

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

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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)?

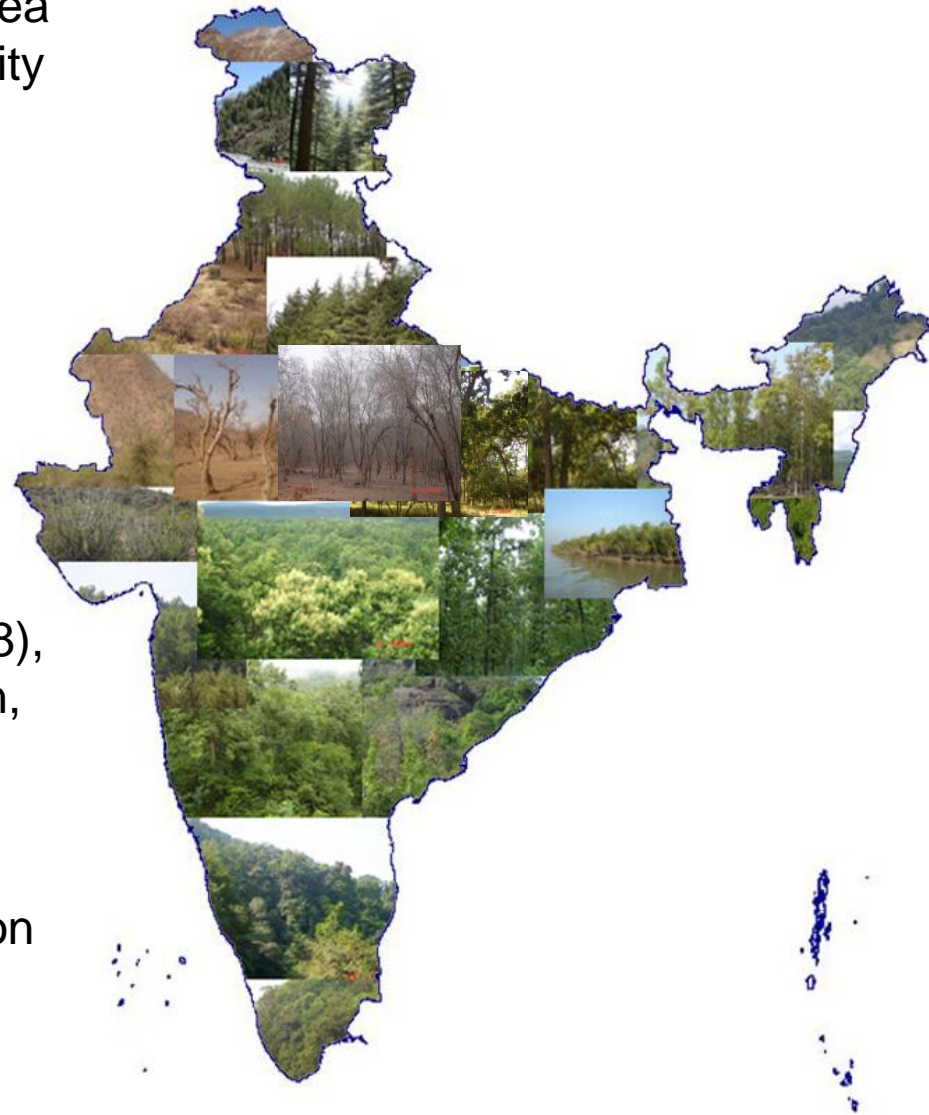
# Forest Types of India

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), Rubner (1925), Thonhwaite (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)**

