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Arun Kumar
Department of Environmental Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Vir Singh
Department of Environmental Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Rajeev Ranjan
Department of Agrometeorology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Ajit Singh Nain
Department of Agrometeorology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Corresponding Author:
Arun Kumar
Department of Environmental Science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Estimation of forest biomass in Nainital district of Uttarakhand using remote sensing technique

Arun Kumar, Vir Singh, Rajeev Ranjan and Ajit Singh Nain

Abstract
Satellite-based remote sensing approach was developed for estimating forest biomass and productivity in large area. Present study was conducted in the sub-tropical forest of Nainital district of Uttarakhand state. In the present study two LANDSAT-ETM+ images of different seasons viz., pre-monsoon and post monsoon seasons dated 27th May and 18th October 2012 were used. The LANDSAT-ETM+ images acquired were processed using ENVI-4.8 image processing software and for digitization of district boundary of Nainital district, Arc-View 3.2a software was used. Subset containing Nainital and the adjoining forest region of each image were extracted and NDVIs were generated. Linear statistical model was developed to calculate the BCD value of the sub-tropical forest of Nainital. The biomass Carbon density (BCD) for 27th May and 18th October 2012 are 93.16MgC/ha and 111.1527MgC/ha respectively.

Keywords: Supervised classification, NDVI, BCD, LANDSAT-ETM+ and ENVI-4.8

Introduction
A forest comprises a major part of terrestrial ecosystems, owing to their huge biomass and high productivity. In remote sensing from satellites the electromagnetic waves are sent to earth surface. Depending upon the property of objects on Earth, the electromagnetic waves of different intensity and wavelengths are absorbed, scattered transmitted and reflected. The reflected waves in the bandwidth of infrared, thermal infrared and microwaves are picked up by sensors mounted on the satellite.

A forest comprises a major part of terrestrial ecosystems occupying about 30% of the world's land area (Dixon *et al*., 1994) [2]. It is estimated that over 80% of global aboveground carbon (C) is stored in forest vegetation (Lieth and Whittaker, 1975; Dixon *et al*., 1994) [5, 2], and the annual C flux between forests and the atmosphere through photosynthesis and respiration is up to 90% of the total annual flux of terrestrial ecosystems (Winjum *et al*., 1993) [8]. Owing to their huge C pool and high productivity, forest ecosystems play a leading role in the global C cycle (Watson *et al*., 2000) [7]. Forest acts as a source and sink of carbon and carbon is main raw material for increasing biomass and productivity of forest.

Satellite observations of vegetation have provided consistent global coverage at relatively high spatial resolution since the early 1980s (Zhou *et al*., 2001; Dong *et al*., 2003, Piao *et al*., 2005) [9, 3]. Compared to previous direct field measurements and inventory-based estimation for large-scale forest biomass, integrated estimation using remote sensing data and inventories data can show spatial explicit pattern for large-scale forest biomass (Piao *et al*., 2005) [6].

Satellite-based remote sensing approach was developed for estimating forest biomass and productivity in large area. Present study was conducted in the sub-tropical forest of Nainital district of Uttarakhand state. Forests are major contributor of terrestrial ecosystem carbon (C) pools, and are thus crucial components for assessing the global C budget. On the basis of forest inventory data and synchronous NDVI (Normalized Difference Vegetation Index) data.

Material and Methods
Study Area
The case study conducted in Nainital district. The district of Nainital lies in the Kumaun division of Uttarakhand. It is located at 29.38°N and 79.45°E. Nainital has temperate summers, maximum temperature 27 °C (81 °F); minimum temperature 7 °C (45 °F). In winter, Nainital receives snowfall between December and February with the temperatures varying between a maximum of 15 °C (59 °F) and a minimum of □3 °C (27 °F). The soil structure and texture also varies from high sandy soils having 70 percent to 80 percent sand to clay soils in which

the clay percentage is up to 20 percent. In between vast tracts possess sandy loamy soils which are neither heavy nor very light. The hilly region of Nainital District is covered with Sal, Pine, Oak, Buruns, Kaphal and other trees. There are small tracts of cultivated lands and fruit orchards in between the forests in this region.

