Evaluation of Sentinel-1A Data For Above Ground Biomass Estimation in Different Forests in India

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Abstract

Use of remote sensing data for mapping and monitoring of forest biomass across large spatial scales can aid in addressing uncertainties in carbon cycle. Earlier, several researchers reported on the use of Synthetic Aperture Radar (SAR) data for characterizing forest structural parameters and the above ground biomass estimation. However, these studies cannot be generalized and the algorithms cannot be applied to all types of forests without additional information on the forest physiognomy, stand structure and biomass characteristics. The radar backscatter signal also saturates as forest parameters such as biomass and the tree height increase. It is also not clear how different polarizations (VV versus VH) impact the backscatter retrievals in different forested regions. Thus, it is important to evaluate the potential of SAR data in different landscapes for characterizing forest structural parameters. In this study, the SAR data from Sentinel-1A has been used to characterize forest structural parameters including the above ground biomass from tropical forests of India. Ground based data on tree density, basal area and above ground biomass data from thirty-eight different forested sites has been collected to relate to SAR data. After the pre-processing of Sentinel 1-A data for radiometric calibration, geo-correction, terrain correction and speckle filtering, the variability in the backscatter signal in relation tree density, basal area and above biomass density has been investigated. Results from the curve fitting approach suggested exponential model between the Sentinel-1A backscatter versus tree density and above ground biomass whereas the relationship was almost linear with the basal area in the VV polarization mode. Of the different parameters, tree density could explain most of the variations in backscatter. Both VV and VH backscatter signals could explain only thirty and thirty three percent of variation in above biomass in different forest sites of India. Results also suggested saturation of the Sentinel-1A backscatter signal around hundred tonnes per hectare for VV polarization and one hundred and forty five tonnes per hectare for VH polarization. The presentation will highlight the above results in addition to potentials and limitations of Sentinel-1A data for retrieving forest structural parameters. Also, background information on different forest types of India, biomass variations and forest type mapping efforts in the region will be presented.

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Evaluation of Sentinel-1A Data Over Different Forest Types of India

India and Forest Types

- Provide an overview on the Indian Forest types and latest status on mapping/monitoring efforts.

Research Question

- Of the three forest properties (tree density, basal area and above ground biomass) which one explains the most variation in the Sentinel 1-A backscatter (Sigma nought)?

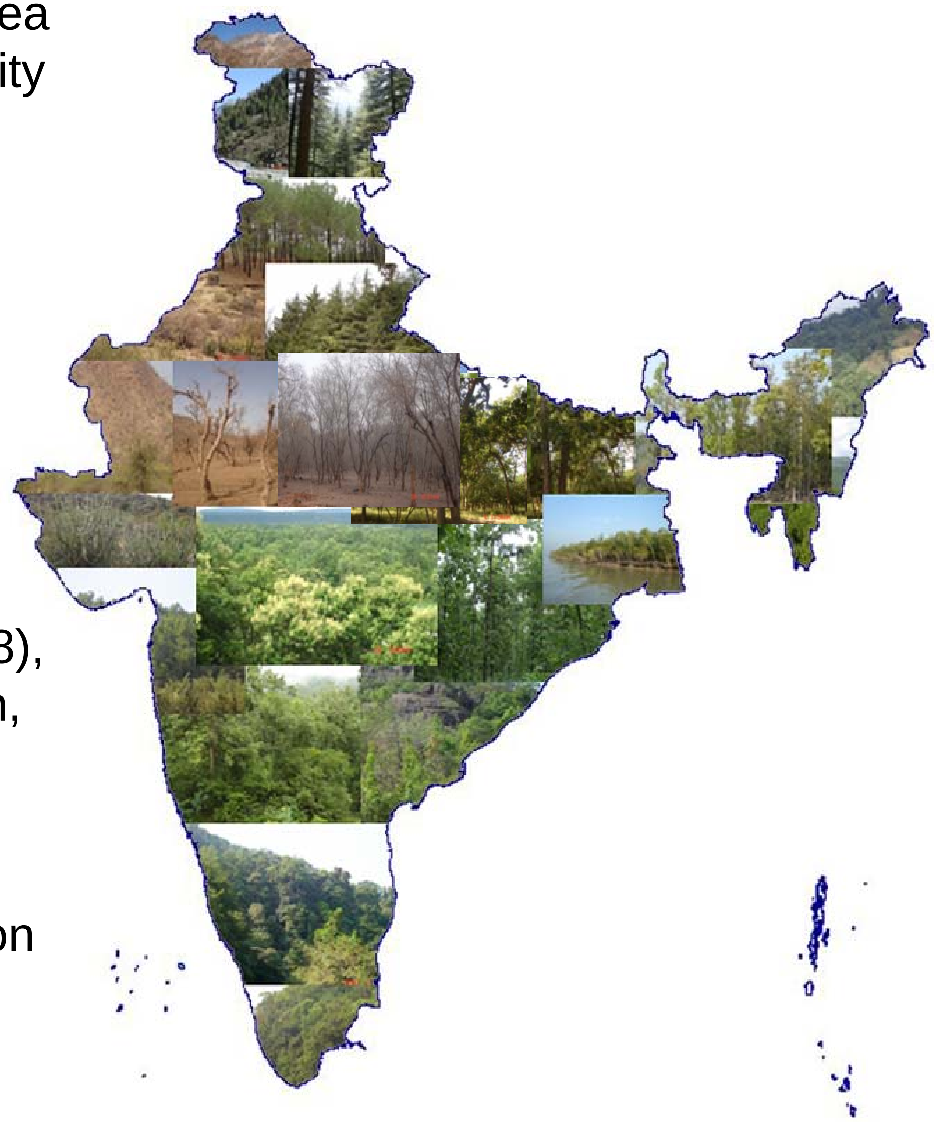
Forest Types of India

India though occupies 2.4% of the world's area is home over 8% of the total global biodiversity

Forests classification based mainly on Vegetation: Beard (1944), Fosberg (1958), Webb (1959)

Forest classification based on Climate: Schimper (1898), Mayr (1909), Rubnern (1925), Thonthwaite (1948), Shanbagh (1958), Emberger (1955), Gaussen (1955), Guassen, Legis and Viart (1961)

Forest classification based on both Vegetation + Climate: Champion (1936), Burtt-Davy (1938), Swain (1938), Kuchler (1949), Puri (1960) and ***Champion and Seth (1968)***