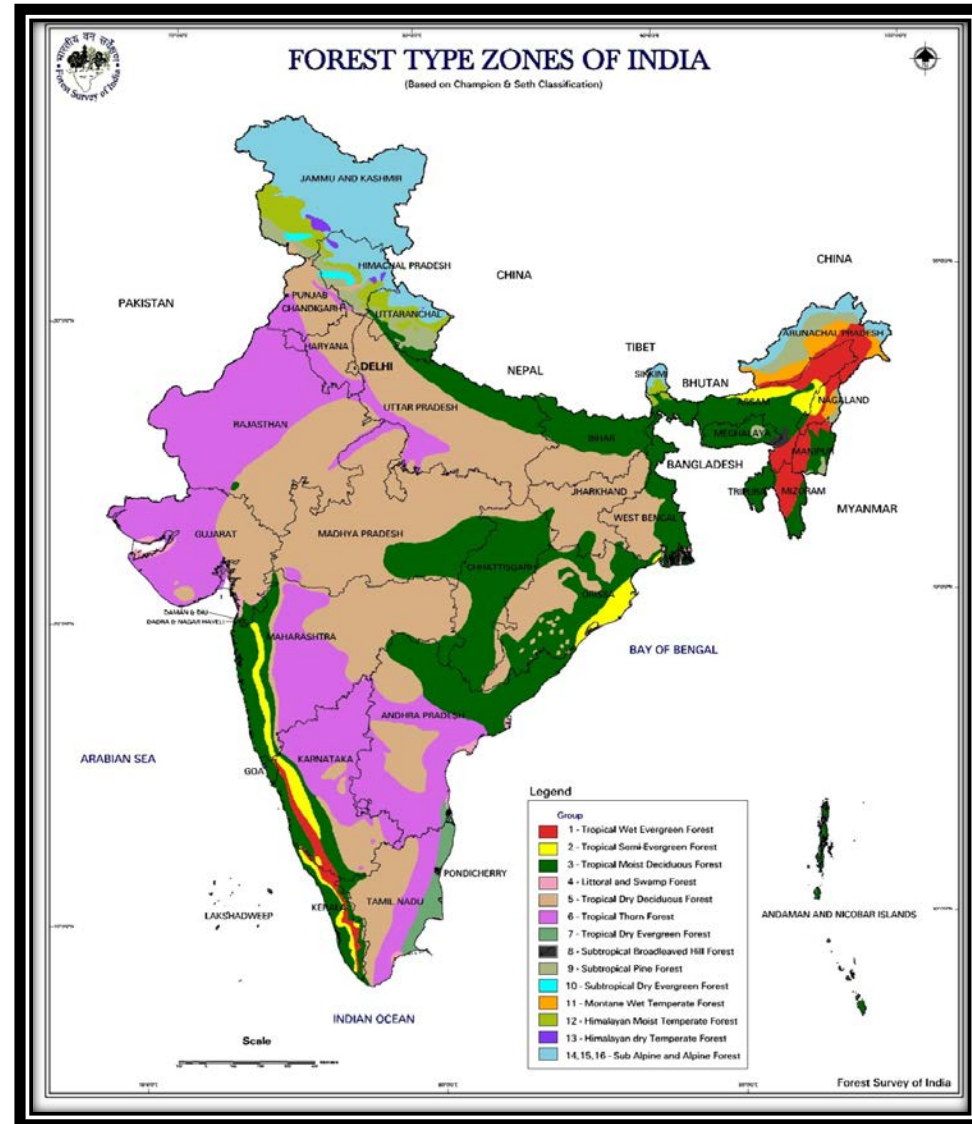


# Champion and Seth (1968) Revised Classification - Forest Types of India

Most widely used classification system for India's forests.

Forests are classified into 6 major groups based on climatic factors

Major groups divided into 16 type groups based on temperature and moisture conditions



# Forest Classification - India

## MAJOR GROUPS

## TYPE GROUPS

**Moist Tropical Forests**

Group 1-Tropical Wet Evergreen Forests

**Dry Tropical Forests**

Group 2-Tropical Semi-Evergreen Forests

Group 3-Tropical Moist Deciduous Forests

**Montane Temperate Forests**

Group 4-Littoral And Swamp Forests

Group 5-Tropical Dry Deciduous Forests

Group 6-Tropical thorn Forests

Group 7-Tropical Dry Evergreen Forests

Group 8-Southern Subtropical Broadleaved Hill Forests

**Montane Subtropical Forests**

Group 9-Subtropical Pine Forests

Group 10- Subtropical Dry Evergreen Forests

Group 11-Montane Wet Temperate Forests

Group 12-Himalayan Moist Temperate Forests

**Sub Alpine Forests**

Group 13-Himalayan Dry Temperate Forests

Group 14-Sub Alpine Forests

Group 15-Moist Alpine Scrub

**Alpine Scrub**

Group 16- Dry Alpine Scrub

**22 SUB-GROUPS**

**200 TYPES**

Source: Champion and Seth classification(1968)



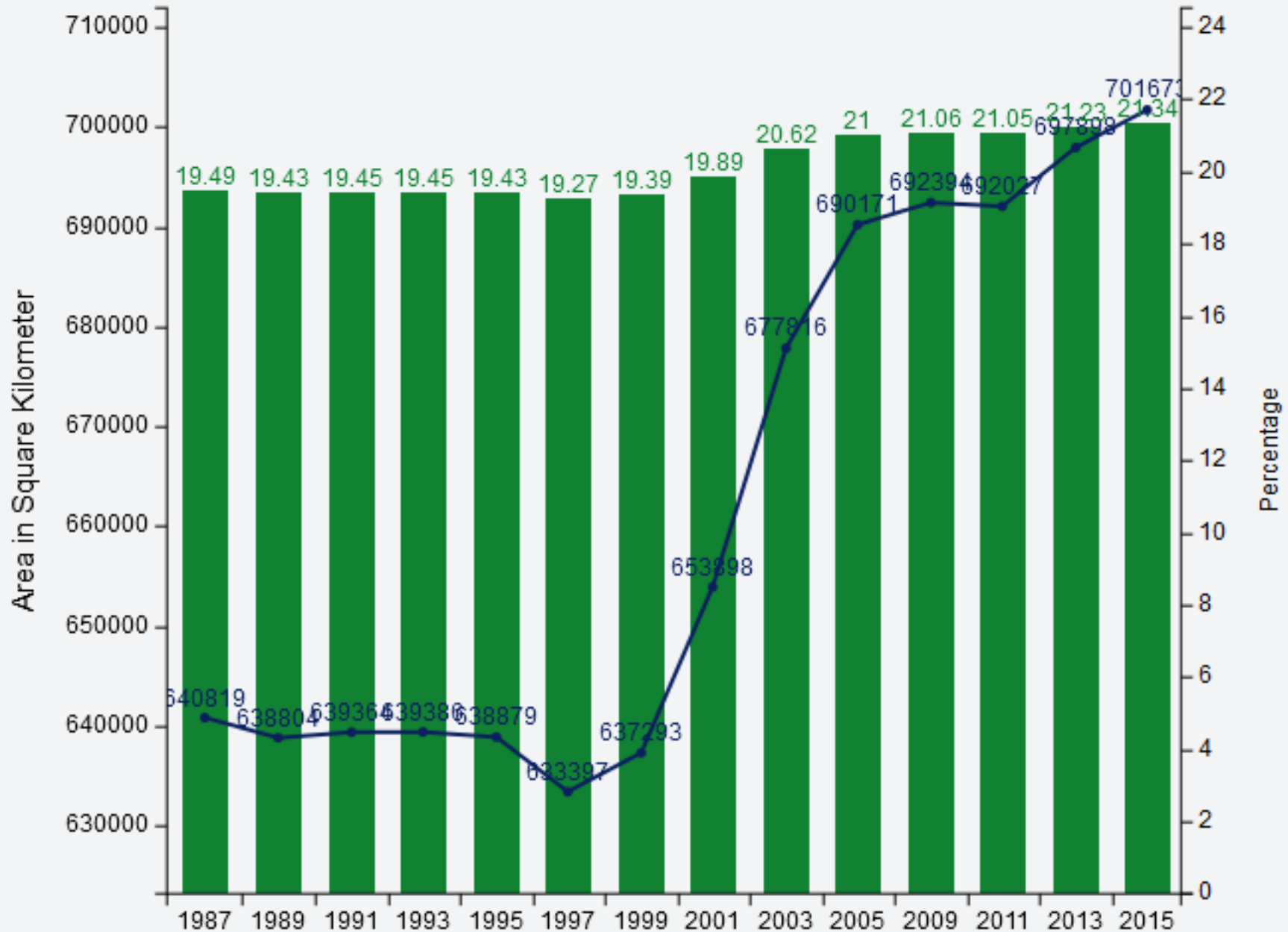
# Biannual Forest Type Mapping in India using Remote Sensing and Ground Truth (Forest Survey of India)