Image acquisition
Satellite image has been acquire from website of USGS (website http://glovis.usgs.gov/). LANDSAT-ETM+ images of path 145 and row 40 were used. Two scenes of satellite images belonging to pre-monsoon and post monsoon seasons dated 27th May (248 days) and 18th October (292 days) 2012 were downloaded from website.

Image processing
The images were processed by using ENVI-4.8 image processing software and for digitization of district boundary of Nainital district. After downloading the image the files from the image were extracted. Subsetting of the image was done by using vector file of nainital. Atmospheric correction of the image was carried out using Quick Atmospheric Correction (QUAC) technique in order to remove the atmospheric error (Path radiance). Destripping of the image was done as image was LE-7. The destipping was done by nearby image to fill the gap of strips. The Gap filled technique was used for destripping. Six region of interest (ROI) like forest, water body, builtup land, fallow land and Agriculture land were made for discrimination of forest cover from other spatial features. The polygons and different colours were choosen for different ROI.

Classification
Supervised classification technique was used for discrimination of different objects in both the LANDSAT-ETM+ images using ROI. Classification gives the information about the area of different classes used in classification. After supervised classification, NDVIs were generated for the image by using the formula.

NDVI= (float(b4)-float(b3))/(float(b4)+float(b3))

NDVI is the vegetation index which is related to NIR and Red band of the image. The colour of NDVI images are brighter where there are more vegetation and darker where there are water bodies. NDVI varies from -1 to +1, +1 for brightest and -1 for darkest pixel of image.

By the classification of images we got the total area under forest in Nainital district, and by NDVI we got the value of NDVI mean which will be used in the equation for calculating BCD, to estimate the biomass and productivity of area.

Results and Discussion
Fig.1 and 2 are classified image of 27th May (pre-monsoon) and 18th October 2012 (post-monsoon) images respectively. Total six classified classes are forest, water body, builtup land, fallow land and Agriculture land. Forest area was 296875 ha and 297071 ha in 27th May (pre-monsoon) and 18th October 2012 (post-monsoon) images respectively, very close to MSME Haldwani report on Brief industrial Profile of Nainital District in year 2006-07 is 2,98,336 ha which was73.4% of total geographical area (4,06,433 ha) (dcmsme.gov.in).

NDVIs were generated for both images (Fig.3 and 4) by using the formula *NDVI= (float(b4)-float(b3))/(float(b4)+float(b3)).* Mean NDVI were observed 0.337 and 0.396 for 27th May and 18th October 2012 images respectively.

Biomass Carbon density (BCD) was expressed as the function of the corresponding NDVImean and forest locations of the area (longitude and latitude) for both the images by using equation given by Piao *et al.* (2005) [6].

BCD=111.521*ln* (NDVI)-0.452lat. 20.034lon +.08568lon² + 1278.29

Where, BCD is forest biomass Carbon density (Mg C/ha), NDVI is NDVImean, and lat. and lon. are latitudes and longitudes of study area.

The biomass Carbon densities (BCD) for 27th May 2012 and 18th October 2012 was calculated as 93.16086 MgC/ha and 111.1527 MgC/ha respectively. Same pattern was found by Dixon *et al*. 1994 [2], as 114 Mg C/ha for china's forest. Kumar A. *et al*., 2019 [4] found maximum as well as minimum value of above ground biomass for evergreen forest was varied from 5.66 t/ha (BCD= 2.83 MgC/ha) to 1480.28 t/ha (BCD= 740.14 MgC/ha) and for deciduous forest was 3.08t/ha (BCD= 1.54 MgC/ha) and 1273.69 t/ha (BCD= 636.845 MgC/ha) in Tarai forest of Uttarakhand. Total forest biomass of Nainital District was found 55.314 and 66.040 in pre-monsoon (27th May 2012) and post-monsoon (18th Oct. 2012). There was gain in total biomass under this forest was 27.38 million ton per year.

