RESEARCH ARTICLE

THE SPECTRAL MODELLING OF ABOVE GROUND FOREST BIOMASS IN JHAJRA FOREST RANGE OF DEHRADUN FOREST DIVISION USING MICROWAVE DATA

Yogesh Kumar[1]*, Sarnam Singh[2] and R.S. Chatterjee[3]

[1]*Research Scholar, Forestry and Ecology Departmant, Indian Institute of Remote Sensing, Dehradun.*
[2]*Scientist G, Indian Institute of Remote Sensing (ISRO), Dehradun*
[3]*Scientist SG, Indian Institute of Remote Sensing (ISRO), Dehradun*
Email: yogesh.iirs@gmail.com

Received-07.10.2017, Revised-23.10.2017

Abstract: Forests play an important role in the global carbon cycle as a carbon sink. Deforestation and degradation of forests lead to carbon emissions, which should be prevented or minimized by protecting forests. Radar remote sensing has proven to be particularly useful tomonitor forests especially in the tropics due toweather and daytime independence. Radar data fromthe ALOS PALSAR-2 provide a potential opportunity to monitor large areas of tropical forests due to the high resolution.The study describes the development of logarithmic model for the estimation of forest above ground biomass and carbon using ALOS-PALSAR-2 synthetic aperture radar (SAR) data. The backscatter coefficient of the SAR data in different polarization were quantified using field data collected Jhajra forest range. A significant correlation has been observed between HV backscatter and plot level biomass with a coefficient of determination (R^2= 0.8918). The up-scaled biomass ranges from 5.2 tonnes/ha to 397.45 tonnes/ha. The total amount of carbon stored in the Jhajra forest range is 237471.99 tonnes. The carbon sequestration potential of the forest is 871522.20 tonnes.

Keywords: Biomass, Backscatter, Spectral Modelling, ALOS-PALSAR-2, Carbon Sequestration

INTRODUCTION

According to The Kyoto Protocol's Clean Development Mechanism (CDM) and reducing emissions from deforestation and forest degradation (REDD), countries are allowed to offset a portion of their greenhouse gas emissions through the carbon sequestration of forestation, so as to reduce environmental pollution. On that way, the government schemes and conservation strategies adopted by India leads to an increase in forest cover. An increasing forest cover is an important factor to reduce the rise of atmospheric carbon dioxide through carbon sequestration. The industrial revolution and development strategies adopted by the countries across globe has seriously degraded the terrestrial ecosystem. It had reduced the actual carbon stored in the ecosystem than their potential carbon reserves (Houghton and Hackler, 2003; Lal, 2008). The amount of carbon stored by the forests, peat swamps, grasslands and other terrestrial ecosystem is more than it is stored by the atmosphere (Lal, 2004). The forests stores the carbon in their wood through the process of photosynthesis contribute in the climate change mitigation. Disturbing the forest ecosystems with deforestation, forest fire, land use land cover change (LULC), diseases leads to the release of the significant amount of stored carbon in the atmosphere (Kareiva *et al.*, 2011).

The traditional methods for above ground carbon stock assessment were based on field inventory data. The forest inventory data collected from statistically based surveys and then estimate carbon stocks using relationships between inventory variables and carbon stocks augmented with models for pools that are not sampled (Intergovernmental Panel on Climate Change (IPCC, 1997). Forest inventory data are a useful basis for estimating carbon stocks and net fluxes for the sampled area. However, not all forest carbon pools are represented well by attributes measured in forest inventories, and so there is a need to augment survey data with data from intensive research sites and models (Birdsey & Heath, 1995; Smith & Heath, 2002, 2004; Heath et al., 2003; Smith et al., 2003). Although the techniques were more accurate and reliable but it took ample amount of resources (Financial and Human resources) and time (Brown, 2002; Coomes et al., 2002; Gibbs et al., 2007; Machar et al., 2016). Therefore for larger and inaccessible area these methods are unusable. The traditional methods were taken by a new technique i.e. "Remote Sensing" which are free from the limitations of old techniques, but has its own limitations. That is why in current scenario numerous research has been carried out to incorporate remote sensing technology for quick and reliable estimation of carbon stock (Goodenough et al., 2005; Mandal and van Laake, 2005; Vicharnakorn et al., 2014). Space borne Synthetic Aperture Radar (SAR) remote sensing systems are active sensors with the advantage of all weather and daylight independency. The retrieval of forest parameters depends upon the wavelength of the sensor, the longer the wavelength the deeper the penetration (Le Toan et al., 2001; Henderson & Lewis, 1998). The backscatter from the forest depends upon the sensor parameters like polarization, incidence angle along with structural