Cycle of Assessment	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).*

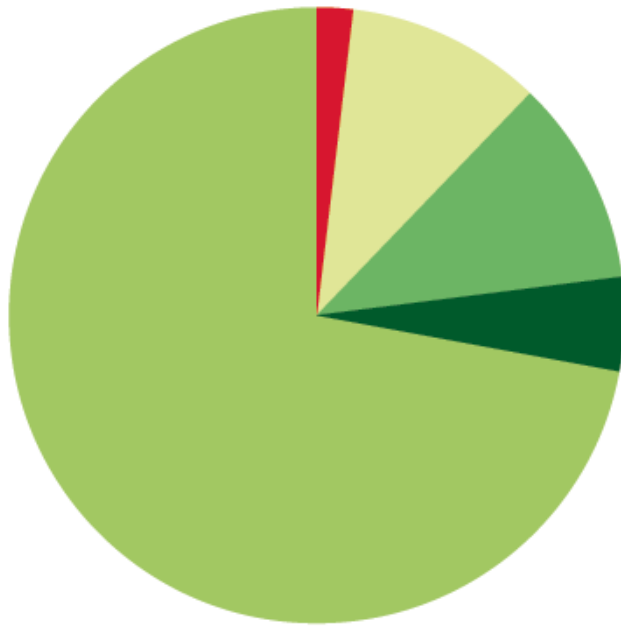
# Forest Cover 1987-2015





# 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%**

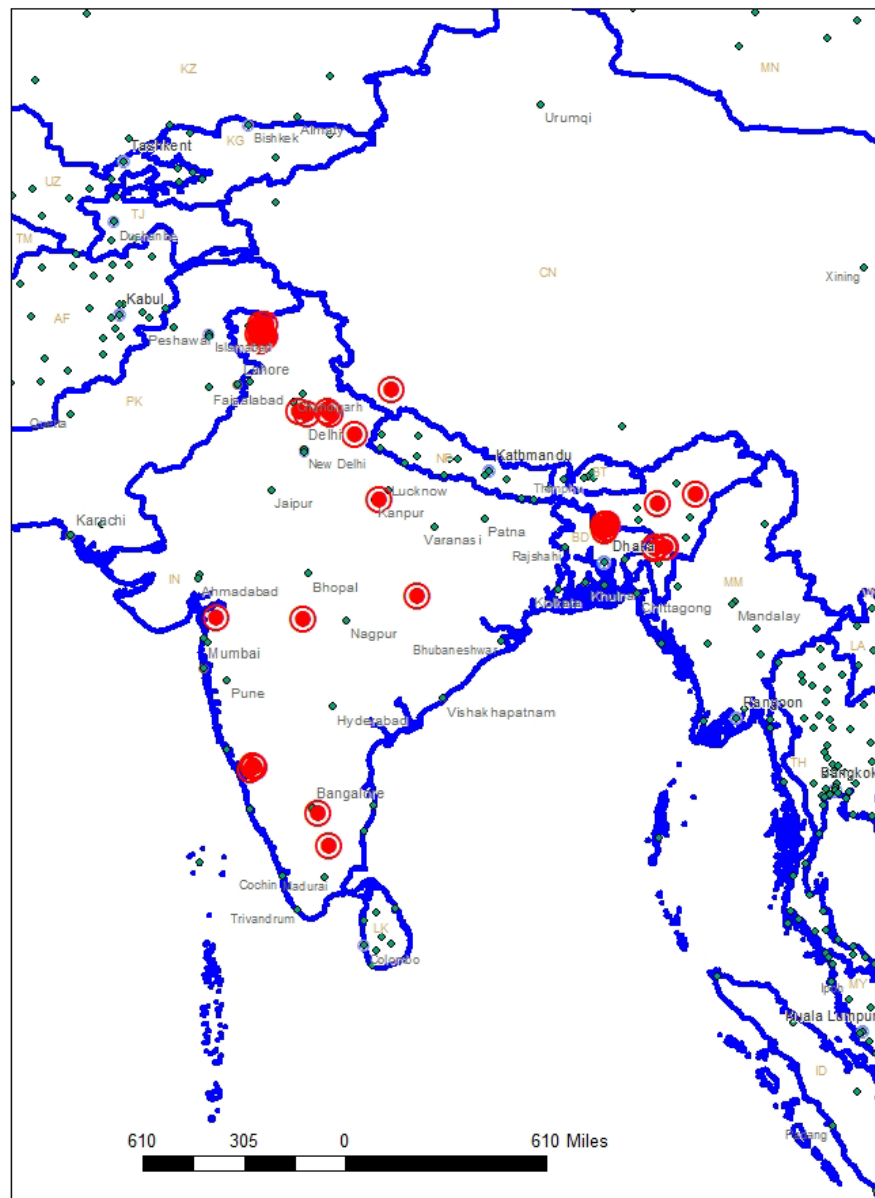
Class	Area (sq km)	percent of Geographical Area
<b>Forest Cover</b>		
Very Dense Forest	85,904	2.61
Moderately Dense Forest	315,374	9.59
Open Forest	300,395	9.14
<b>Total Forest Cover*</b>	<b>701,673</b>	<b>21.34</b>
Scrub	41,362	1.26
Non Forest	2,544,228	77.40
<b>Total Geographic Area</b>	<b>3,287,263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