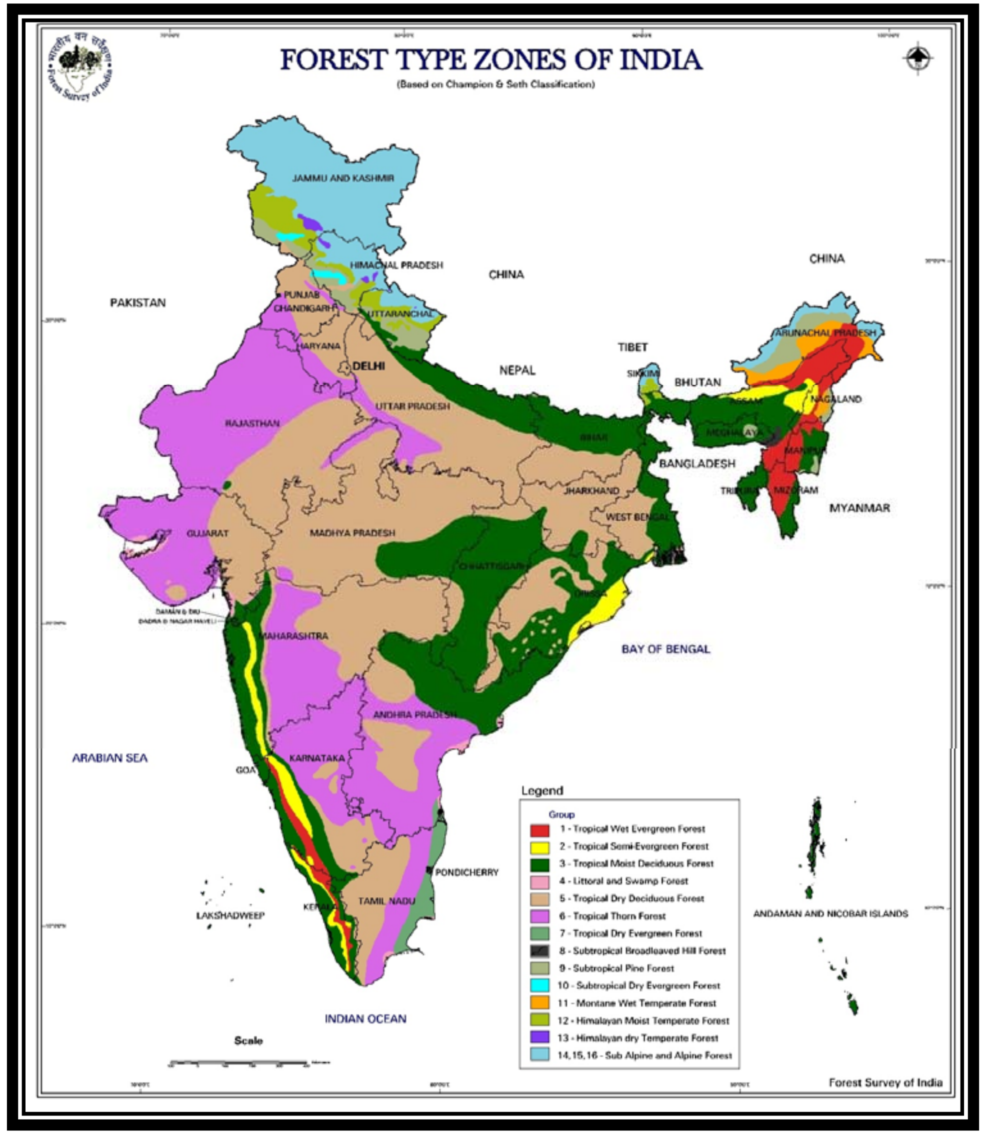
Source: Subhash, FSI, 2015

Champion and Seth (1968) Revised Classification - Forest Types of India

Most widely used classification system for India’s forests.

Forests are classified into 6 major <u>groups</u> based on climatic factors

Major groups divided into 16 <u>type groups</u> based on temperature and moisture conditions



Forest Classification - India

MAJOR GROUPS	TYPE GROUPS	
Moist Tropical Forests	Group 1-Tropical Wet Evergreen Forests Group 2-Tropical Semi-Evergreen Forests Group 3-Tropical Moist Deciduous Forests Group 4-Littoral And Swamp Forests	**22 SUB-GROUPS**
Dry Tropical Forests	Group 5-Tropical Dry Deciduous Forests Group 6-Tropical thorn Forests Group 7-Tropical Dry Evergreen Forests	
Montane Temperate Forests	Group 8-Southern Subtropical Broadleaved Hill Forests Group 9-Subtropical Pine Forests Group 10- Subtropical Dry Evergreen Forests	
Montane Subtropical Forests	Group 11-Montane Wet Temperate Forests Group 12-Himalayan Moist Temperate Forests Group 13-Himalayan Dry Temperate Forests	**200 TYPES**
Sub Alpine Forests	Group 14-Sub Alpine Forests	
Alpine Scrub	Group 15-Moist Alpine Scrub Group 16- Dry Alpine Scrub	

Source: Champion and Seth classification(1968)

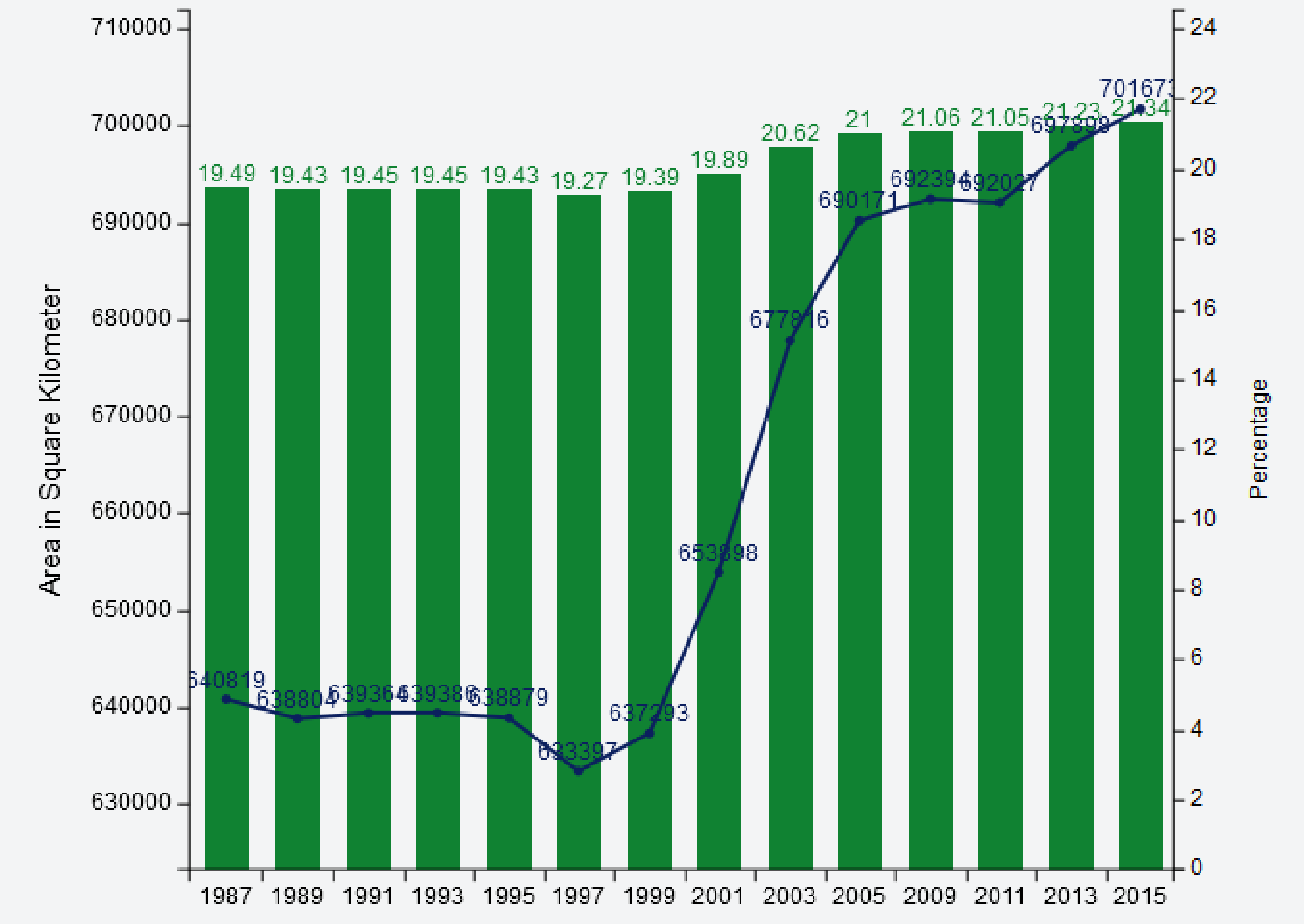
Biannual Forest Type Mapping in India using Remote Sensing and Ground Truth (Forest Survey of India)

Cycle of Assess ment	Year	Data Period	Sensor	Spatial Resolution	Scale	Minimum Mappable Unit (ha)	Mode of Interpretation
I	1987	1981-83	LANDSAT-MSS	80 m	1:1 million	400	Visual
II	1989	1985-87	LANDSAT-TM	30 m	1:250,000	25	Visual
III	1991	1987-89	LANDSAT-TM	30 m	1:250,000	25	Visual
IV	1993	1989-91	LANDSAT-TM	30 m	1:250,000	25	Visual
V	1995	1991-93	IRS-1B LISS-II	36.25 m	1:250,000	25	Visual & Digital
VI	1997	1993-95	IRS-1B LISS-II	36.25 m	1:250,000	25	Visual & Digital
VII	1999	1996-98	IRS-1C/1D LISS-III	23.5 m	1:250,000	25	Visual & Digital
VIII	2001	2000	IRS-1C/1D LISS-III	23.5 m	1:50,000	1	Digital
IX	2003	2002	IRS-1D LISS-III	23.5 m	1:50,000	1	Digital
X	2005	2004	IRS-1D LISS-III	23.5 m	1:50,000	1	Digital
XI	2009	2006	IRS-P6-LISS-III	23.5 m	1:50,000	1	Digital
XII	2011	2008-09	IRS-P6-LISS-III & IRS-P6 AWiFS	23.5 m 56 m	1:50,000	1	Digital
XIII	2013	2010-11	IRS P6-LISS-III IRS-Resourcesat-2 LISS-III	23.5 m	1:50,000	1	Digital
XIV	2015	2013-14	IRS P6-LISS-III IRS-Resourcesat-2 LISS-III	23.5 m	1:50,000	1	Digital

What Constitutes Forest Cover ?