*Corresponding Author

properties like roughness and dielectric constant (Imhoff, 1995a; Lu, 2006). A significant relationship has been established between the backscattering coefficients and the above ground biomass within particular types of forest (Baker et., 1994; Le Toan et al., 1992; Dobson et el.,1992; Imhoff, 1995b). It has already been proved that Longer wavelengths are more useful because of an increasing backscatter range with changing biomass (Castro et al., 2003; Dobson et al., 1992; Lu, 2006; Luckman et al., 1997). The estimation of AGB are valid up to certain threshold which depends on the wavelength and the models used for the estimation. For L-band backscatter published saturation levels range from 40 t/ha (Luckman et al., 1997; Imhoff, 1995) to 150 t/ha (Kuplich et al., 2005; Lucas et al., 2007; Mitchard et al., 2009). Austin et al. (2003) stated that the L band saturation level is possibly up to 600 t/ha.

Study Area

The study was conducted in the Jhajra range which is located in the south western part of Dehradun forest division. The study area lying between latitudes 30° 33’ N to 30° 43’ N and longitude 77° 83’ E to 78° 03’ E. The annual temperature in the region ranges from 1.8° C in January to 40° C in June. The area received an average annual rainfall of 2025.43 mm. The region receives most of its annual rainfall during June to September, the maximum rainfall occur in July and August. In Jhajra forest range comes under subtropical dry deciduous forests where*Shorea robusta* (sal),*Terminalia alata* are the dominant overstory species. The middle storey are represented by *Mallotus philippensis, Syzygium cumuni*in, *Ehertia laevis* tree species. *Clerodendron viscosum* and *Lantana camara* are present in the lowermost tree canopy, and the understory shrub and herb. Some abundantly found species from this site were *Murraya koinigii* L. Spreng., *Parthenium hysterophorus* L., *Xanthium indicum* Koenig., *Jasminum nudiflorum* Lindl., *Colebrookea oppositifolia* Smith., *Alternanthera sessilis* (L.) R. DC., *Phlogacanthus thyrsiflorus* (Roxb.) Nees., *Pogostemon benghalense* (Burm. f.) Kuntze., *Ziziphus mauritiana* Lam., *Androsace umbellata* (Lour.) Merrill, *Anisomeles indica* (L.) Kuntze, *Asparagus racemosus* Willd.

MATERIAL AND METHOD

Satellite Data

ALOS PALSAR -2 High-Sensitive mode full (Quad) Polarimetry (HBQ) scene was obtained from Japan Aerospace Exploration Agency (JAXA). The image was acquired with an off-nadir angle of 33.2° and covered an area of 70×70 km^2. The image was acquired in the month of March, 2016. The description of the data are given below:

Satellite	Polarization	Frequency Band	Range Resolution (m)	Azimuth Resolution (m)	Incidence Angle
ALOS PALSAR-2	Quad (HH+HV+VH+VV)	L	5.1	4.3	33.2°

