Forest Biomass Estimation Through Vegetation Structure Analysis Using Geospatial Technology: A Case Study of Almora District, Uttarakhand

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Abstract

Forest plays an important role in Biomass as use of forest biomass is carbon-neutral, because the carbon contained in wood originates from the atmosphere and it is released to the atmosphere by wood decay or by combustion. The carbon released by burning fossil fuels is not part of the 'natural' carbon cycle. It rapidly increases the CO^2 content of the atmosphere. In 2011 about 90 percent of total CO^2 emissions were caused by burning fossil fuels. The use of fossil fuels creates a carbon debt that will be a huge burden for future generations. Replacing fossil fuels with renewable energy has to be the core strategy with regards to future climate policies. Utilizing biomass from sustainably managed forests can play an important role in this strategy. Several countries have demonstrated that a build-up of carbon in forests and an increase of forest biomass for energy are simultaneously achievable by good forest management practice. On the planet earth a natural carbon cycle exists between the atmosphere, the ocean and land. The plants sequester carbon from the atmospheric CO^2 using the photosynthesis process, which is powered by energy directly from the sun. This carbon is later released to the atmosphere by the decay of the organic matter or by its use as food or as biomass for energy. Using biomass for energy production means taking part in that natural carbon cycle. In contrast to the biological carbon cycle, the combustion of fossil fuels injects additional carbon stored over millions of years deep beneath the earth's surface into the atmosphere and thus unbalances up the global carbon cycle. The natural sinks are not big enough to absorb the huge amounts of fossil derived carbon, so part of it remains in the atmosphere with an ensuing negative impact on the climate. The study has been presented on how the natural carbon sinks of Almora district, are changing with the passage of time as a consequence to various dimensions of human land use change as well as vegetation degradation. In Al mora district, Deodar is found to have a major role in carbon sequestration for both 2015 and 2017 due to its wider area of coverage.

Keywords: Biomass, Remote Sensing, CO^2

1. Introduction

Forest is one of the most important renewable natural resources and has significant role in the human life and environment. Forests play a major role in maintaining environmental balance on the earth. They have a prominent role in global carbon cycle, exchanging large fluxes of carbon with the atmosphere through the processes of photosynthesis, respiration and decomposition (Warning and Running, 1998). Forest resources are important socially, economically and environmentally. Forest produces wood, protects wildlife, maintain groundwater levels, protect the soil fertility, and absorb carbon and another pollutant gases from the atmosphere. All these forest functions influence the continuity of life and have global implications (Heri*et. al.,* 1999) as well. Forests have traditionally been used for many products, including timber, fuel, and fodder. Standing forest biomass forms an essential part of active carbon pool participating in the global carbon cycle. Mapping the amount and geographic distribution of forest biomass and its change with time is important to understand the development of the carbon cycle.

Information on the spatial distribution of forest biomass is, therefore, important for forest industry and sustainable forestry. Forest stands are defined as the primary mapping and description units, which delineate patches of relatively homogeneous forest in terms of tree cover and site conditions.

Forest Biomass is a biophysical parameter required by many scientific disciplines. Maps of forest Biomass can be used to refine model predictions of the global carbon cycle (Plummer, 2000).Biomassis any organic matter that can be used as an energy source. Wood, crops, and yard and animal waste are examples of biomass. People have used biomass longer than any other energy source. For thousands of years, people have burned wood to heat their homes and cook their food. Biomass gets its energy from the sun. Plants absorb sunlight in a process called photosynthesis. With sunlight, air, water, and nutrients from the soil, plants make sugars called carbohydrates. Foods that are rich in carbohydrates (like spaghetti) are good sources of energy for the human body. Biomass is called a renewable energy source because we can grow more in a short period of time. Until the mid-1800s, wood gave Americans 90 percent of the energy they used. Today, biomass provides us almost five percent of the energy we use. It has been replaced by coal, natural gas, petroleum, and other energy sources. Industry is the biggest biomass consumer today; it uses 47.6 percent of biomass to make products. The transportation sector uses 26.8 percent of biomass by consuming ethanol and other bio-fuels. Power companies use biomass to produce electricity. Over 11 percent of biomass is used to generate electricity today. Homes and businesses are the third biggest users; about one in ten homes burn wood in fireplaces and stoves for additional heat. Less than three percent use wood as their main heating fuel. Most use a source other than wood for heating. In the future, plants may be grown to fuel power plants. Farmers may also have huge farms of energy crops to produce ethanol and other bio-fuels for transportation.

