to C Band Sentinel 1B SAR. The relationship between AGB and the HV polarization was better rather than HH polarization.
- This study also demonstrates the high and low tree diversity zones in Ranchi municipal corporation. The grid based technique proved useful in estimating the buildup density and vegetation density. The image classified and by measuring the percentage area of built-up land and vegetation in each grid, respectively. The result exhibited that central and western parts in Ranchi township were under very high (>60%) to high (40–60%) built-up density and devoid of vegetation cover (<10%) indicating substantial absence of green cover in the urban landscape of Ranchi municipal corporation.
- Assessment of the tree cover health status in the Ranchi municipal corporation is based on the cloud free Sentinel 2 imagery. Several indices were used for monitoring of the tree cover health analysis. The land surface temperature value was ranged from 26.06 Celsius to 41.45 Celsius for the year 2020.
- Chlorophyll content and LAI is higher in the western part of the study area but the tree biomass/ carbon stock is less. But in the southern part near to the HEC, Dhurwa, the chlorophyll content is moderate and biomass is also very good. Hence, it shows that the environment condition is good. Environment condition in the central part of the city is very poor due to less tree cover related to the other parts of the city.

Recommendations

- This study recommends that to identify the zones within the built-up area i.e. the central, northern, and the eastern parts of the Ranchi municipal corporation for developing the tree cover or for the planting activity. So, the living environment can be improved.
- Plants that intake more carbon need to be planted more and more. Some species are like *Magnifera Indica, Ficus religiosa, Azadirachta indica, Syzygium Cumini* have very good carbon storage capacity.
- This study also recommends that to develop the built-up in the future with less alteration in the vegetation cover.
- Green walls and roofs on building envelopes can also be used as effective air pollution abatement measures..

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Thank you!

Confusion matrix and LULC accuracy of the LU/LC of study area

LULC TYPES	Built up	Water	Other	Vegetation	Users Accuracy	Producers Accuracy
Built up	47	0	0	0	100	97.91
Water Body	0	37	0	2	94.87	100
Other	0	0	43	0	100	100
Vegetation	1	0	0	33	97.05	94.28

Overall accurracy = (47+37+43+33)/163

= 160/163

= 98.15 %

$$\hat{K} = \frac{M\sum_{i=j=1}^{r} n_{ij} - \sum_{i=j=1}^{r} n_i n_j}{M^2 - \sum_{i=j=1}^{r} n_i n_j}$$

$$= (163 * 160) - \frac{[(47*48)+(39*37)+(43*43)+(34*35)]}{163^2-[(47*48)+(39*37)+(43*43)+(34*35)]}$$

Kappa Coefficient = 0.975

Summary of accuracy assessment results for support vector machine classification

Overall accuracy = (2+12+11+15+10+6)/64

= 56/64

= 87.50 %

Overall Kappa coefficient = 0.924

Classification based on support vector machine		
Tree Species	**Producers Accuracy**	**Users Accuracy**
Saraca asoca	100.00%	74.57%
Eucalyptus grandis	70.58%	80.00%
Magnifera indica	78.57%	100.00%
Ficus religiosa	100.00%	100.00%
Shorea robusta	100.00%	100.00%
Tectona grandis	100.00%	100.00%