“The term "Forest Cover" refers to all lands more than 1ha in area with a tree canopy of more than 10% irrespective of land use, ownership and legal status” **(State of the Forest Report, 2015; Forest Survey of India).**

Forest Cover 1987-2015



Forest Cover 2015 (21.34% of total area)

Forest Cover of India

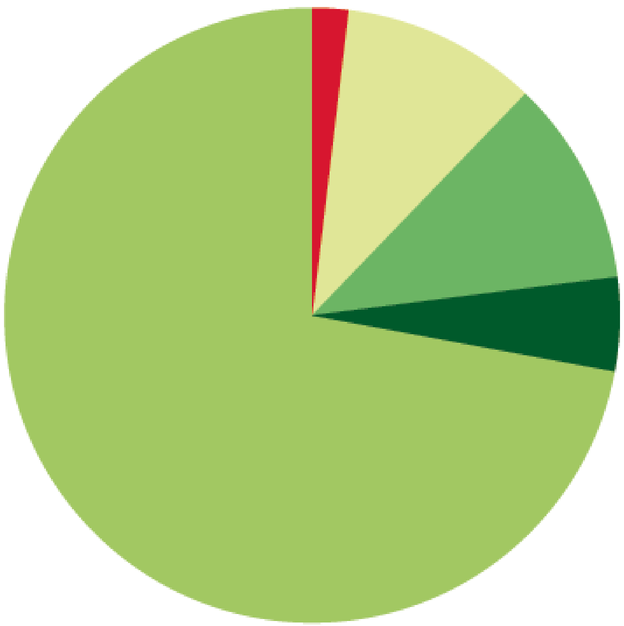


Fig. 2.3 Pie Chart showing Forest Cover of India

- Non Forest **77.40%**
- Scrub **1.26%**
- Open Forest **9.14%**
- Moderately Dense Forest **9.59%**
- Very Dense Forest **2.61%**

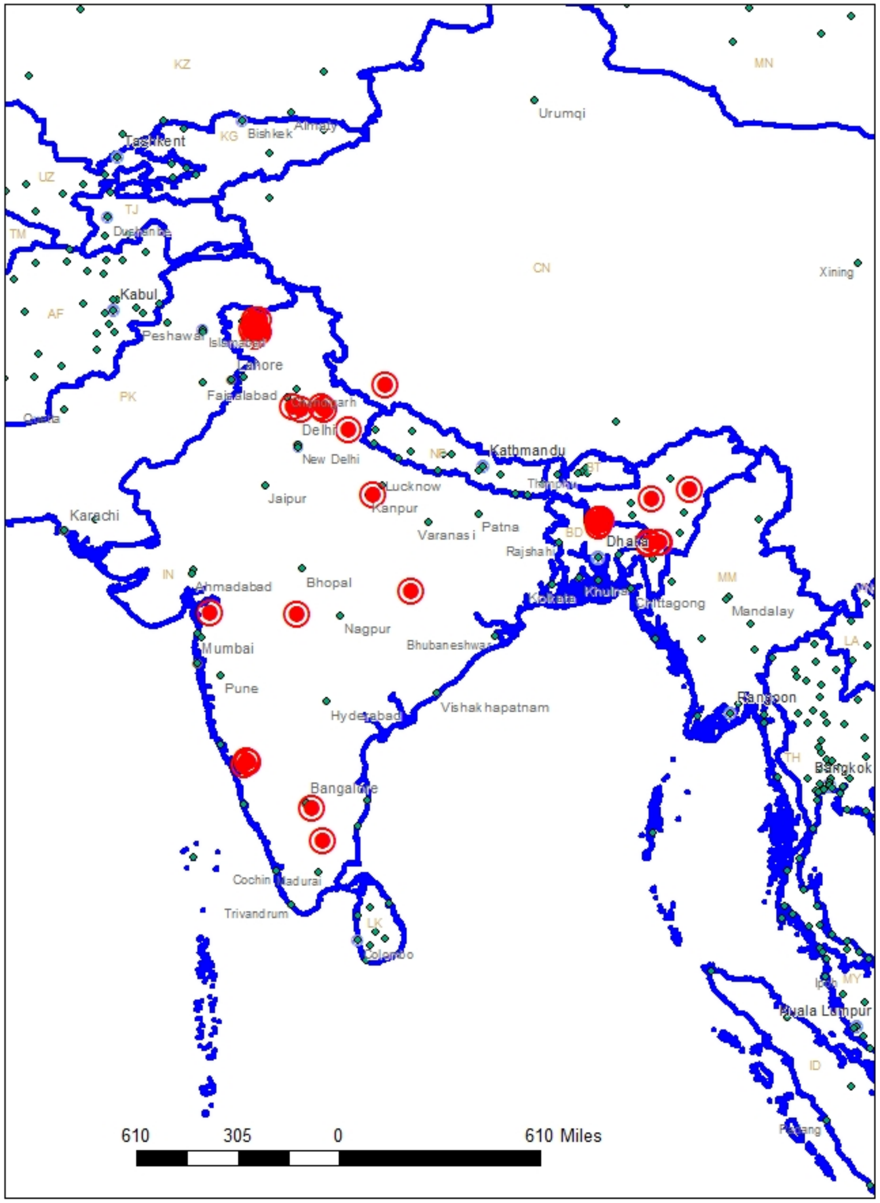
Class	Area (sq km)	percent of Geographical Area
Forest Cover		
Very Dense Forest	85,904	2.61
Moderately Dense Forest	315,374	9.59
Open Forest	300,395	9.14
Total Forest Cover*	701,673	21.34
Scrub	41,362	1.26
Non Forest	2,544,228	77.40
Total Geographic Area	3,287,263	100.00

**Includes 4,740 sq km under mangroves*

Research Question Addressed:

Of the three forest properties (tree density, basal area and above ground biomass) which one explains the most variation in the Sentinel 1-A backscatter?

