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Research Article

ASSESSMENT OF VEGETATION CARBON POOL USING REMOTE SENSING TECHNIQUE

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Abstract: The present investigation of vegetation carbon pool was carried out at Tanda, Bhakda and Pipalpadao forest ranges of Tarai Central Forest Division, Western Circle, Uttarakhand, India during 2013-14. Random sampling of forest was done in the sample plot size 10m×10m. The sampling was done for plant inventory like LAI, height, DBH, wood density and plant density. ENVI 4.8 software was used for processing of satellite image. NDVI of forest ranged from 0.615 to 0.866 according to vegetation type. The linear regression model was developed between NDVI and calculated aboveground biomass having R^2 value 0.788 & 0.803 with r (correlation coefficient) 0.888 & 0.896, RMSE 198.47 t/ha & 134.12 t/ha for evergreen and deciduous forests respectively. Total vegetation carbon was 3.113, 1.85 and 2.715 million tons (mt) in Tanda, Bhakda and Pipalpadao range respectively.

Keywords: Carbon Pool, Biomass, Remote Sensing, NDVI and ENVI 4.8

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Introduction

Carbon of the terrestrial biosphere is stored in forests: they hold 86% of the planet's terrestrial above-ground carbon. The global C budget is considered as constant, and C conservation follows the first law of thermodynamics. However, the total concentration of atmospheric CO_2 has increased greatly since 1750 (from 280 to 385 ppmv) as a result of human activities, and now far exceeds pre-industrial values [1]. The forests have significant role in carbon storage and sequestration, these activities have increased forests importance manifold and brought them to the centre-stage of climate change mitigation strategies.

In the terrestrial ecosystem, aboveground biomass (AGB) estimation is necessary for studying productivity, carbon cycles, nutrient allocation, and fuel accumulation [2-5]. Remote sensing techniques allow the scientists to examine properties and processes of ecosystems and their inter-annual variability at multiple scales because satellite observation scan be obtained over large areas of interest with higher visitation frequencies [6-8]. The remarkable developments in space borne remote sensing technology and its application during the last three decades have firmly established immense potential for mapping and monitoring of various natural resources. Remote sensing is largely concerned with measurement of surface reflectance of energy from the object and drawing inference from such reflectance for identification of objects. Remote Sensing based Normalized Difference Vegetation Index (NDVI) data have been used extensively in vegetation monitoring, crop yield assessment and forecasting. Stand level biomass is frequently calculated from linear and nonlinear regression models established by species with field measurements [9-12]. Estimates of AGB vary with species composition, tree height, basal area, stand structure and bole diameter at breast height (dbh). These are the most commonly used and widely available variable for calculating AGB [9]. The overall objectives of this study were to combine field observations and remotely sensed data to: (1) To produce a high-resolution map of the landscape; (2) To generate a spatially explicit AGB map using our map and various vegetation indices as driving variables; and (3) To examine spatial patterns of AGB in an intensively managed landscape.

Material and Methods

Study Area

Field study was conducted in three forest ranges namely Tanda range (29º2'-29º6´N latitude, 79º21'-79º31´E longitude) Bhakda range (29º5´-29º13´N latitude, 79º22´-79º28´E longitude) and Pipalpadao range (29º5´-29º13´N latitude, 79º14´-79º26´E longitude)of Tarai Central Forest Division, Western Circle, Uttarakhand, India. These area lies in "Tarai" belt located in foot hills of the Himalayas.

Software Used

Image Processing Software: ENVI with version 4.8 software was used for the visualization, analysis, and processing the remote sensing imageries.

GPS Software: GPS was used for geographic position (latitude and longitude) of the sampling sites, which was used at the time of image processing as a ground truth.

Instrument Used

Abney's Level: used to measure degrees, percent of grade, topographic elevation, andtree height (by measuring angle).

Ceptometer LP-80: It measures PAR interception of canopy and calculate leaf area index (LAI) at any location within a plant or forest canopy.