Table 1: Average Biomass Carbon (C) Density, area and total biomass of Nainital District, Using the Approach Developed in This Study

Date of image acquisition	Forest area (10^3 ha)	Total geographical area (10^3 ha)	Forest percentage (%)	BCD (Mg C/ ha)	Biomass (BCD X 2) (Mg / ha)	Total biomass (10^6 ton)
27th May 2012	296.875	406.433	73.04	93.16086	186.322	55.314
18th Oct. 2012	297.071	406.433	73.09	111.1527	222.305	66.040

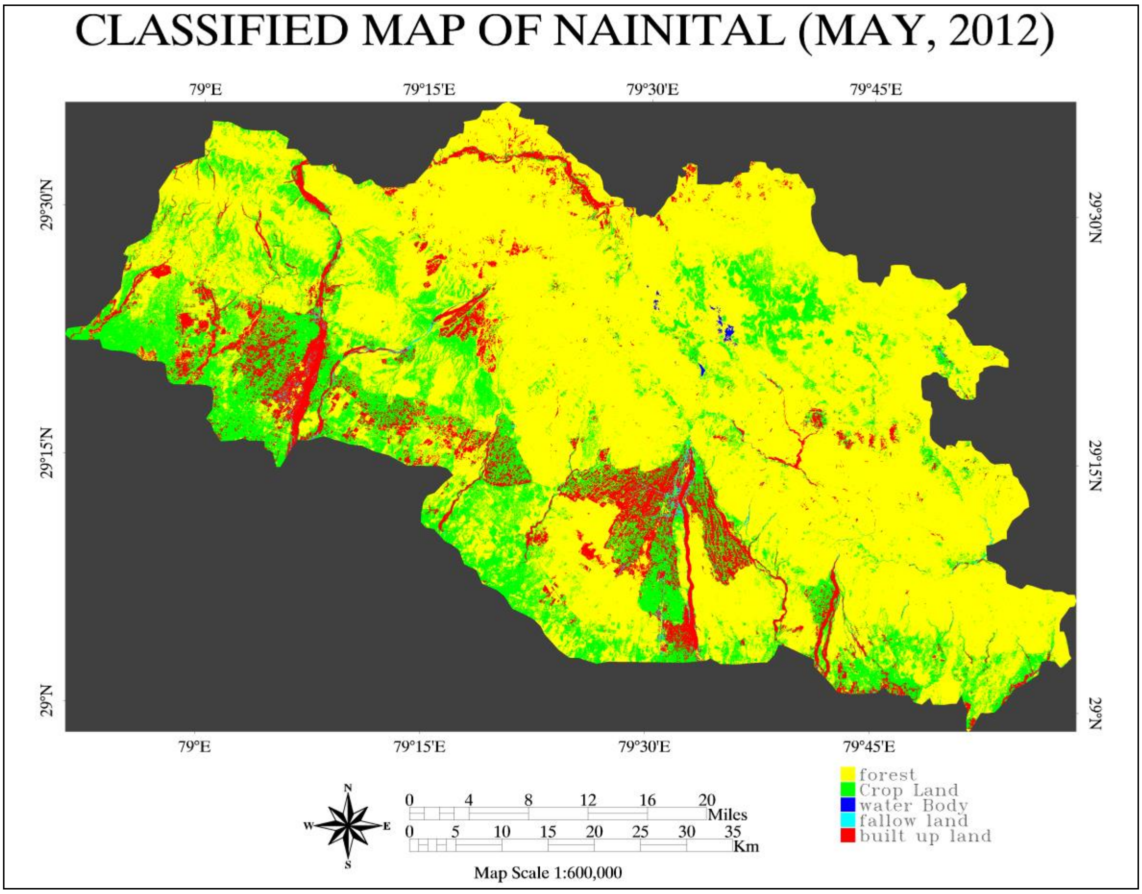

Fig 1: Classified image of Nainital district (May, 2012)