\*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

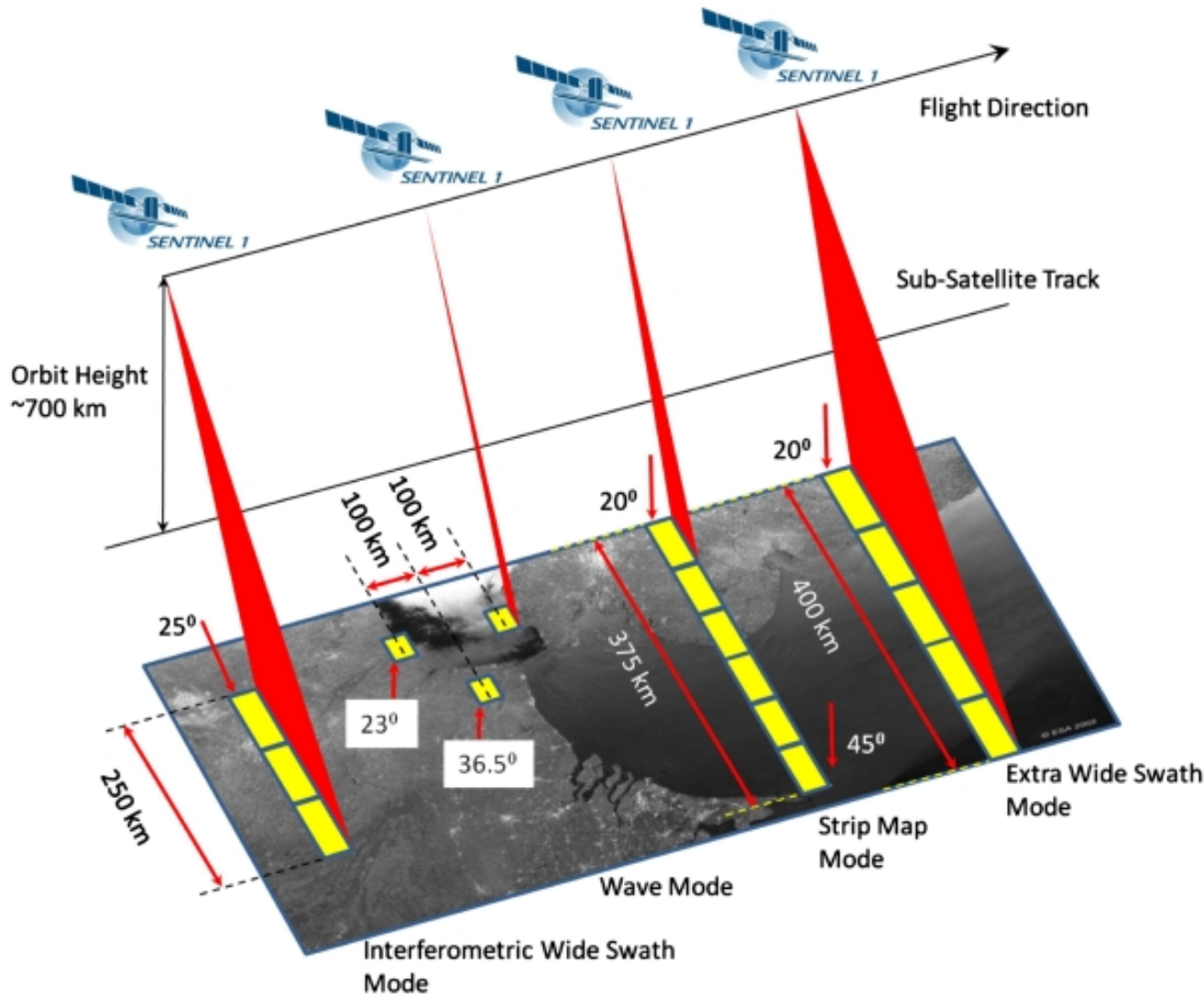


- Data over 38 different sites covering India for Tree Density (/ha), Basal Area (m<sup>2</sup>/ha) and Forest Biomass (t/ha) has been collected from University researchers, published literature and forest department data.
- Sentinel 1A data for different sites for the 2015 or 2016 (December) has been 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*

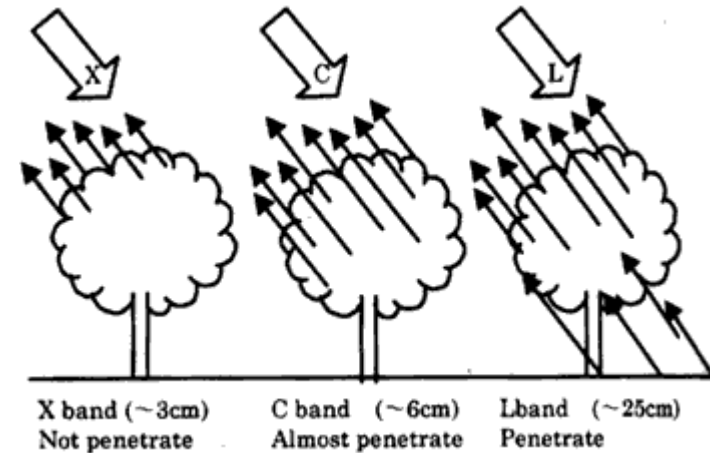
Extra-Wide Swath (EW): 400 km swath, 20 x 40 m spatial resolution

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



# Interferometric Wide Swath

Characteristic	Value
Swath width	250 km
Incidence angle range	29.1° - 46.0°
Sub-swaths	3
Azimuth steering angle	± 0.6°
Azimuth 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°