Satelite Image

LANDSAT-8 image was used for this study. The LANDSAT image of date 10th June 2014 was downloaded having the file specification LC81450402014161LGN00. The acquired satellite image was used for generating land use/land cover map of Tanda, Bhakda and Pipalpadao forest ranges of Uttarakhand.

Methodology

Field Survey and Biomass Calculation

The LP-80 was used to calculate LAI by means of measuring the difference

between light levels above the canopy and at ground level, and factoring in the leaf, solar zenith angle, angle distribution and plant extinction coefficient. The sampled trees height in the experimental plot was recorded with the help of an instrument "Abney's Level" which is based on trigonometric calculation. The diameter of sampled trees of the experimental plot was measured with a diameter tape at breast height (1.3 meter above the ground).

Biomass calculation

Wood density of collected wood samples of Kanju, Shisam, Sal, Teak, Poplar, Rohini, Eucalyptus, Kher were determined by dividing their oven dried mass with volume. AGB of trees was determined using non- destructive method. Observations on height, density and diameter were used to calculate biomass of individual tree by using Luckman Equation (2007) [13].

Luckman Equation (2007): $Y= 0.0899(DBH^2)^{0.9522*}(H^{0.9522})*(S^{0.9522})$

Here, H= height, S=density, DBH= diameter at breast height. Calculated tree biomass was depicted in kg/tree.

The sampling quadrants were of regular shape of dimension 10 m × 10 m, nested within each plot. Number of trees of each species which came under 10 m×10 m quadrate was counted and the contribution of each species as per their number in plot was calculated. The biomass of each species were summed together and converted on per hectare basis.For below-ground biomass calculation, root-to-shoot ratio value of 1:5 was used. It means that below-ground biomass was calculated as 20% of above-ground biomass [14].

Satellite Image Processing

Reduction of atmospheric and illumination effects on remote sensed data to retrieve physical parameters of the earth's surface such as atmospheric conditions (temperature, emissivity), thermal & atmospheric radiance and transmittance functions, Atmospheric Correction of Satellite Imagery was done. Atmospheric correction was done using ENVI-4.8 image processing software. Digitization of forest range boundary was done by Quantum GIS software. The polygons of each forest range were later imported in ENVI-4.8 as an ".evf" format (ENVI vector file) to be used for making subset of each range from the LANDSAT image. The vector file was exported as ROI (Region of Interest) and after that the image file was subset via ROI to obtain the subset image covering each range with outside pixels off. The maximum likelihood algorithm of supervised classification technique was used for identifying different objects. Image classification using maximum likelihood classifier was carried out by taking ROIs at different classes using ENVI-4.8 software. Training classes are groups of pixels (ROIs) or individual spectra from which ROIs were selected that are homogenous. Supervised classification was used to cluster pixels in a dataset into classes corresponding to user-defined training classes. Spectral signature of different classes was generated based on the information collected during ground truth. The class statistics was generated for different classes in order to know the area of different classes in hectares under different forest range. Land use/land cover patterns were generated using supervised classification techniques in Tanda, Bhakda and pipalpadao ranges of Uttarakhand. Various ground cover features (forest, agricultural land, built-up land, fallow land and water body) were selected based on their spectral features. NDVI of all three-forest range were generated. NDVI of the images were generated using Red and NIR band. Average NDVIs of the selected forest plots were calculated through band math module of the ENVI 4.8 image processing software and followed by overlaying the ROIs using overlay option of ENVI. NDVI, which is indirect method of biomass measurement, was calculated using following equation [15].

$$NDVI=NIR-R/NIR+R$$

Where, NIR and Red are the reflectance or radiances in the red and near- infrared spectral channels, respectively.

Development of Model for Estimation of Biomass

The biomass and NDVI relation require matching inventory data to remote sensing derived index such as NDVI. Therefore, to develop relationship between NDVI and inventory data simple linear regression models was developed between biomass and NDVI of the sampled plot. This linear equation was different for evergreen and deciduous forest. Masking of forest area was done by using the ENVI 4.8 software. Mask was build using the classified image of forest range for evergreen and deciduous forests separately and applied this mask layer to NDVI image of that forest range. Masking was done in order to separate the evergreen and deciduous forest. The equation applied on masked NDVI image separately for evergreen and deciduous forest. Then the statistics calculation option of software used to calculate biomass of the forest.