Forest and Satellite Data 2015-2016

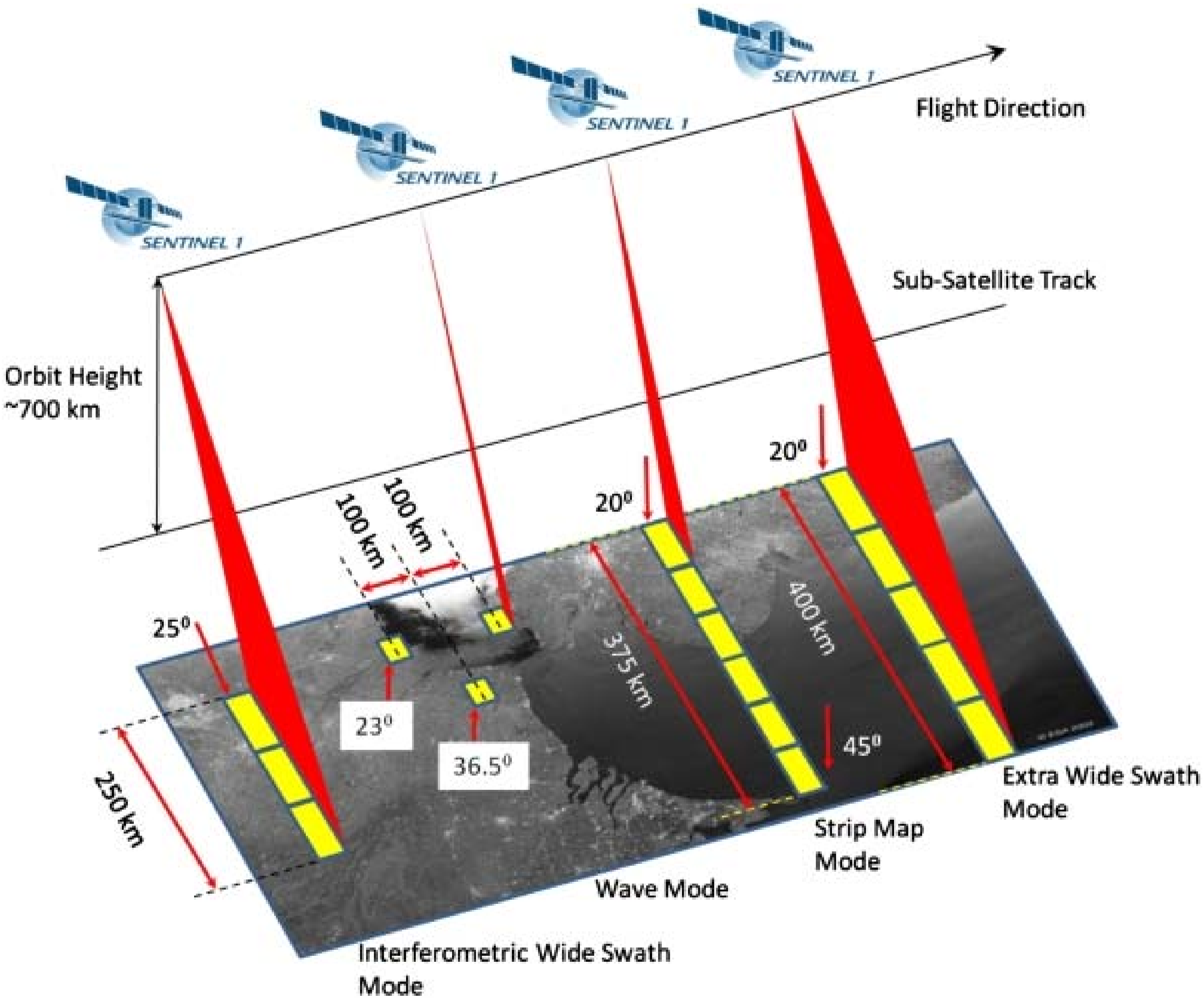


- Data over 38 different sites covering India for Tree Density (/ha), Basal Area (m2/ha) and Forest Biomass (t/ha) has been collected from University researchers, published literature and forest department data.
- Sentinel 1A data for different sites for the 2015 or 2016 (December) has been collected from Copernicus Sentinel online data hub.

Forest Data

	Place name	Forest type	Tree density (ha)	Total basal area (m2/ha)	ABG Biomass (t/ha)
1	Garhwal Himalayas	Pine-Oak forest	889	75.12	8
2	Shoolpaneshwar wildlife sanc	Tropical dry deciduous	NA	NA	88
3	Bilaspur circle of Korba, Chattisgarh	Tropical dry forest	306	20.2	155
4	Tehri Garhwal,	Mixed deciduous forest	NA	NA	130
5	Garo Hills, NEAST-1	Shorea robusta (60 year old growth)	570	54.9	259.8
6	Garo Hills, NEAST-2	60 year old plantation	608	54	255.96
7	Garo Hills, NEAST-3	Mixed Sal forest - 60 yr	688	58	272.83
8	Garo Hills, NEAST-4	Mixed Sal natural forest 50 yr	640	42.67	204.15
9	Garo Hills, NEAST-5	As above	690	49.21	233.25
10	Garo Hills, NEAST-6	Primary forest undisturbed	846	67.18	314.02
11	Himalayas, Kashmir	Coniferous	120	NA	90
12	Kashmir Himalayas	Himalayan temperate forest	210	NA	150
13	Kolli forests, Eastern Ghats	Tropical Evergreen forest	1946	NA	336
14	Chikaldhara hill station	Tropical mixed forest	NA	NA	49
15	Banthra, Lucknow	Tropical dry deciduous	554	29.9	30
16	Northern Haryana	Tropical Mixed deciduous	564	27	132
17	Assam Gibbon	Evergreen forest	286	90.29	135.3
18	Assam Kholahat	Evergreen forest	416	62.49	146.42
19	Bhuban Hills, Assam-1	Evergreen forest	396	16.96	NA
20	Bhuban Hills, Assam-2	Evergreen forest	590	21.14	NA
21	Bhuban Hills, Assam-3	Evergreen forest	344	17.21	NA
22	Bhuban Hills, Assam-4	Evergreen forest	614	38.44	NA
23	Bhuban Hills, Assam-5	Evergreen forest	718	42.54	NA
24	Bhuban Hills, Assam-6	Evergreen forest	794	45.07	NA
25	Uttara Kanara	Wet semi-evergreen forest	414	25.62	249.67
26	Ekkambi	Wet semi-evergreen forest	1087	43	417
27	Hosur	Wet semi-evergreen forest	1409	42.95	417
28	Malgi	Wet semi-evergreen forest	928	34.1	344
29	Togralli	Wet semi-evergreen forest	1647	36.19	361
30	Malgi	Wet semi-evergreen forest	468	33.67	340
31	Ananthnag District, Kashmir	Low lying temperate forests	NA	NA	NA
32	Ananthnag District, Kashmir-2	Juglans regia	1201	36.1	204
33	Ananthnag District, Kashmir-3	Populus deltoides	220	38.5	157
34	Ananthnag District, Kashmir-4	Salix sp.	195	43.6	284
35	Ananthnag District, Kashmir-5	Pinus wallichiana	199	44.9	272
36	Ananthnag District, Kashmir-6	Cedrus deodara	196	46.7	276
37	Ananthnag District, Kashmir-7	Abies pindrow	197	51.9	294
38	Ananthnag District, Kashmir-8	Betula utilis	103	19.4	100.8

Sentinel 1 Data



Strip Map (SM): 80 km swath, 5 x 5 m spatial resolution

Interferometric Wide Swath (IW): 250 km swath, 5 x 20 m spatial resolution

Extra-Wide Swath (EW): 400 km swath, 20 x 40 m spatial resolution

Wave (WV): 20 x 20 km, 5 x 5 m spatial resolution Over land, Sentin

Interferometric Wide Swath

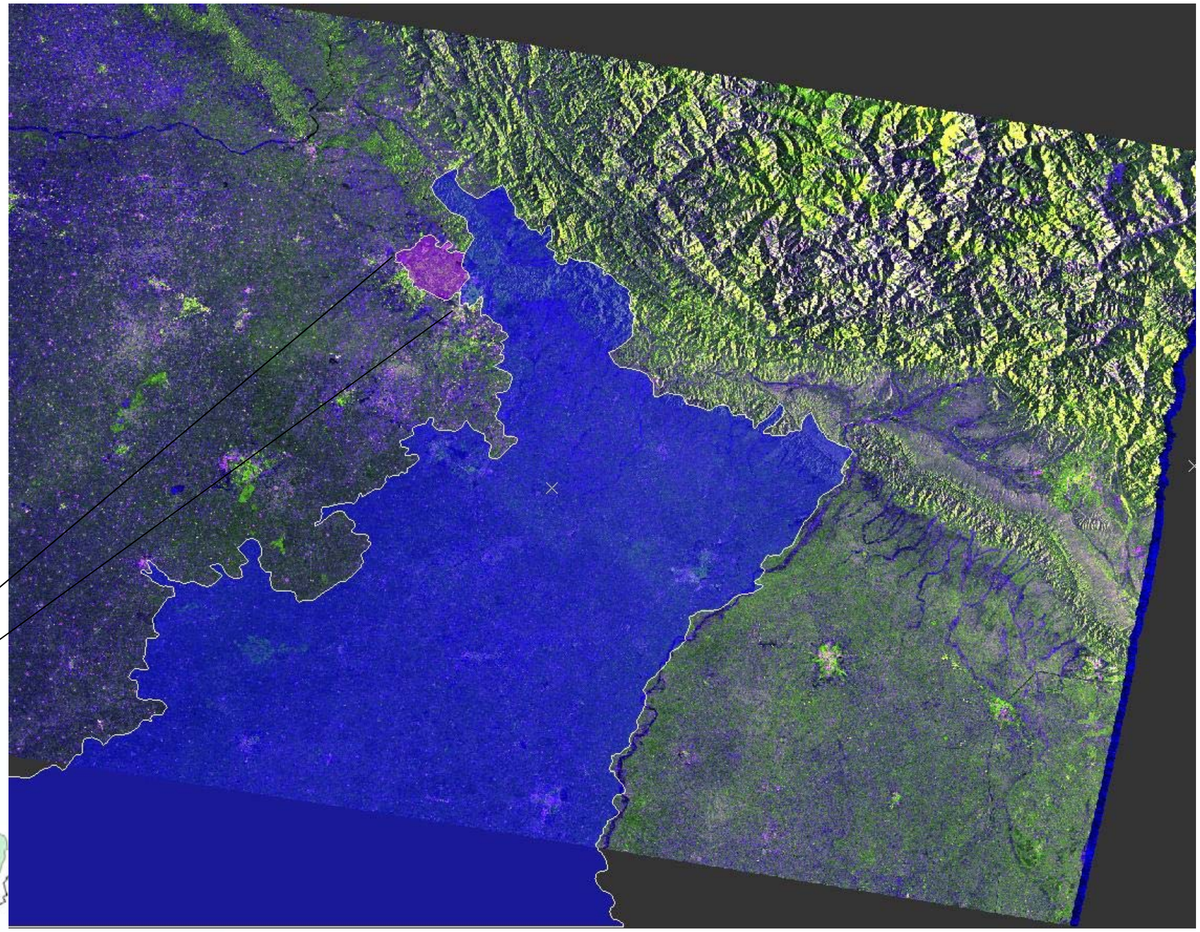
Characteristic	Value
Swath width	250 km
Incidence angle range	29.1° - 46.0°
Sub-swaths	3
Azmiuth steering angle	± 0.6°
Azmiuth and range looks	Single
Polarisation options	Dual HH+HV, VV+VH Single HH, VV
Maximum Noise Equivalent Sigma Zero (NESZ)	-22 dB
Radiometric stability	0.5 dB (3σ)
Radiometric accuracy	1 dB (3σ)
Phase error	5°