2. Study Area

The state of Uttarakhand in the Northern part is lying between 30.33^0N 78.06^0E covering an area of about 20,650 km^2 (Fig. 1). Uttarakhand is separated from Uttar Pradesh as Uttaranchal in 9 November 2000.

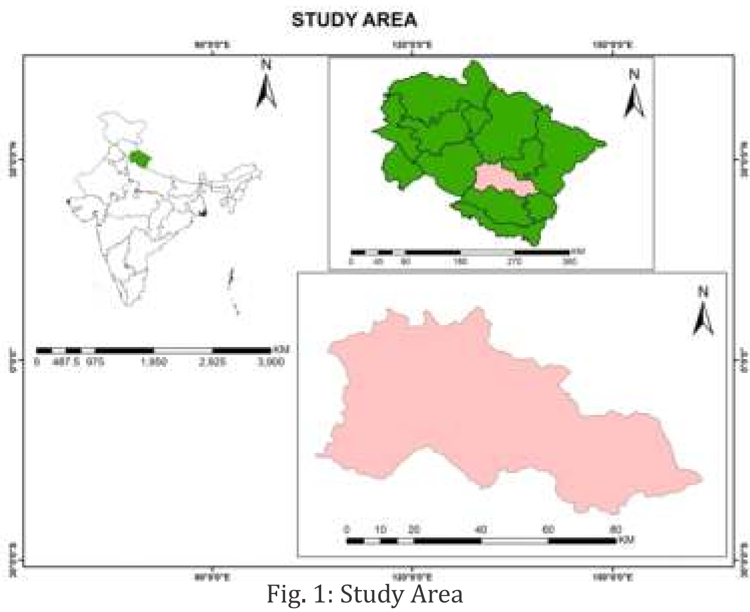

Fig. 1: Study Area

1 January 2007 it is renamed as Uttarakhand. It is often referred to as the Devbhoomi (land of god). Uttarakhand is known for its natural beauty of the Himalaya, the Bhabhar and Tarai. The state is divided into two divisions, Garhwal and Kumaon with a total of 13district. Almora is in the northern part of India located in Kumaon region at 29.62^0 N. latitude and 79.67^0E longitude. According to the 2011 census Almora district has a population of 621,927. Its ranking is 517th in India. The District has a population density of 198 inhabitants per sq. km. Its population growth rate over decade 2001-2011 was -1.73 percent. Almora has sex ratio of 1142 females for every 1000 males and literacy rate is 81.06 percent. It is 1,638 meter above sea level. The town of Almora is surrounded by Pithoragarh district to east, Garhwal region to the west, Bageshwar district to the north and Nainital district to the south.

1. Material and Methods

The satellite data used in the present study by using imagery LANDSAT-8 Operational land imager ("OLI") Sensor imagery of April 2015 and 2017. With resolution of 30m nominal panchromatic resolution is 15m map projection used is "UTM" datum used is "WGS 84" And UTM Zone is 44.

3.1 Software Used

In this study ERDAS IMAGINE is a remote sensing application with raster graphics editor abilities designed by ERDAS or geospatial. ERDAS IMAGINE is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance digital image for mapping use in GIS or software.

- ERDAS imagine 2014
- Arc GIS
- Microsoft office (data sheet preparation and word processing).

3.2 Data acquisition

This step is divided into two parts, in which first we have to download vector file (.shp) format of the study area. Then we have to download the satellite imagery of the study area from USGS. In this study we had taken satellite imagery of Landsat -8 of year 2015 and 2017. We used Operational land imager ("OLI") and "TIRS" sensors respectively. Operational Land Imager (OLI) it will measure in the visible, near infrared and short wave infrared portions of the spectrum. Its images will have 15 meter panchromatic and 30 meter multi-spectral spatial resolution.Thermal infrared sensor (TIRS) the specification require TIRS to collect image data for two thermal infrared spectral bands with a spatial resolution of 120m across a 185 km swath from the nominal 705 km Landsat altitude.