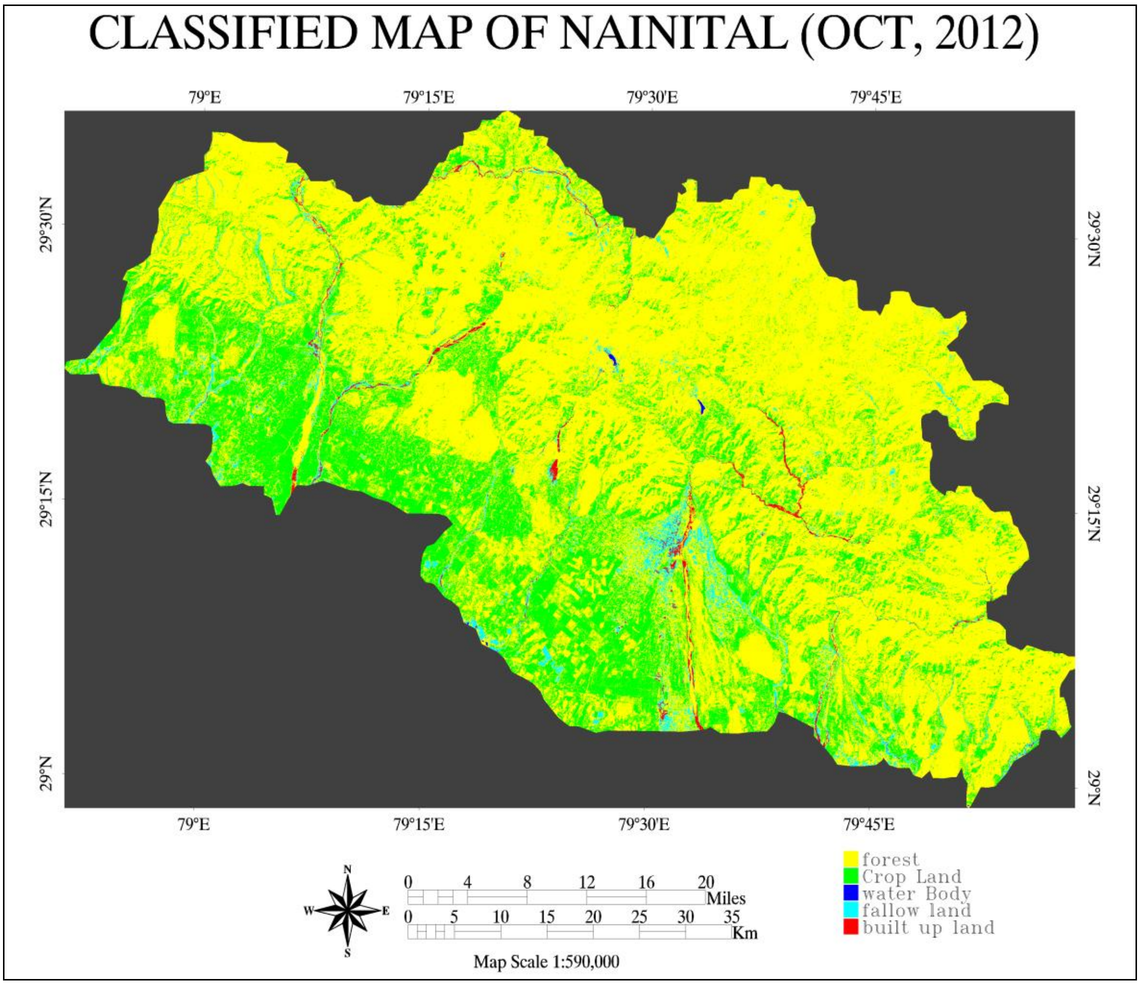

Fig 2: Classified image of Nainital district (October, 2012)