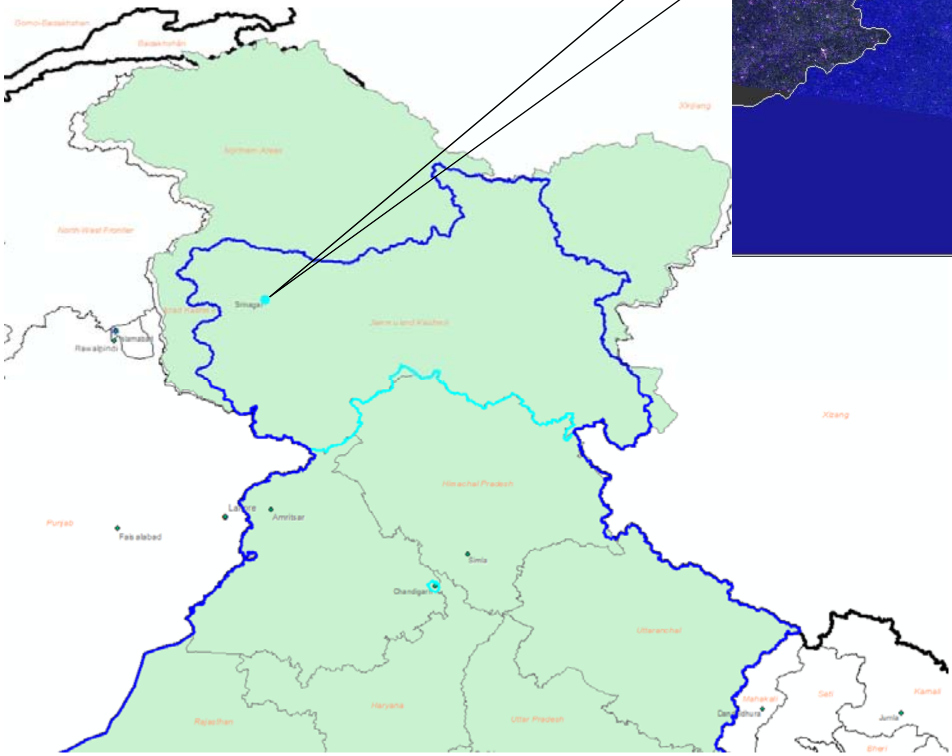
Level-1 Single Look Complex data comprising complex imagery with amplitude and phase (systematic distribution limited to specific relevant areas) (typical size 8GB/product)

Level-1 Ground Range Detected data with multilook intensity only (systematically distributed) (typical size 1GB/product)

Pre-processing: Multilook (20m resolution)-Radiometric calibration to Sigma nought)-Geocorrection-Terrain Correction with SRTM 30m using Range-Doppler Terrain Correction-Speckle Filtering using Lee filter;

Georeferenced GPS points of Forest data and overlaid Country/state boundary Vector Files over Sentinel 1A Image (Haryana, India)