3.3 Radiometric Correction

Radiometric correction is to avoid radiometric errors or distortions. When the emitted or reflected electro- magnetic energy is observed by sensor on board an aircraft or spacecraft, the observed energy does not coincide with energy emitted or reflected from the same object observed from a short distance. This is due to the sun's azimuth and elevation, atmospheric conditions such as fog or aerosols, sensors response etc. which influence the observed energy. Those radiometric distortions must be corrected. There is need to apply radiometric correction on satellite images to avoid radiometric errors and distortions.

3.4 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. NDVI has found a wide application in vegetative studies as it has been used to estimate crop yields, pasture performance, and rangeland carrying capacities among others. It is often directly related to other ground parameters such as percent of ground cover, Photosynthetic activity of the plant, surface water, leaf area index and the amount of biomass. NDVI was first used in 1973 by Rouse et al. from the Remote Sensing Centre of Texas A&M University. Generally, healthy vegetation will absorb most of the visible light that falls on it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Bare soils on the other hand reflect moderately in both the red and infrared portion of the electromagnetic spectrum (Holme et al, 1987).

NDVI= (Band 5 – Band4)/(Band 5 + Band4)

This formulation allows us to cope with the fact that two identical patches of vegetation could have different values, for example in bright sunshine, and another under a cloudy sky. The bright pixels would all have larger values, and therefore a larger absolute difference between the bands. This is avoided by dividing the sum of the reflectance. Theoretically, NDVI values are represented as a ratio ranging in value from -1 to 1 but in practice extreme negative values represent water, values around zero represent bare soil and values over 6 represent dense green vegetation.

3.5 Land use/land cover

The Landsat images of both time periods were classified using unsupervised classification technique into various land use/land cover classes (including vegetation types) to assess the quantitative change in land use/Land cover (LULC) classes for a period of three years. The output LULC classified images were then analyzed to estimate the total area under each vegetation types for both the periods.

Local Name Botanical Name CBH(cm) Dia(cm) Height (mts) Vol_Eqn_useddbh (D) m Radius m Basal area LogD D2 D3 DH D2H SqrtD Volume SqrtV V/D2 V/D2H SP_gravity Biomass (t) Biomass/ha.

1. Deodar (*Cedrusdeodara*): $V = -0.087+0.289\times D^2 xH^2$
2. Banj (*Quercusleucotrichophora*): $V= 0.014796+0.319061\times D^2 xH$
3. Buransh (*Rhododendron arboreum*): $V= 0.06007-0.21874\sqrt{D}+3.63428\times D^2$
4. Moru (*Quercus floribunda*): $V= 0.01480+0.31906xD^2 xH$
5. Anyar (*Lyoniaovalifolia*): $V= 0.03468-0.56878\times D+4.72282\times D^2$

Where

V= volume; D = diameter at breast height.

The above ground biomass was worked out by multiplying the calculated volume with the specific gravity of the tree. Species wise specific gravity (Deodar-0.497, Banj-0.826, Buransh-0.600, Moru-0.600, Kafal-0.600, Anyar-0.600, Utis-0.319, Chir-0.537, Kaill-0.600(FSI -2017).

Biomass (B) = Volume (V)* Specific Gravity (SG)