Result and Discussion

The plot in which experiment was conducted has Shisam, Kanju, Khair, Poplar, Teak, Eucalyptus, Koa and Rohini tree species. The species have been selected for the various measurements and characterization of the forest. Forest biomass estimation involved two phases: selection of sample plots wherein tree variables (DBH, tree height and wood density) were measured. The biomass data in second phase are used to apply biomass equation to each sampled tree in a plot. The biomass of the plots derived using the allometric equation and their respective satellite derived NDVI values have been depicted in [Table-1] and [Table-2] for evergreen and deciduous forests respectively. NDVI image of TandaBhakda and pipalpadao ranges have shown in [Fig-6, 5 and 7] respectively. To establish the relationship between NDVI and biomass simple regression model was applied. The value of coefficient of determination (R2) is 0.788 and 0.803 for evergreen and deciduous forests respectively which shows a good and acceptable relationship between them. In a study of Dadhwal *et al.* (2009) [16], over fir forest in Jammu and Kashmir (J&K) a regression model had been developed between NDVI and biomass, with an equation and

R^2 values: $y= 998.72x + 114.91$; $R^2 = 0.6423$.

The NDVI values varied from 0.615 to 0.866 according to vegetation type. Devagiri *et al.* (2013) [17] found that the NDVI valued varied across the vegetation types ranging from 0.46 to 0.86.

Table-1 *NDVI values and biomass of plots under evergreen forest*

NDVI	AGB (t/ha)
0.788	840.513
0.78	728.239
0.803	841.527
0.866	921.267
0.66	200.013
0.853	1095.86
0.652	545.822
0.746	176.155
0.681	64.384
0.827	1184.46
0.617	150.412
0.685	323.069
0.843	1179.94
0.615	29.684

Table-2 *NDVI values and biomass of plots under deciduous forest*

NDVI	AGB (t/ha)
0.659	102.071
0.631	33.181
0.768	439.625
0.619	77.059
0.651	66.536
0.701	135.545
0.646	355.412
0.803	880.233
0.829	1121.21
0.623	54.293
0.687	114.146
0.671	125.768
0.637	197.004
0.732	416.899
0.635	113.882
0.641	183.654

These results indicate that there is relationship between NDVI and forest type and in turn with biomass. The model validation was based on calculation of RMSE values were calculated from the above ground biomass observed and the above ground biomass estimated using the model.

Result demonstrated that using linear regression model between NDVI and AGB having R^2 value 0.788 and 0.803 along with RMSE 198.47 t/ha and 134.12 t/ha for evergreen and deciduous forest respectively. The correlation coefficient (r) was 0.888 and 0.896 for evergreen and deciduous forest respectively. Goh *et al.* (2013) [18] showed RMSE 152 t/ha in his experiment on biomass estimation in humid tropical forest. The land use and vegetation classification of study area were done using Maximum likelihood algorithm and the results on spatial extent of different categories of land cover is [Table-3] showing distribution pattern of land use and land cover in TandaBhakda and Pipalpadao forest range respectively. The classified image of Tanda, Bhakda and Pipalpadao ranges have shown in [Fig-12, 11 and 13] respectively.

Table-3 *Spatial extent of land use pattern*

SN	Land use categories	Area (ha)		
		Tanda	Bhakda	Pipalpadao
1	Evergreen forest	3899.52	3399.12	3553.38
2	Deciduous forest	2693.88	3197.7	2964.42
3	Fallow land	590.85	2174.48	2491.56
4	Builtup land	3.24	0.27	4.41
5	Water bodies	0.09	36.27	1400.04
6	Agricultural land	116.46	0.9	687.24
	Total area	7304.04	8808.74	11101.1