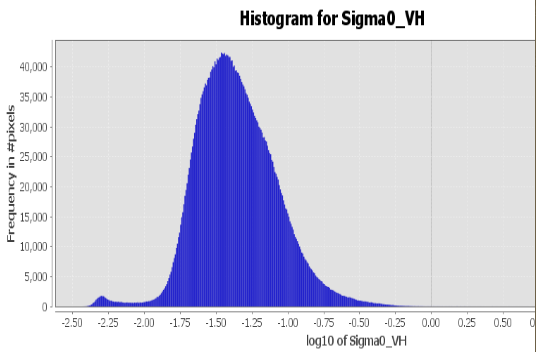


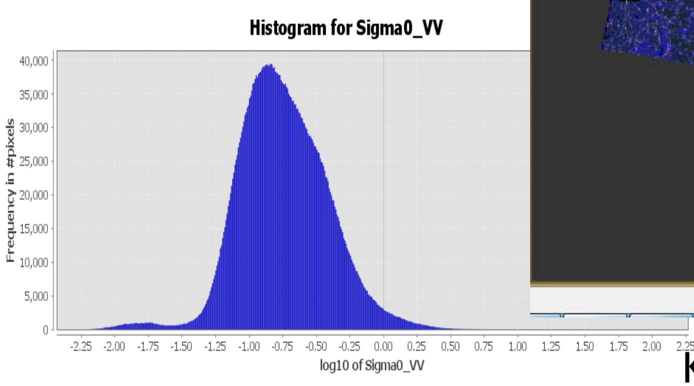


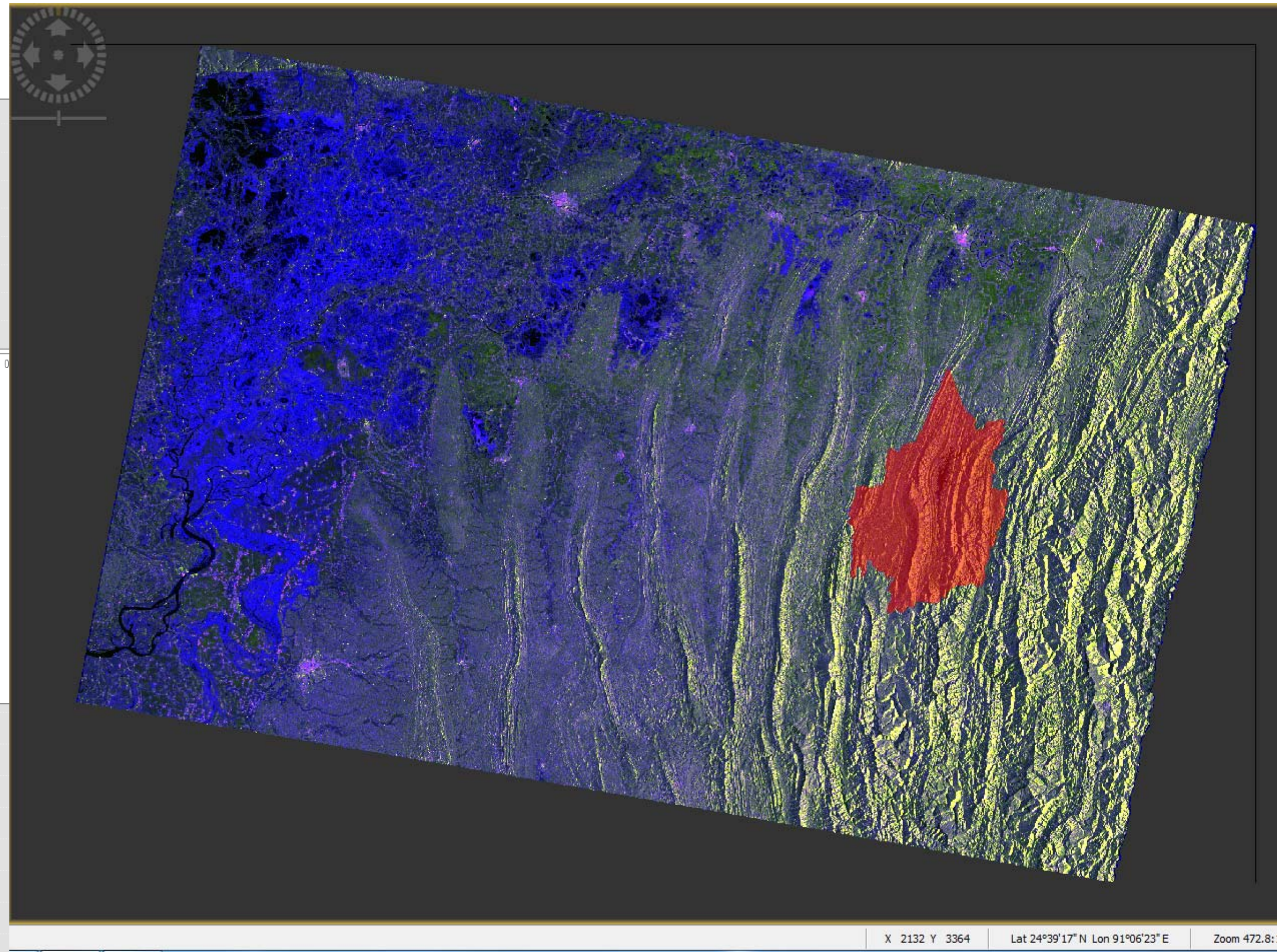
Haryana, India

Sentinel 1A, 2016, 12/27
RGB – Sigma VV, Sigma VH, Sigma VV/VH

Sentinel 1 Data

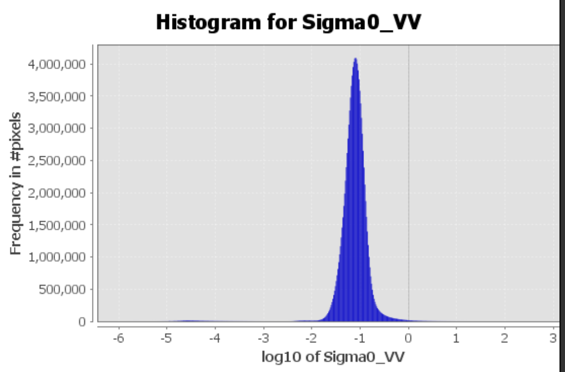


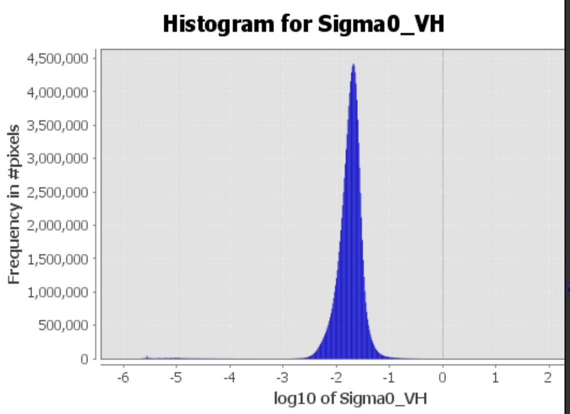


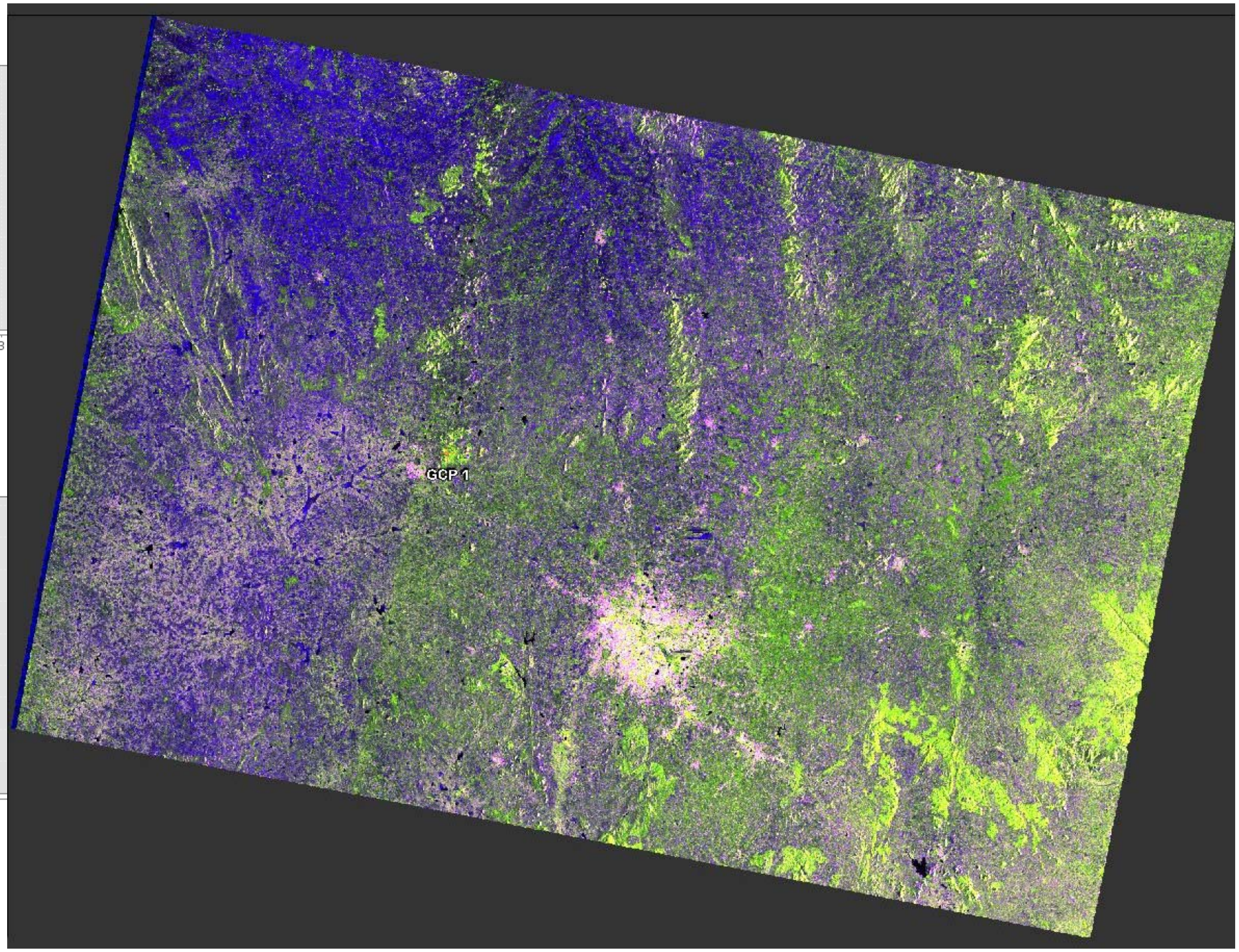


Kolasib, Mizoram, Northeast India
Sentinel 1A, 2016-12-16
RGB - – Sigma VV, Sigma VH, Sigma VV/VH