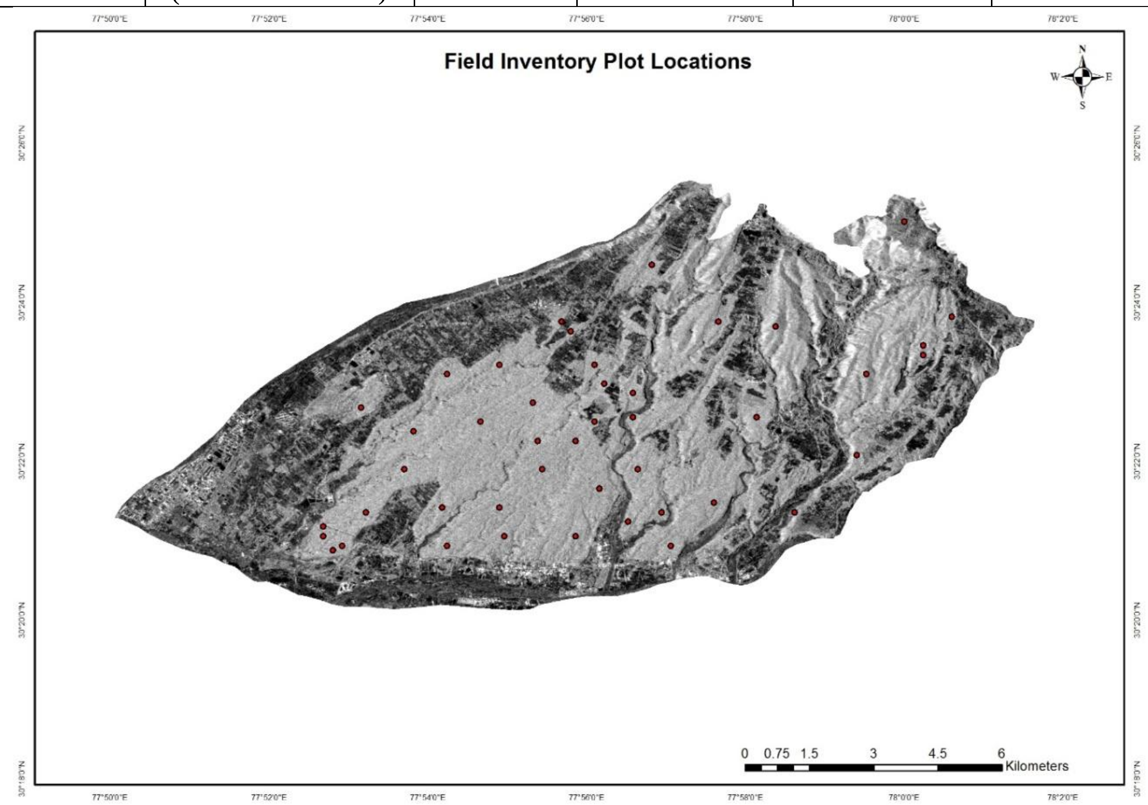

Figure 1. The location of *in-situ* field observation.

Field Inventory Data

A total of 44 sample plots were laid down randomly in the entire study area. The vegetation was analysed by the means of random sampling to give most representative composition of vegetation. A point one hectare (0.1ha) plots were laid out in the area. The girth at breast height (1.37m) were measured using measuring tape and height were measured using hypsometer. The location of the plot were recorded by using geographic positioning system (GPS). The locations were shown in the figure 1.

Estimating tree Volume and plant Biomass from field inventory data

The allometric equations developed by Forest Survey of India (FSI, 1996) were used for assessment of tree volume. The girth at breast height were converted into dbh, and basal area was calculated. The volume equations for a species were carefully chosen considering the ‘n’ (total number of sample tree on which regression equation are based) and ‘R^2’ (Coefficient of determination) for the nearest geographic region. The volume was multiplied with wood specific gravity (Forest Research Institute, 1996) and Biomass expansion factor (BEF) to estimate the biomass (Biomass = Volume × Specific Gravity× BEF). The plot level biomass was further scaled to pixel level biomass (per pixel biomass) as well as tones/ha biomass.