1. Result and Discussion

The satellite data used in the present study by the using imagery LANDSAT-8 Operational land imager ("OLI") Sensor. Imagery is of April 2015 and 2017. The Landuse/ Landcover (LULC) map generated by using satellite images of Landsat ''OLI" 2015 and 2017 are shown in figure number 5.1. These classified maps were analyzed to estimate the area under each vegetation type in the study area during the two time periods (Fig. 2). LANDSAT-8 Operational land imager ("OLI") data were classified into eight landuse/ landcover (LULC) classes according to 2015 and 2017 namely Very dense for 2015(756.1 km^2) and 2017(752.1 km^2), Dense for 2015(382.5 km^2) and 2017(381.3 km^2), Moderate for 2015(161.5 km^2) and 2017(151.3 km^2), Open forest for 2015 (110.4 km^2) and 2017 (107.8 km^2), agriculture for 2015 (1200 km^2) and 2017(1210 km^2), Barren land 2015 (80.23km^2 and 2017 (81.23 km^2 and Settlement 2015(20 km^2 and 2017(25.8 km^2) water body 2015 (23.83 km^2 and 2017 (24.8 km^2). The slope of a line is the ratio of the amount that y increases as 'x' increases some amount. Slope tells you how steep a line is, or how much 'y' increases as 'x' increases. The slope is constant anywhere on the line. Aspect is directional measure of slope. Aspect searts with 0^0 at the north, moves clockwise, and ends with 360^0 also at the north. Because it is a circular measure, an aspect of 10^0 is closer to 360^0 than to 30^0. We often have to manipulate aspect measures before using them in data analysis. A common method is to classify aspect into the four principal directions (north, east, south, and west) or eight principal directions (north, north-east, east, southeast, south, south-west, west, and northwest) and to treat aspects as categorical data. Rather than converting aspect to categorical data, chang and Li (2000) have proposed a method for capturing the principle direction while retaining the numeric measure.

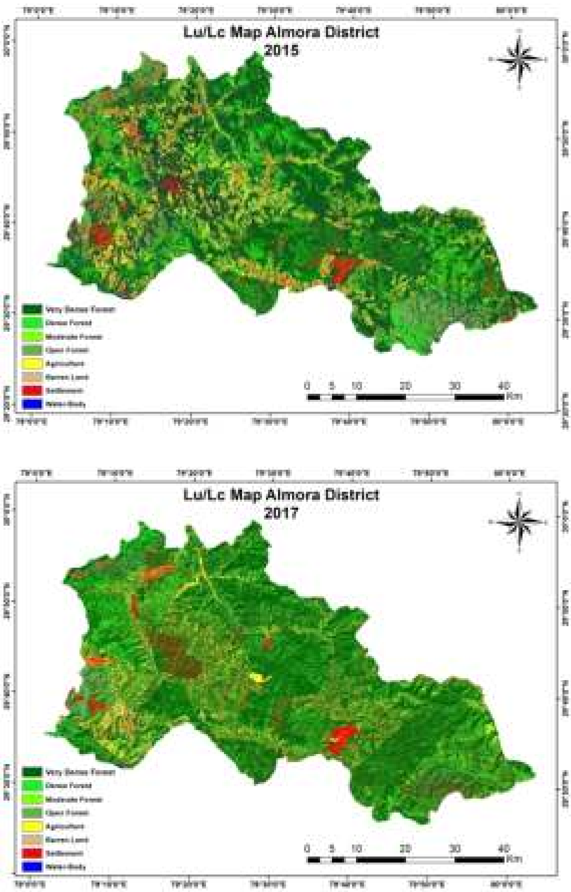

Fig: 2 LU/LC Classified Map of Almora district 2015 and 2017

5.2 Estimation of biomass:

Non-destructive allometric equation approach was adopted for assessing biomass/carbon, which requires the parameters like tree measurements (height and DBH), application of standard volume equations and species specific gravity for each tree species. Tree volume was estimated by using the site or region specific (phytogeographic/ physiographic) volume, general and biomass equations, procured from State Forest Departments, Forest Research Institute and Forest Survey of India (Dadhwal *et al.*, 2009). Species specific gravity data were obtained from Forest Research Institute (FRI 1996). Species volume equation and species specific gravity of recorded tree species are summarized.