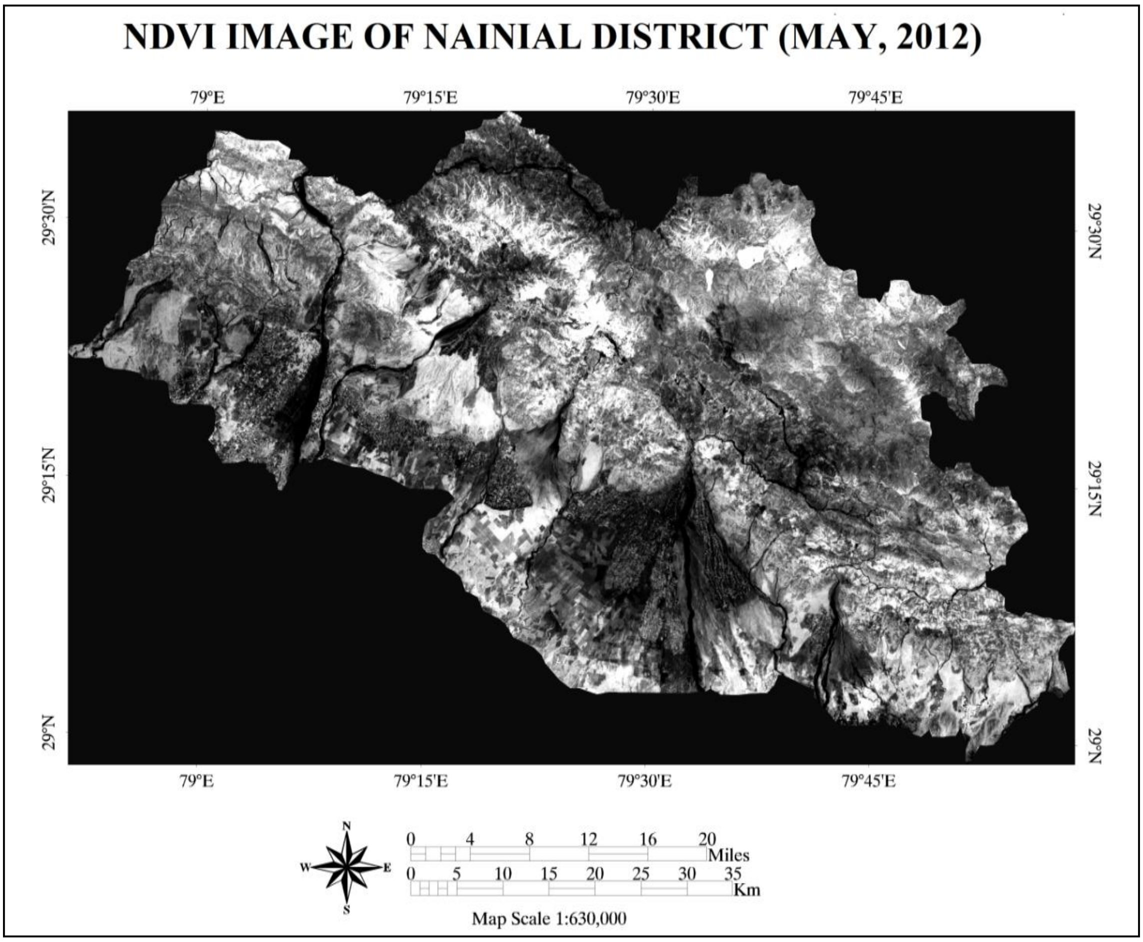

Fig 3: NDVI image of Nainital district (May, 2012)