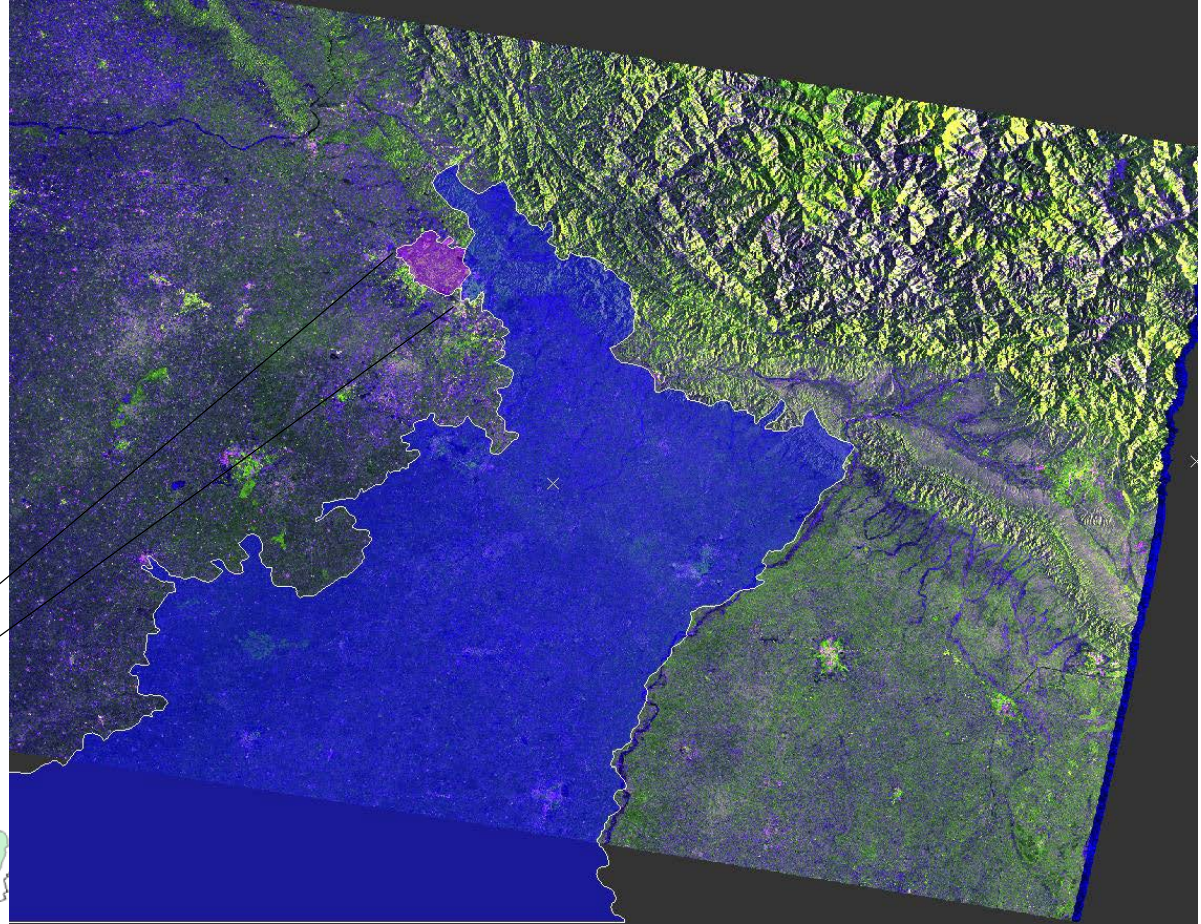
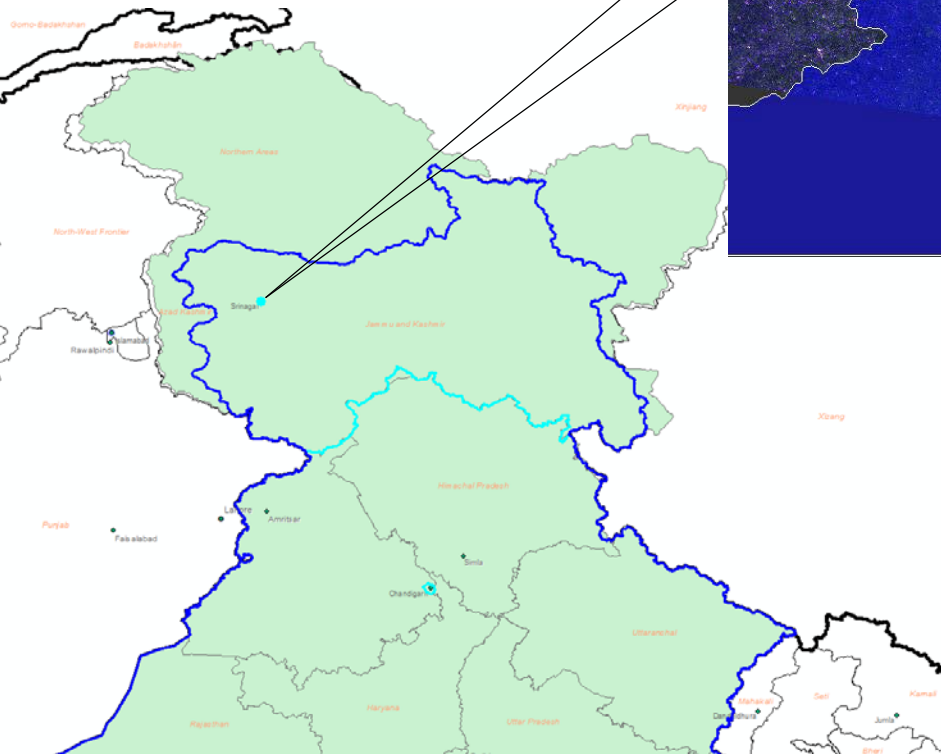
Level-1 Single Look Complex data comprising complex imagery with amplitude and phase (systematic distribution limited to specific relevant areas) (typical size 8GB/product)