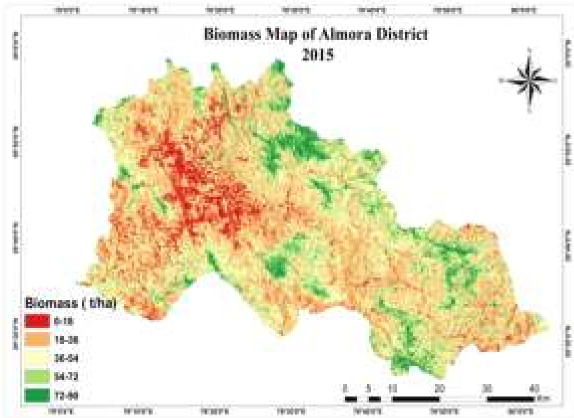

Fig. 3 Biomass map of Almora district (2015)

The DBH and height for each tree species were used for regression analysis to get an estimate of biomass (Roy *et al.*, 1996). The formula used for calculating biomass was as follows: Biomass (t· ha-1) = Volume of tree × Species specific gravity. The tree volume of each individual species was calculated by using the volume equations as suggested by FSI (1996).Tree biomass at (72.4548525 t/ha) was Maximum at (Almora way to terega on). However, minimum biomass was recorded at (70.7140175t/ha), (palana) for 2015. Tree biomass at (50.50344 t/ha)was maximum at Bhagtola. However, minimum biomass was recorded at Palna (9.754509t/ha) for 2017 (Fig. 3).

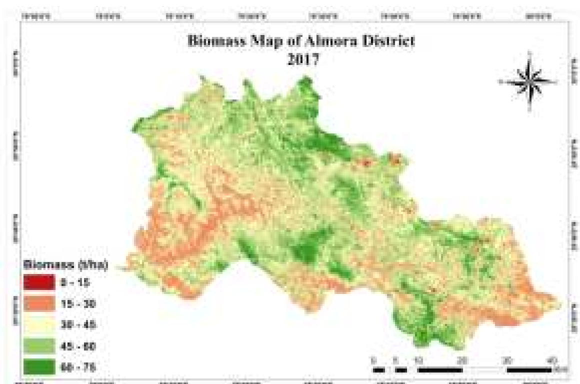

Fig. 4 Biomass map of Almora district (2017)

AGB was estimated by measuring for all woody stems greater than 30 cm in GBH. The estimation of biomass was made using the existing allometric equations. The different levels of basal area, above ground biomass were analysed. It is evident that large number of plots 1 Palna (Kail) in the basal area range (High-8.17 Low -1.32) m2 and in biomass range (High-27.04 Low-3.46) t/ha .and Salt (Banj) in the basal area range (High-15.4 Low -2.20) m2 and in biomass range (High-60.16 Low-8.31) t/ha and Sheherfatak (Devdar) in the basal area rang (High-30.17 Low-0.92) m2 and in biomass rang (High-121.8 Low-1. 619) t/ha and Chitai (chir) in the basal area rang (High-10.20 Low-1.03) m2 and in biomass rang (High-68.8 Low-3.9) t/ha and Bhgtola (Chir) in the basal area rang (High-19.6 Low-3.58) m2 and in biomass rang (High-141.0 Low-16.12) t/ha and Garapani (Mix forest) in the basal area rang (High-12.34 Low-0.82) m2 and in biomass rang (High-48.59 Low-1.92) t/ha (Fig. 4).

The assessed NDVI values (2015 and 2017) from satellite imageries were correlated with the bio-mass value of the year 2015 and 2017 respectively to get the biomass value at the spectral level.

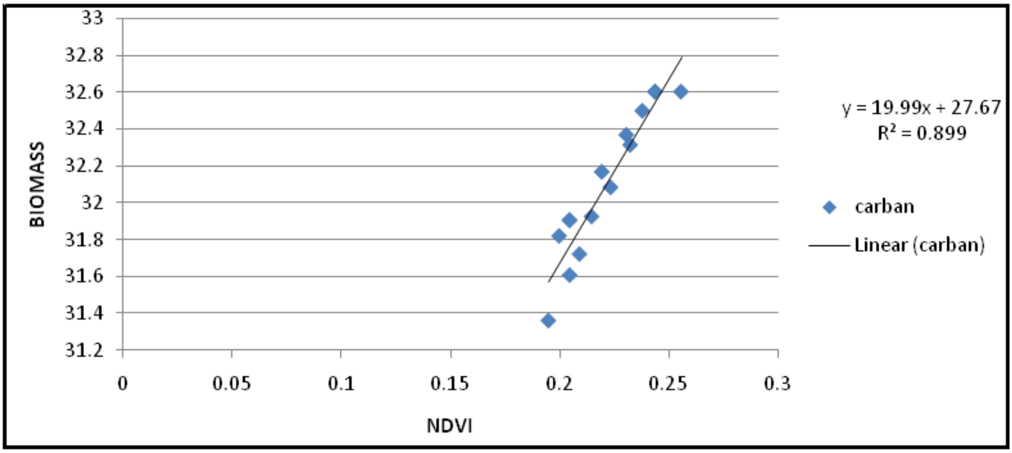

Fig. 5 Relationship between NDVI values andbiomass (2015)