Sentinel 1 Data

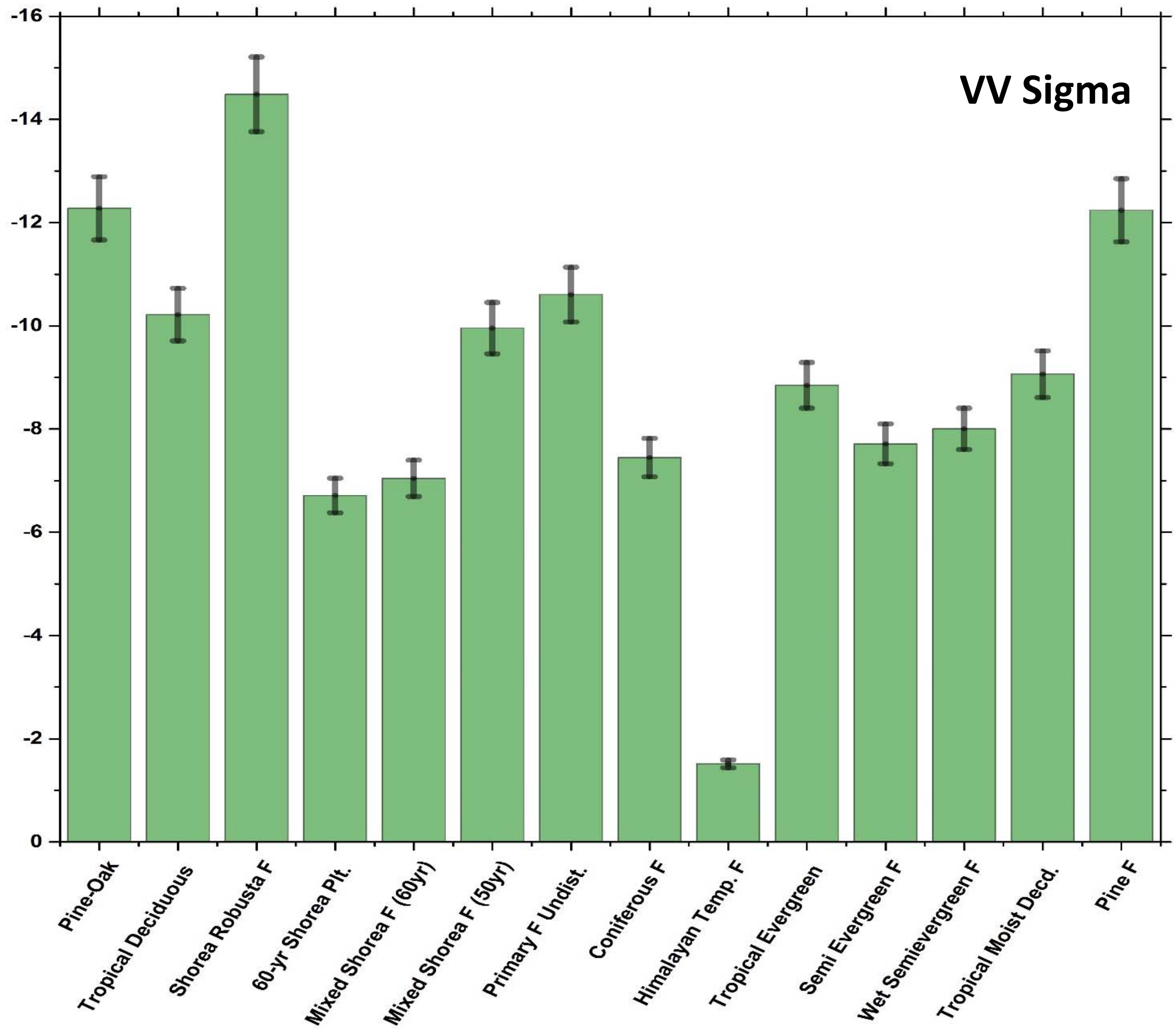




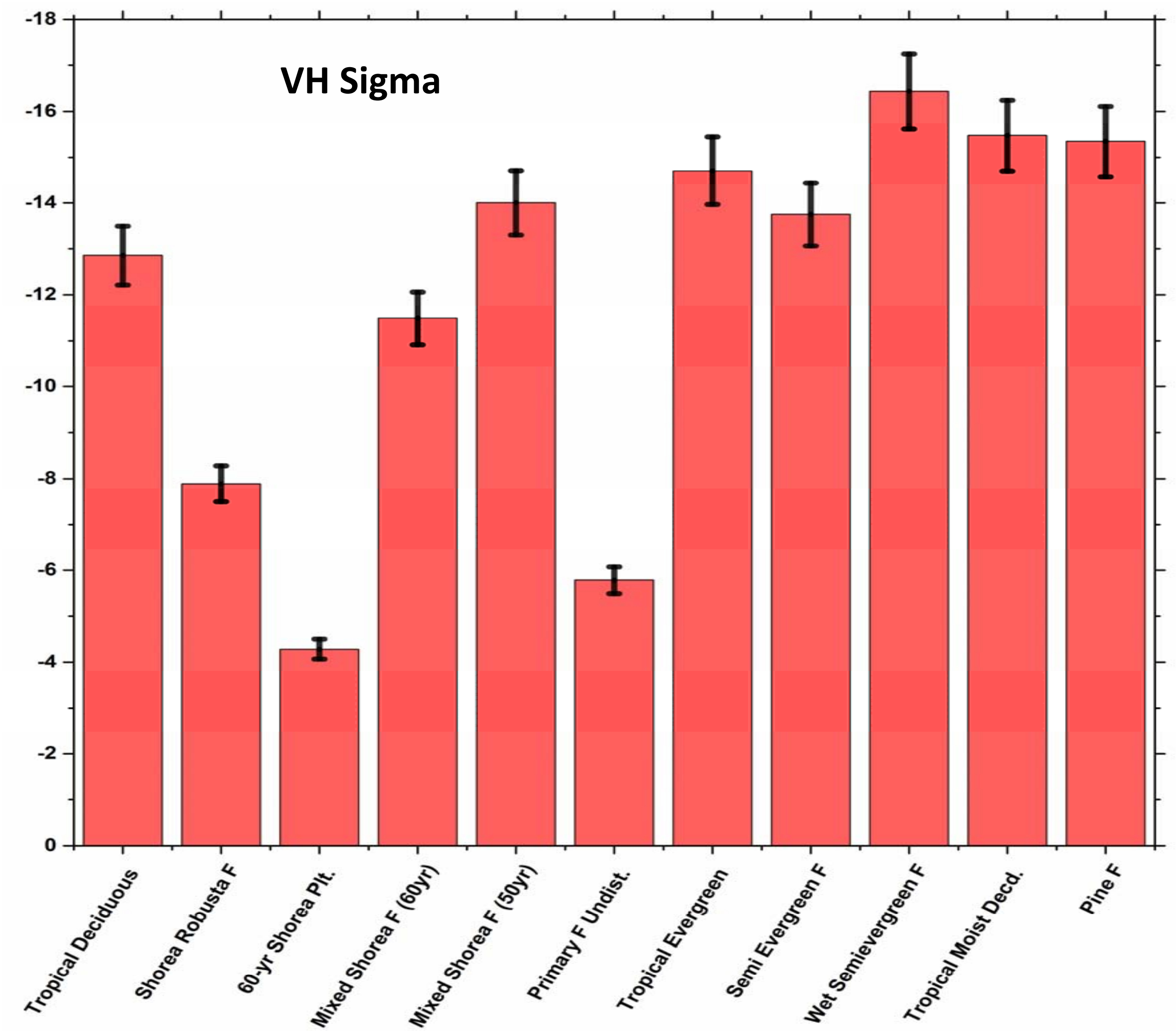


Hosur, Karanataka (Bangalore)
Sentinel 1A, 2016-12-29
RGB - – Sigma VV, Sigma VH, Sigma VV/VH