**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)



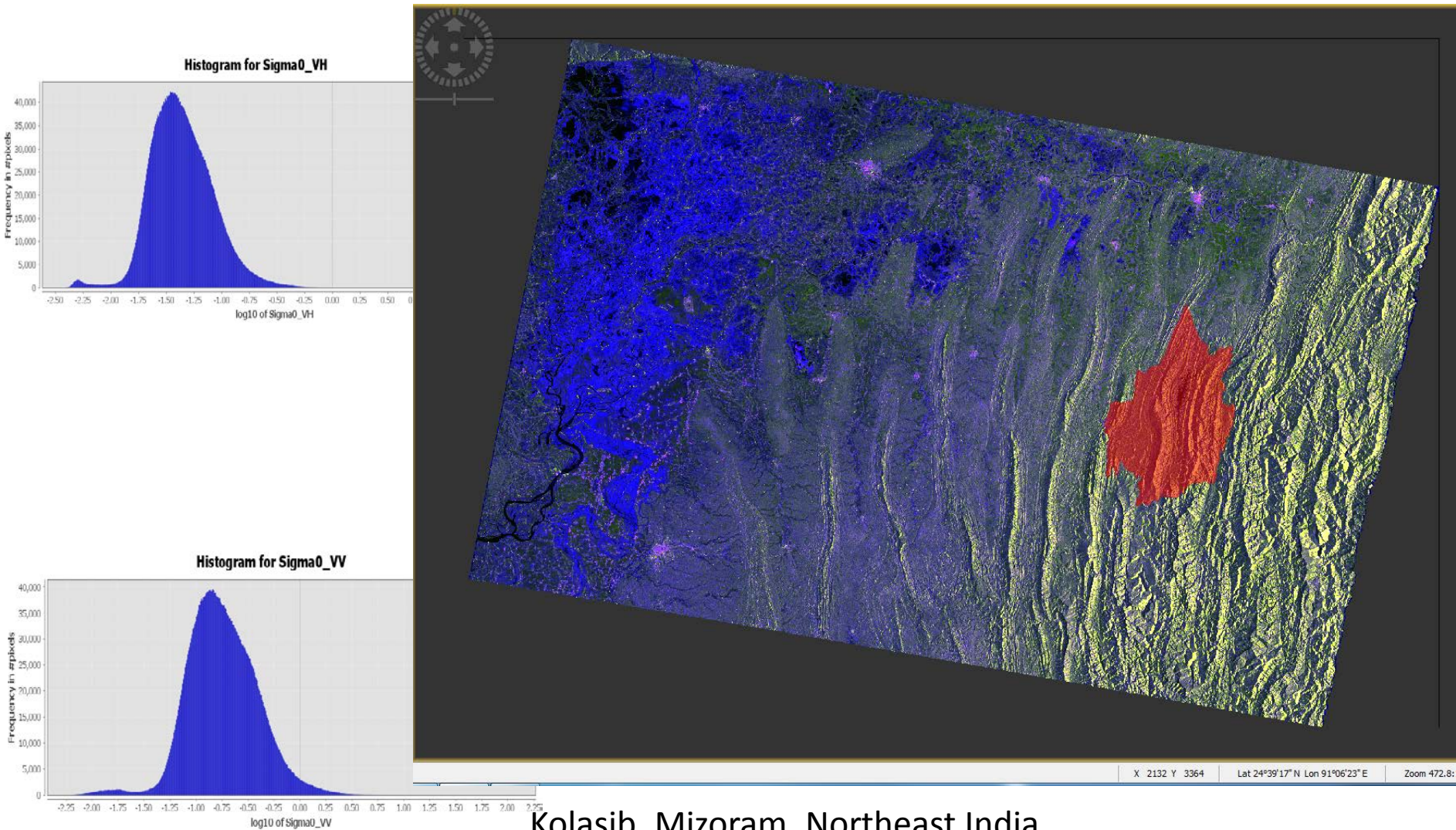
Haryana, India

Sentinel 1A, 2016, 12/27

RGB – Sigma VV, Sigma VH, Sigma VV/VH