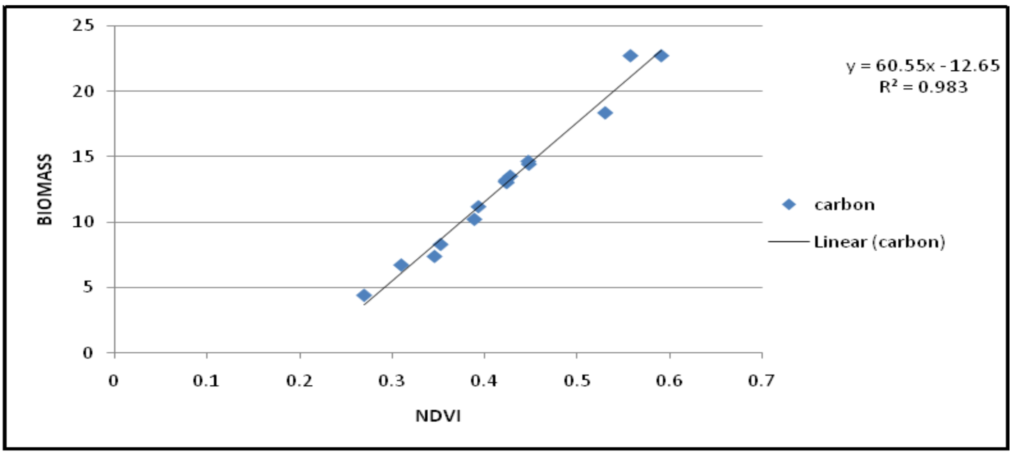

Fig. 6 Relationship between NDVI values and biomass (2017)

The significant positive linear correlation (r^2 = 0.899 for 2015 and r2 = 0.983 for 2017) as found in between the NDVI value and the biomass measured at sample plots have been used in the spatial extrapolation of Biomass values to produce the per-pixel Biomass maps for both the time periods. The change of biomass between 2015 and 2017 was assessed the biomass value of 2015 from 2017 (Fig. 5 and 6).

Conclusion

Forests are the largest carbon pool on earth. It acts as a major source and sinks of carbon in nature. Thus, it has a potential to form a chief component in the mitigation of global warming and adaptation to climate change. Estimation of the forest carbon stocks will enable us to assess the amount of carbon loss during deforestation or the amount of carbon that a forest can store when such forests are regenerated. The principal element for the estimation of forest's carbon stocks is the estimation of forest biomass. Although there has been numerous studies carried out to estimate the forest biomass and the forest carbon stocks, there is still a further need to develop robust methods to quantify the estimates of biomass of all forest components and carbon stocks more accurately.

The study has been presented on how the natural carbon sinks of Almora district, are changing with the passage of time as a consequence to various dimensions of human land use change as well as vegetation degradation. In Almora district, Deodar is found to have a major role in carbon sequestration for both 2015 and 2017 due to its wider area of coverage. On the contrary, in spite of higher carbon assimilation rate, overall contribution of kail remainsinsigni-ficant for both the time periods. It also highlights the contribution of the three major forest types (Deodar, kaill, Banj, Buransh, Moru, Anyar, Chir, Utis,andKafal,) in sequestering carbon from atmosphere depending on their biomass accumulation rate. Since carbon balance is most vital for life on earth by influencing the climate, the changes in carbon dynamics over space and time due to unprecedented anthropogenic inter-vention, has always been a significant issue in ecological studies. With the rising threat of climate change, accurate forest carbon inventory would result in a robust impact assessment of landuse dynamics on the environment, aiding the future land management and policy decisions.

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