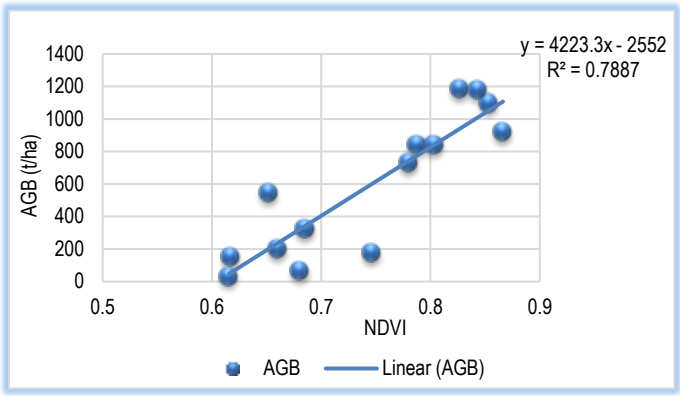

Fig-1 Relationship between NDVI and AGB for evergreen forest

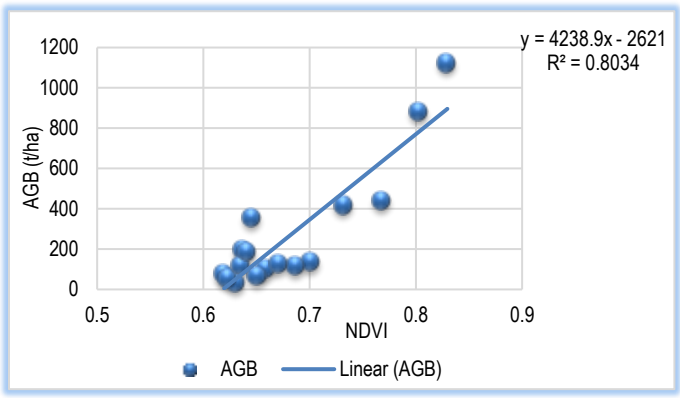

Fig-2 Relationship between NDVI and AGB for deciduous forest

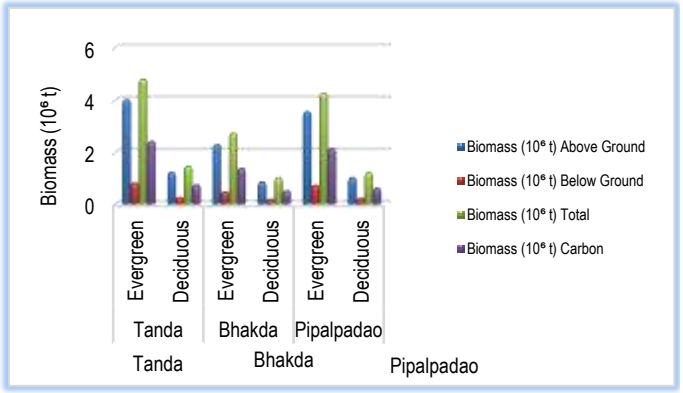

Fig-3 Graphical representation of above ground, below ground and total biomass along with biomass carbon in mega tons of Tanda, Bhakda and Pipalpadao range

Total area of TandaBhakda and Pipalpadao ranges were estimated by remote sensing image are 7304.04 ha, 8808.74 ha and 11101.05 ha respectively while the data collected from Tarai Central Forest Division (Western Circle), Haldwani, Uttarakhand was 7287.45 ha, 8841.49 ha and 11101.19 ha respectively, which is showing almost similar results.

Biomass and vegetation carbon pool of the forest

The model estimated the AGB according to the NDVI of the image when linear equation of the model was applied on the NDVI of satellite image. For separate AGB estimation of evergreen and deciduous forest masking was done. The model estimated the minimum, maximum and mean above ground biomass of Tanda, Bhakda and Pipalpadao range is shown in [Table-4]. The below ground biomass (Root biomass) was calculate as 20% of above ground biomass [14] and total biomass was calculated [Table-5] and [Fig-3].