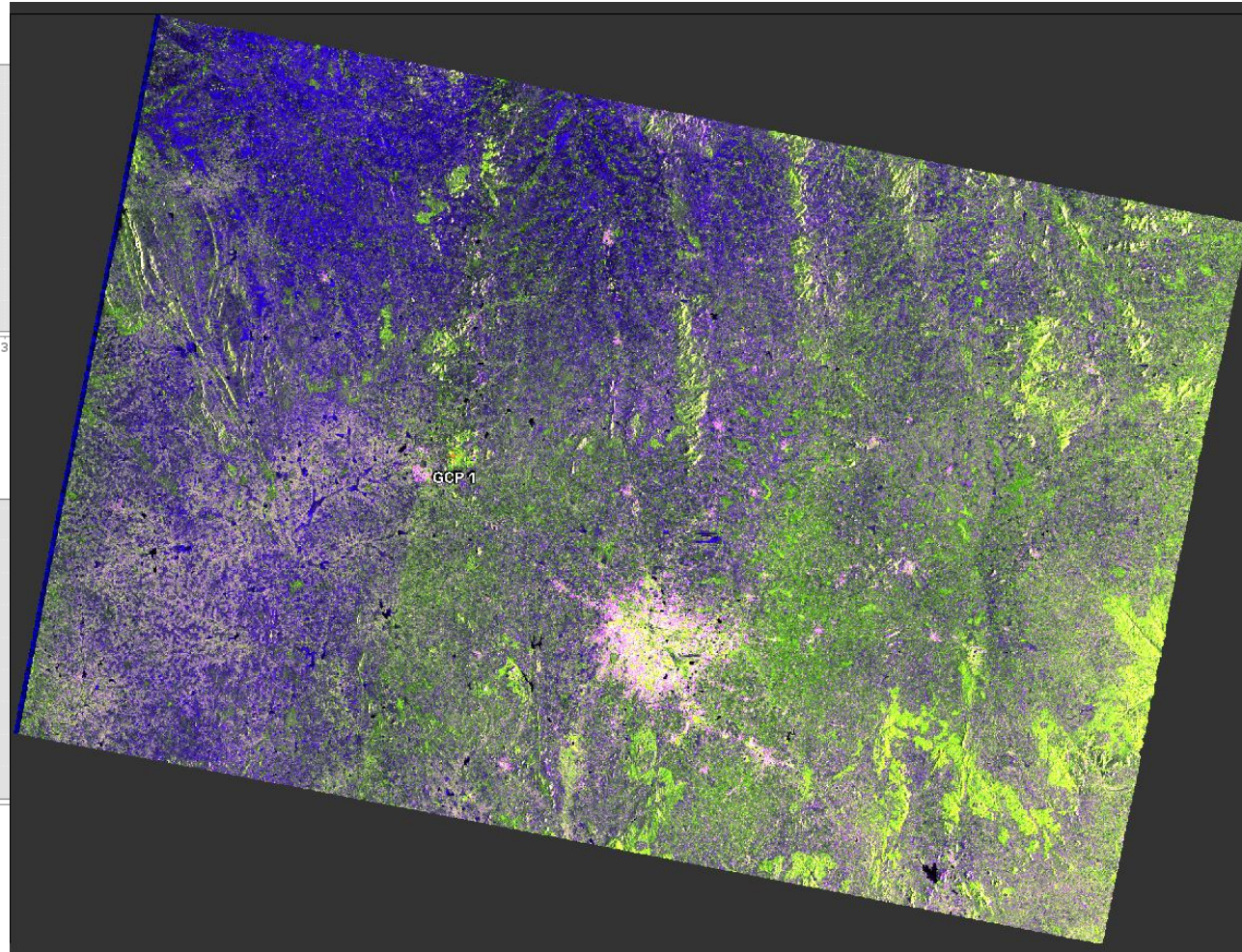
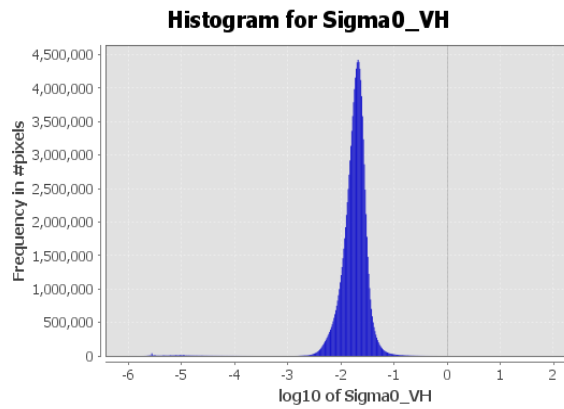
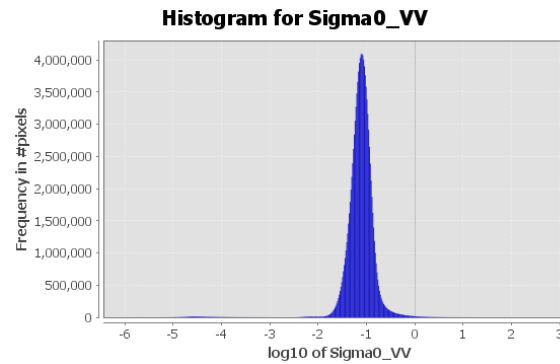
# Sentinel 1 Data