ALOS PALSAR data Processing

The data was processed in SNAP software. It was calibrated to provide imagery in which pixel value can be directly related to radar backscatter of the scene. Typical SAR data processing, which produces level 1 images, does not include radiometric corrections and significant radiometric bias remains. Therefore, it is necessary to apply the radiometric correction to SAR images so that the pixel values of the SAR images truly represent the radar backscatter of the reflecting surface. The image was studded with speckle which is due to coherent interference of the wave. Multi-looking was performed to reduce the speckle and improves interpretability. The image was further applied with speckle filtering (Refined Lee). Due to topographical variations of a scene and the tilt of the satellite sensor, distances can be distorted in the SAR images. Image data not directly at the sensor’s Nadir location will have some distortion. Terrain corrections are intended to compensate for these distortions so that the geometric representation of the image will be as close as possible to the real world. The backscatter intensity image was converted into decibel (Sigma naught, σ°).

Spectral Modelling and Estimation of Carbon Sequestration

The spectral information were exported with the help of plot location. The relationship has been established between plot level biomass and backscatter coefficient of different polarization. The significant relation was used for the upscaling of phytomass from pixel to regional level. The biomass map gives the total amount of forest above ground biomass. The carbon stock has been calculated by multiplying the biomass with a factor of 0.47. The carbon sequestration by forests was calculated by multiplying the total amount of carbon by 0.36 (Belop, S.V., 1976,1980).

RESULT AND DISCUSSION

The result of this study can be seen in three ways i.e. the field data statistics, the derivatives of SAR imagery and the graphical representation of relationship between backscatter coefficient and biomass.The plot level forest inventory reveals that the top height of the plot varies from 12 m to 41 m. The number of trees varies from 12 in few plots to 53 in some plots. The biomass per plot varies from 8.2 tonnes/ha to 452.51 tonnes/ha. The processing of SAR image results in the generation of image having different polarization. The plot level biomass were plotted against the backscatter coefficient. It was concluded according to figure (2b) that the HV backscatter gave the highest correlation with a coefficient of determination (R^2) of 0.8918. It was followed by VV polarisation (R^2= 0.869) and HH (R^2 = 0.855). The correlation analysis indicates that the AGB has a logarithmic relationship with the variables. Based on the correlation analysis, the backscatter of HV polarisation was selected as the AGB predictionmodel as it gave the best R^2compared to the other variables.The cross polarized (HV) L-band backscatter appears to respond slightly more to differences in vegetation than the co-polarized (HH & VV) polarization. These observations support other studies of the SAR remote sensing of forests (Baker et al., 1994; Le Toan et al., 1992; Dobson et al., 1992) and are in agreement with predictions made by models of radar backscatter from forest targets (Richards, 1990).