Table-4 *Estimated AGB (t/ha) of Tanda, Bhakda and Pipalpadao range*

		Above Ground Biomass (t/ha)		
		Tanda	Bhakda	Pipalpadao
Evergreen forest	Minimum	31.48	5.66	46.66
	Maximum	1480.28	1293	1376.16
	Average	1022.29	664.69	992.43
Deciduous forest	Minimum	4.89	3.08	4.99
	Maximum	1249.3	1106.02	1273.69
	Average	447.04	260.23	337.56

Table-5 *Above ground, below ground and total biomass along with biomass carbon in million tons of Tanda, Bhakda and Pipalpadao range*

		Biomass (10^6 t)			
		Above Ground	Below Ground	Total	Carbon (10^6 t)
Tanda	Evergreen	3.986	0.7972	4.7832	2.3916
	Deciduous	1.204	0.2408	1.4448	0.7224
Bhakda	Evergreen	2.259	0.4518	2.7108	1.3554
	Deciduous	0.832	0.1664	0.9984	0.4992
Pipalpadao	Evergreen	3.526	0.7052	4.2312	2.1156
	Deciduous	1.001	0.2002	1.2012	0.6006

The forest carbon stocks are widely estimated from the allometric equations for forest biomass. Generally, the carbon concentration of the different parts of a tree is assumed to be 50% of the biomass [19]. The estimated above ground biomass for evergreen forest was varied from 31.48 t/ha to 1480.28 t/ha with mean 1022.29 t/ha in Tanda forest while 5.66 t/ha to 1293 t/ha with mean 664.69 t/ha in Bhakda forest and 46.66 t/ha to 1376.16 t/ha with mean 922.43 t/ha in Pipalpadao forest. For the deciduous forest maximum as well as minimum value of above ground biomass was less as compare to evergreen forest. Deciduous forest of Tanda, Bhakda and Pipalpadao range have above ground biomass in range between 4.89 t/ha to 1249.3 with mean 447.04 t/ha, 3.08t/ha to 1106.02 t/ha with mean 260.23 t/ha and 4.99 t/ha to 1273.69 t/ha with mean 337.56 t/ha respectively. Swamy *et al.* (2010) [20] reported above ground biomass 397 to 527 t/ha for evergreen forest, 46.7 to 326 t/ha was reported by Singh and Singh (1991) [21] for dry deciduous forest. Devagiri *et al.* (2013) [17] found the AGB in moist deciduous forest ranged between 61.86 to 143.17 t/ha and dry deciduous forest from 7.69 to 20.48 t/ha. Zheng *et al.* (2004) [22] predicted the AGB values across the landscape ranged from 1 to 358 Mg/ha. Because of plantation forest, the density of trees in the plot was high and, in many plots, there were very old trees having high average plant height even more than 25 meter and average DBH was also more than 35cm and upto 84 cm, the above ground biomass of forest in this study showing high value of AGB. The total biomass of vegetation of forest was calculated using the area of forest estimated through classification of satellite image of study area and then biomass carbon was calculated. Tanda, Bhakda and Pipalpadao forest having total (evergreen as well as deciduous) biomass carbon 3.113 mt (million tons), 1.854 mt and 2.716 mt respectively.

Conclusion

The average aboveground biomass was 1022.29 t/ha, 664.69 t/ha & 992.43 t/ha in evergreen and 447.04 t/ha, 260.04 t/ha & 337.56 t/ha in deciduous forests in Tanda, Bhakda & Pipalpadao forest respectively. This shows significant difference in aboveground biomass of evergreen and deciduous forest.

Below ground biomass (root biomass) was calculated as 20% of aboveground biomass. Then total biomass was calculated using aboveground biomass, belowground biomass and area (from the class statistics of classified image). Total biomass of Tanda, Bhakda and Pipalpadao range was 4.78 mt (million tons), 2.72 mt & 4.23 mt in evergreen forest and 1.44 mt, 0.99 mt & 1.20 mt in deciduous forest respectively.

Application of research: Study the environmental aspect of forest as a carbon sequester

Research category: Environmental Science, Forestry, Geospatial Technology

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Study area / Sample Collection: Three forest ranges namely Tanda range, Bhakda range and Pipalpadao range of Tarai Central Forest Division, Western Circle, Uttarakhand, India.

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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