VV (Sigma) over different forest types

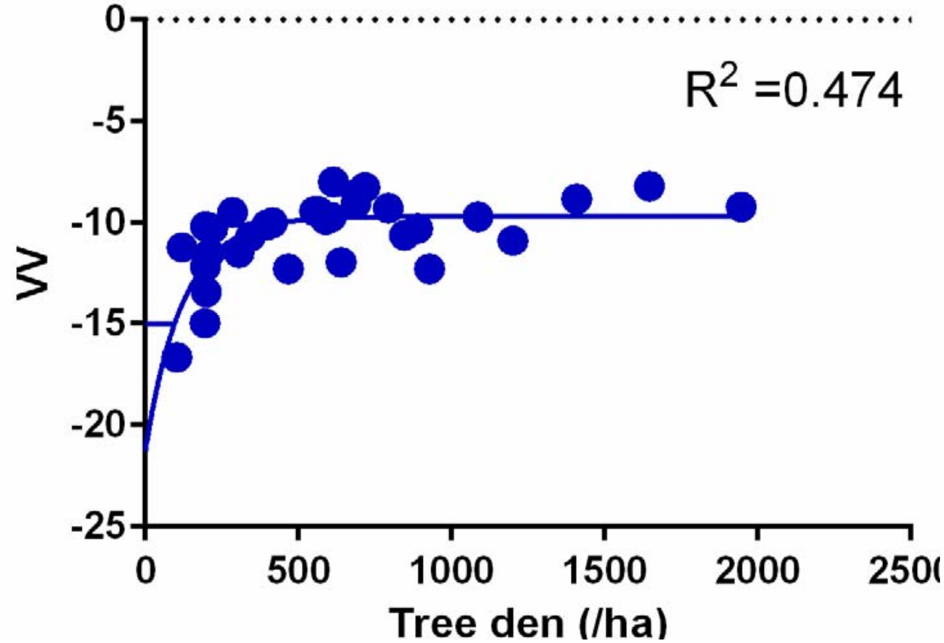


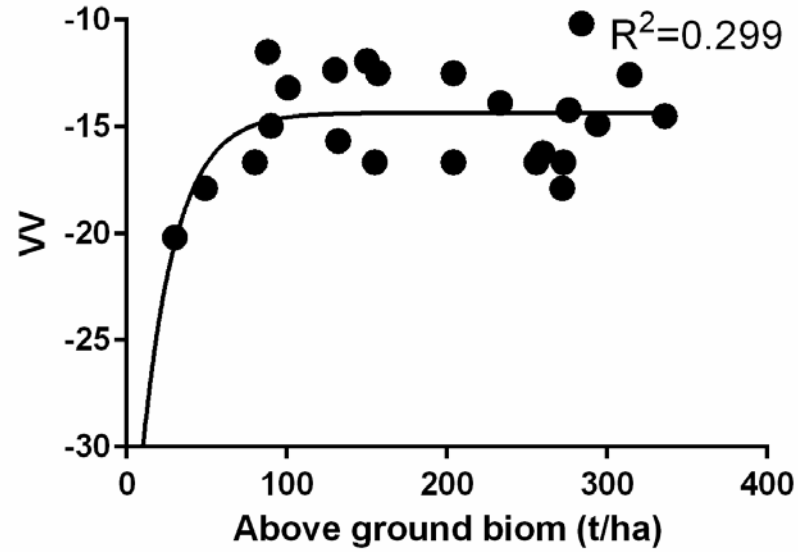
VH (Sigma) over different forest types

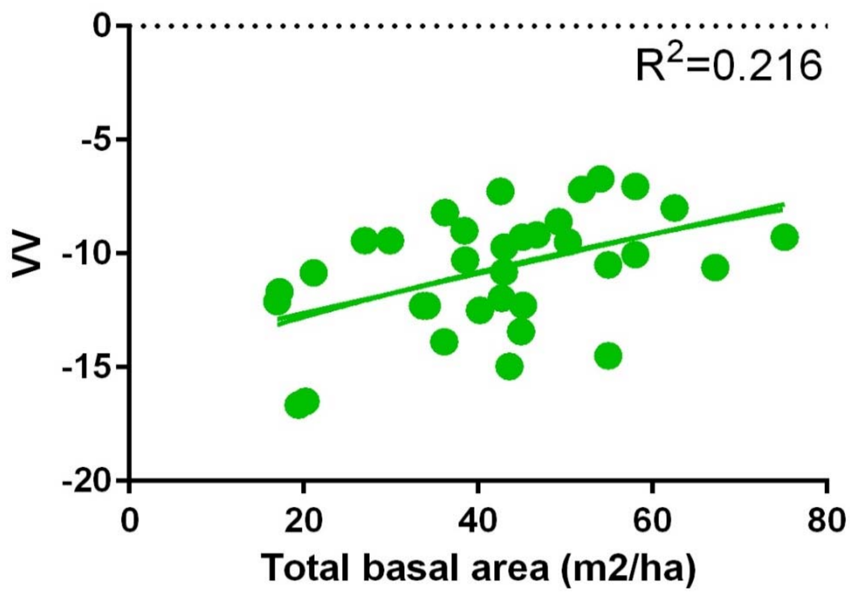


Of the three forest properties (tree density, basal area and above ground biomass) which one explains the most variation in the Sentinel 1-A backscatter?

Variance Explained (VV)

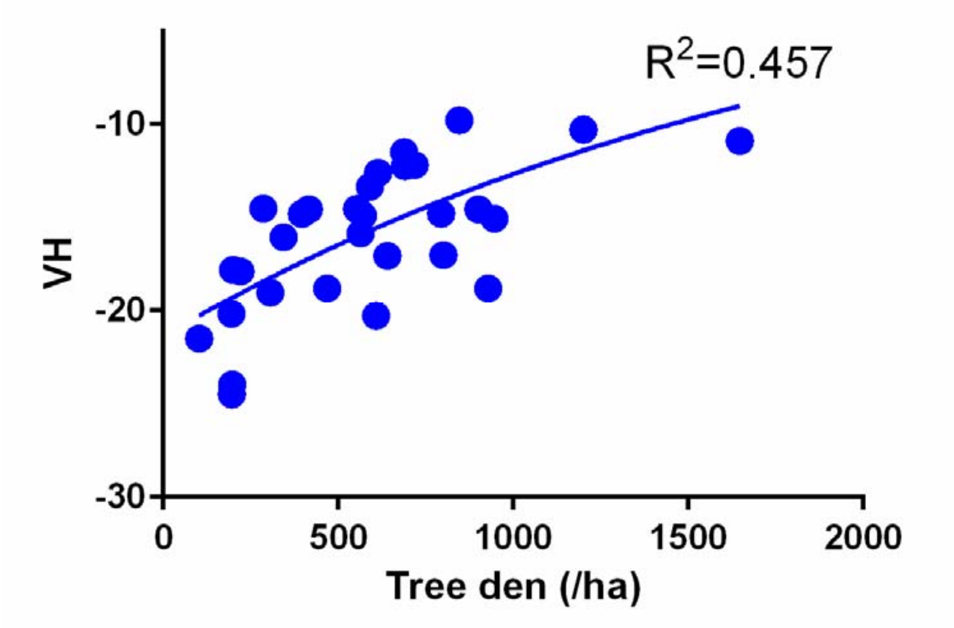


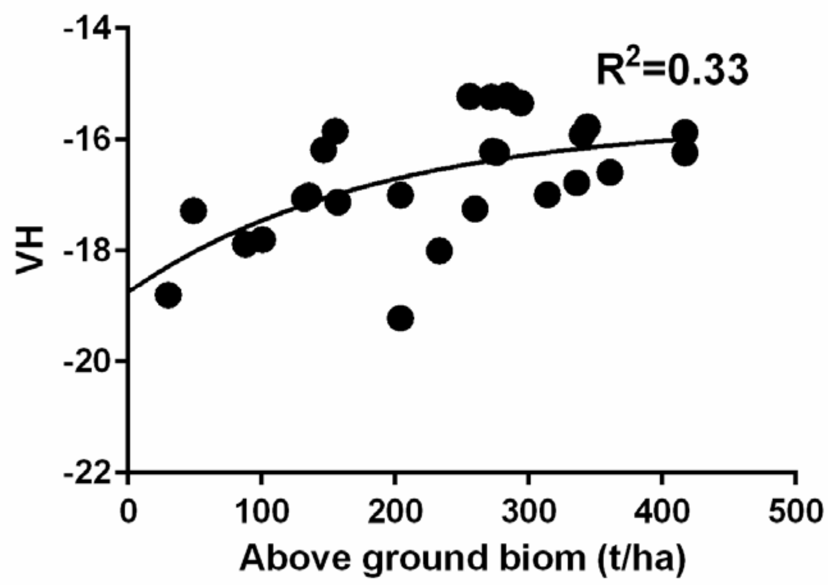


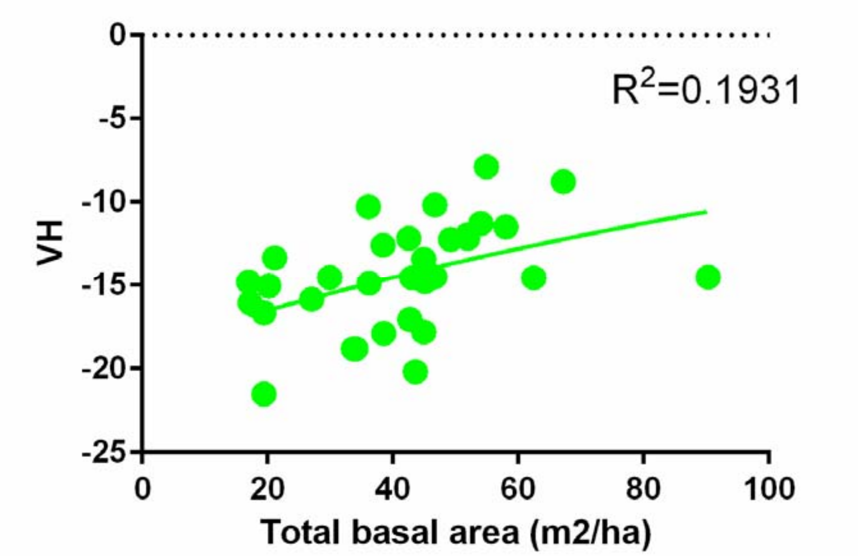


Exponential model fitting with outliers removed; Linear for basal area

Variance Explained (VH)







Exponential model fitting with outliers removed; Linear for basal area

Summary

- Of the tree density, basal area and above ground biomass, tree density could explain most of the variation.

- Not too much differences in VV versus VH signal; Relatively, Sentinel 1-A backscatter for:
  -Tree density - VV ~ VH
  -Basal Area – VV> VH
  -Above ground biomass – VH>VV

- Incidence angle influence yet to be studied.

- More data is needed to distinguish signal variations between different forest types.