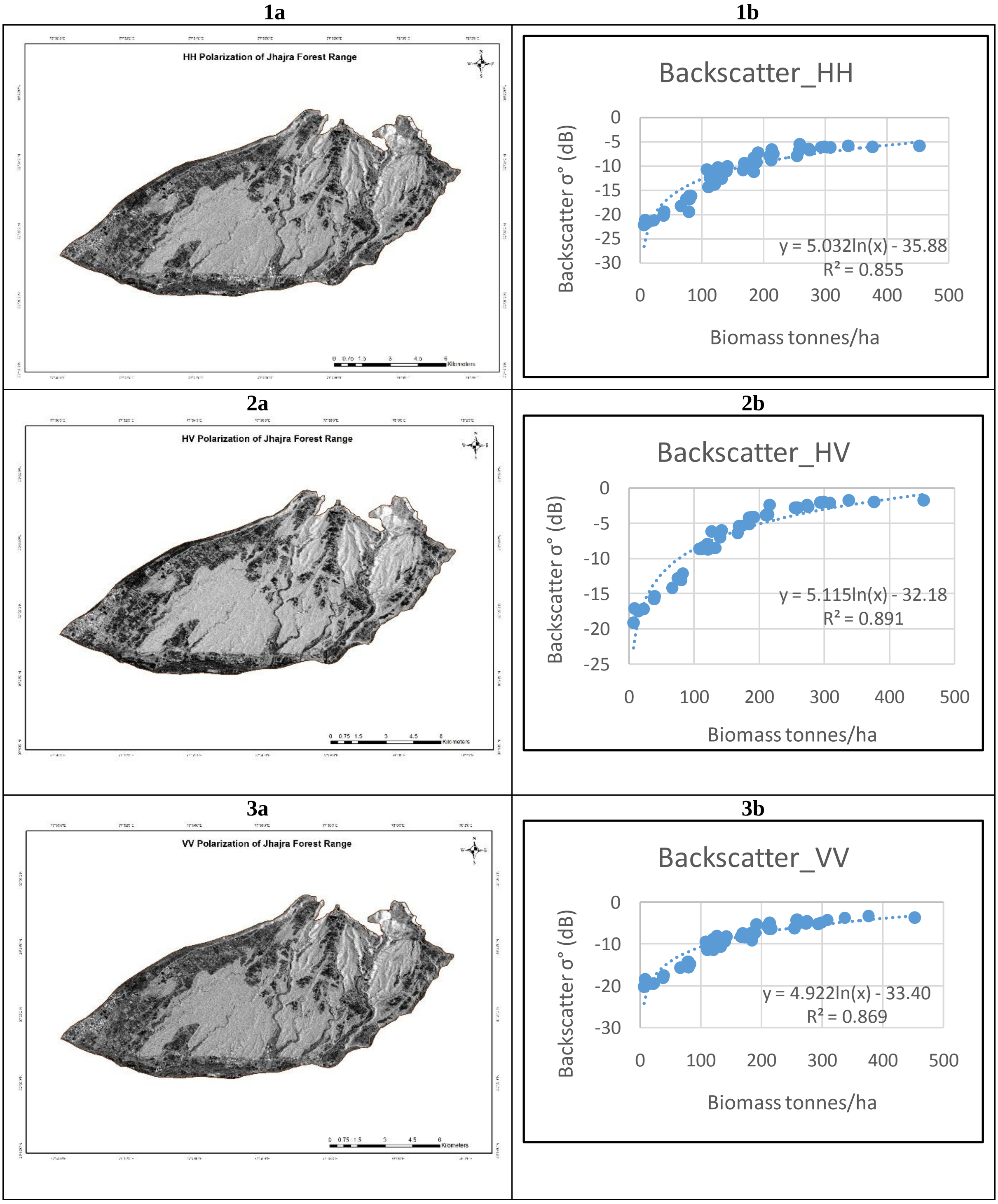

Figure 2: The SAR processed images are represented as 1a (HH Pol.), 2a (HV pol.) and 3a (VV pol.) and the respective backscatter relations are represented in 1b, 2b and 3b.

The modelled biomass ranges from 5.2 tonnes/ha to 397.45 tonnes/ha. It shows great relevance with the *in-situ* data. The underestimation of biomass through modelling is due to the saturation of biomass at higher level. It was observed that the study area is dominated with biomass greater than 150 tonnes/ha. The table 1 describes the distribution of modelled biomass and carbon in the study area. A total of 5, 05,259.55 tonnes of biomass is stored in the study area along with 2, 37,471.99 tonnes of carbon. The carbon sequestration potential of the study area is 8, 71,522.20 million gram carbon. There is no information for 225.14 ha of the area because of the effect of layover and foreshortening. This effect has been eliminated from the scene because it results in overestimation of biomass because of very high backscatter.

Table 1. The distribution of biomass and carbon in different density class of study area.

Forest Density Class	Total Area (ha)	Modelled Biomass (Tonnes)	Modelled Carbon (Tonnes)	Carbon Sequestration Potential(Million gram carbon)
Open Forest (<50t/ha)	712.58	21477.16	10094.27	37045.96
MDF (50-150 t/ha)	1862.23	205888.15	96767.43	355136.47
VDF (>150 t/ha)	1238.94	277894.24	130610.29	479339.78
NF	6724.01	0.00	0.00	0.00
Layover & Foreshortening	225.14	0.00	0.00	0.00
Total	**10762.9**	**505259.55**	**237471.99**	**871522.20**