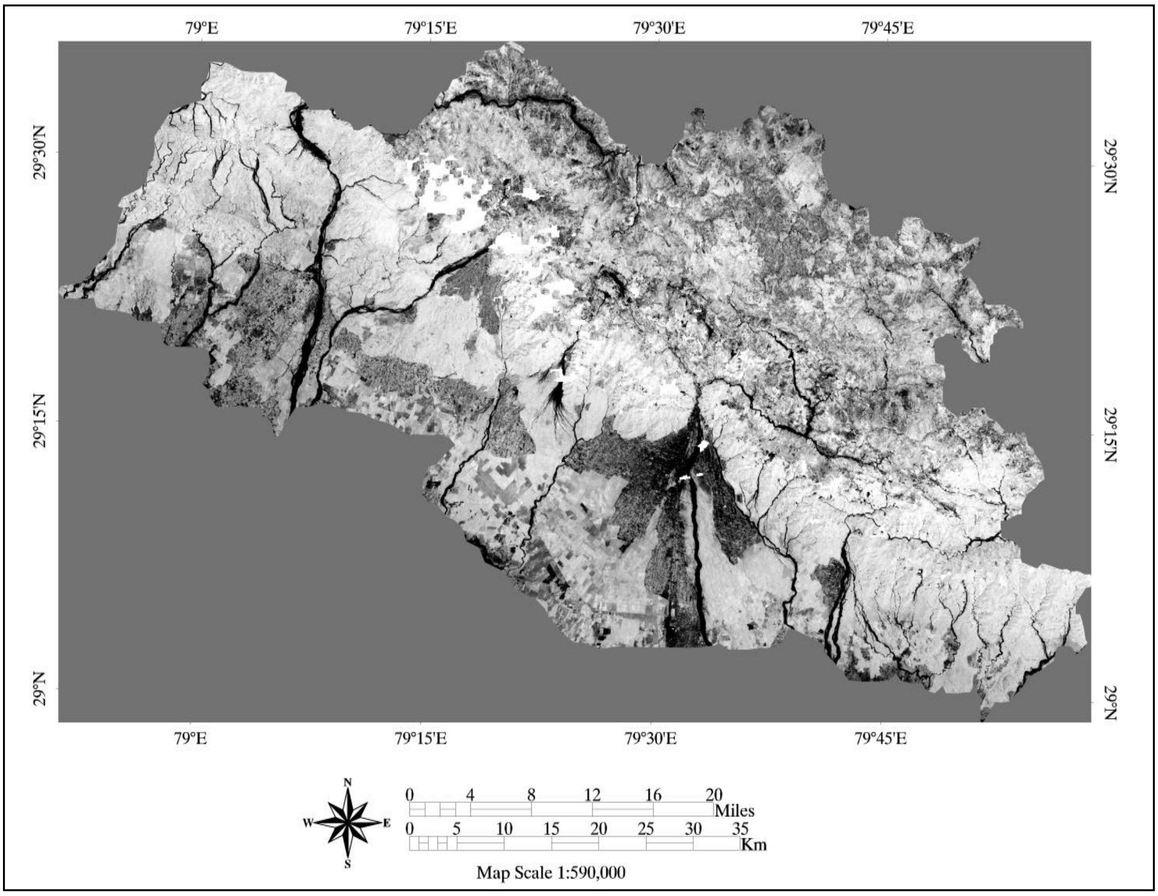

Fig 4: NDVI image of Nainital district (October, 2012)

Conclusion

Estimation of forest biomass precisely at different regions either regional or global level is a significant research challenge. In this assignment, an empirical statistical model for estimating Nainital forest biomass C stocks was developed by integrating NDVI data and forest inventory. From our model a good fitness between independent inventory biomass density and corresponding estimates indicate that relevant geographic data (longitude and latitude) in combination with coarse resolution remotely sensed data can be used to map distribution of forest biomass with a relative good accuracy over large areas. Estimated forest biomass of Nainital District was 55.314 million ton in pre-monsoon and 66.040 million ton in post-monsoon, sowing significant gain 27.38 million ton per year.

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