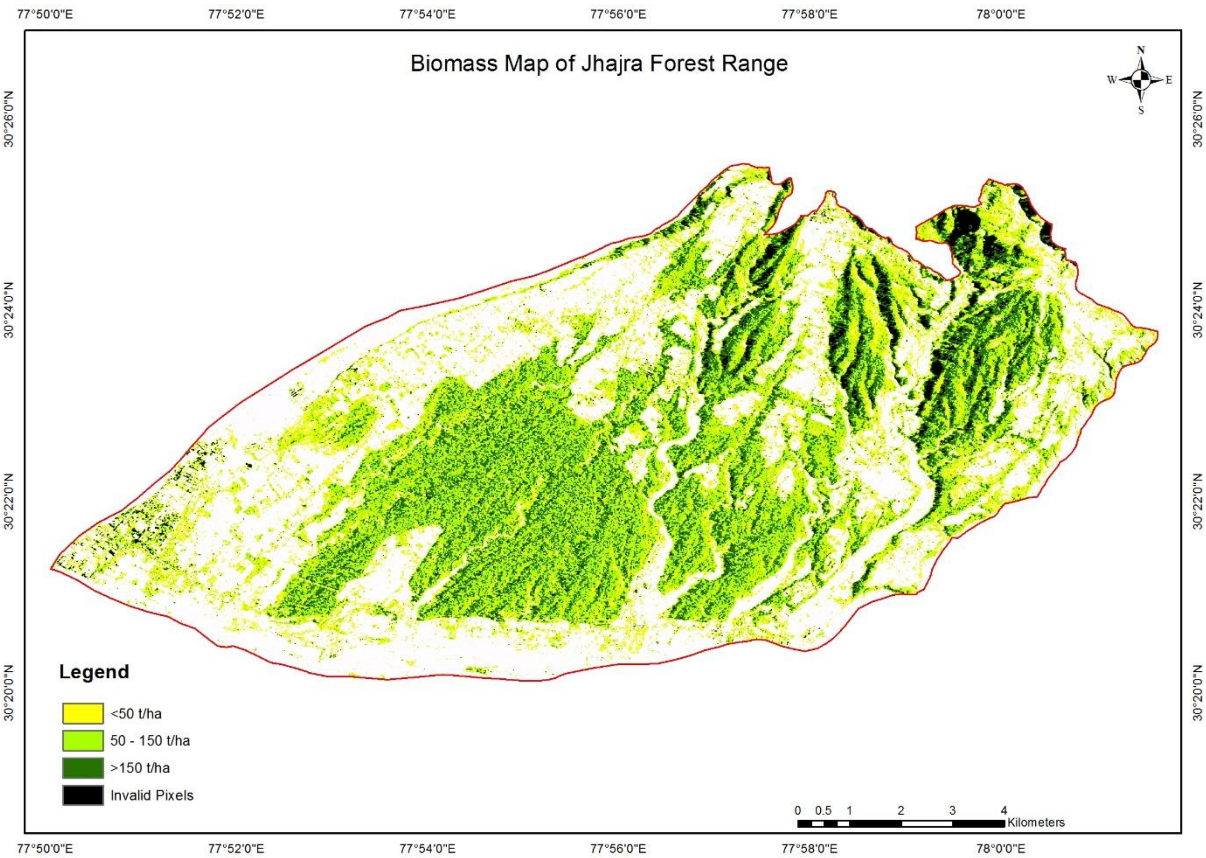

Figure 3. Biomass map derived from HV backscatter image.

CONCLUSION

This study provides a relevant information about the amount of biomass and carbon stored in the study area. It demonstrate the potential of L-band ALOS PALSAR-2 data to delineate the spatial distribution of biomass and carbon in Jhajra forest range.The study will be helpful to estimate the biomass for areas having similar species composition and topography. It will help in quick and accurate estimation which will reduce the human labour and time. The simple logarithmic regression approach used in the study is the most commonly used approach throughout the world. The integration of different polarization and inclusion of different parameters in the model will further enhance the accuracy and reliability. The effect of layover and foreshortening can be overcome by using different SAR scene having different incidence angle. The effect is very less in tropical forests but as we move up from tropical to sub-tropical and temperate the effect keep on increasing.

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