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



# Sentinel 1 Data

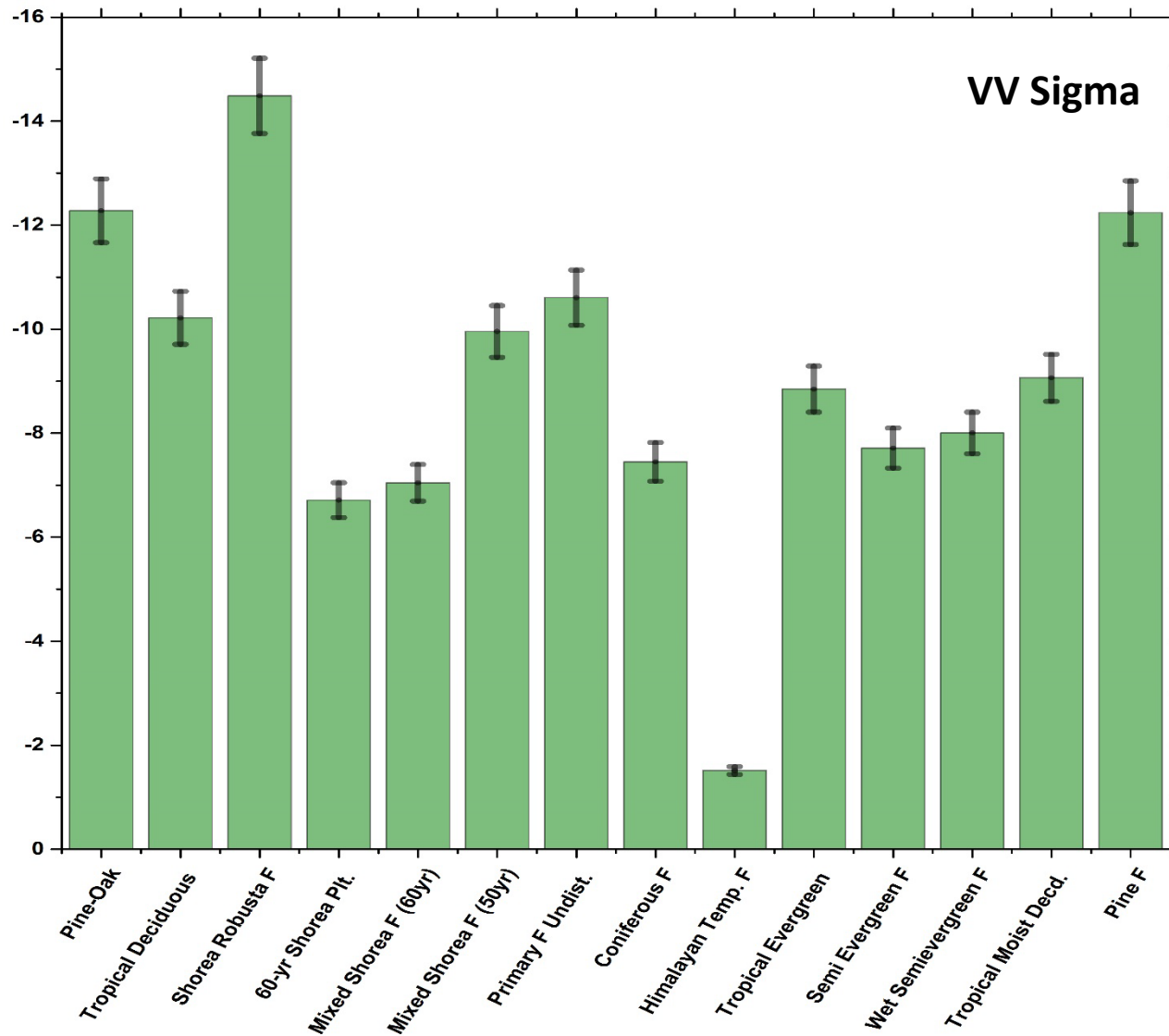


Hosur, Karnataka (Bangalore)

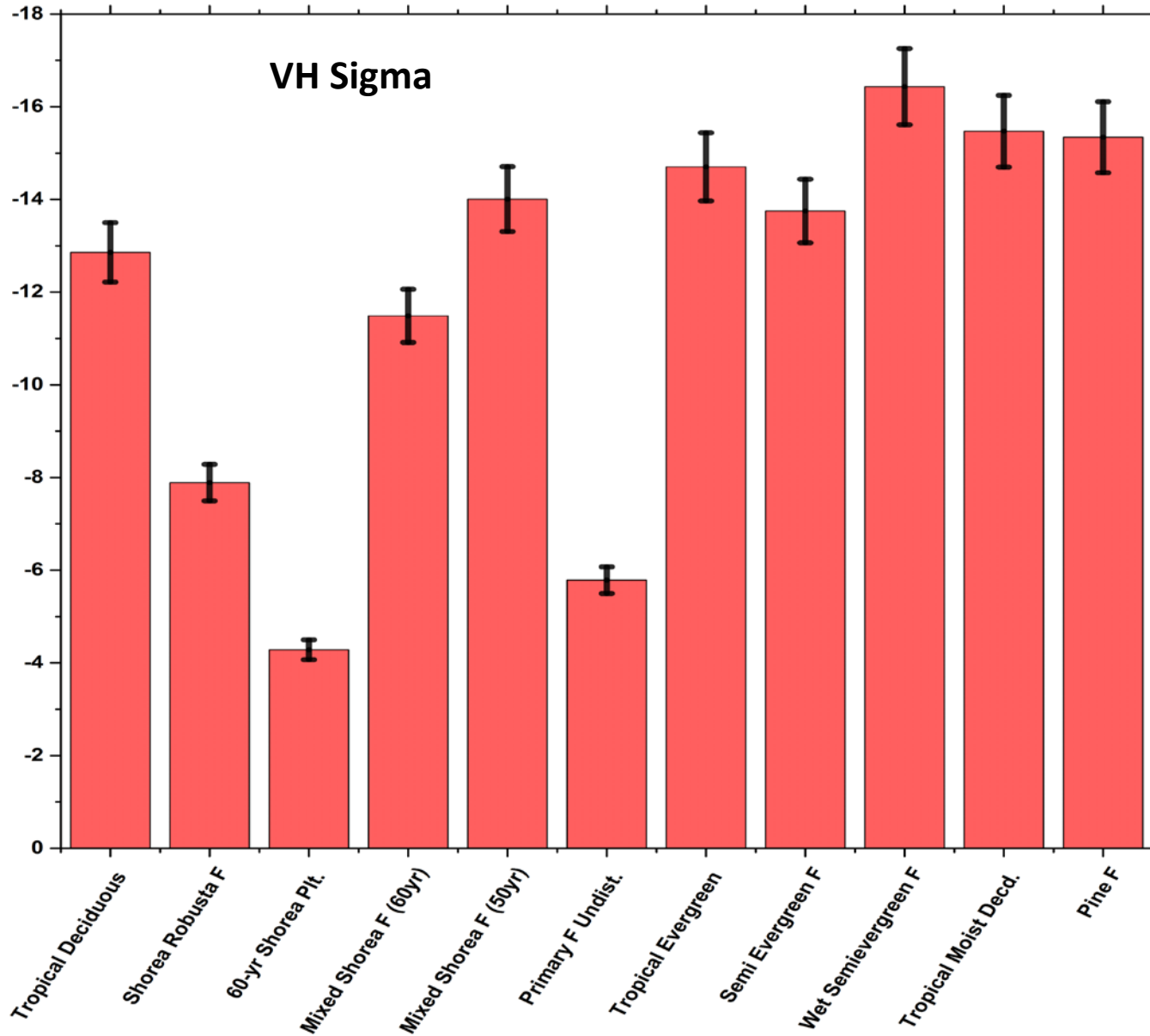
Sentinel 1A, 2016-12-29

RGB - - Sigma VV, Sigma VH, Sigma VV/VH

# VV (Sigma) over different forest types



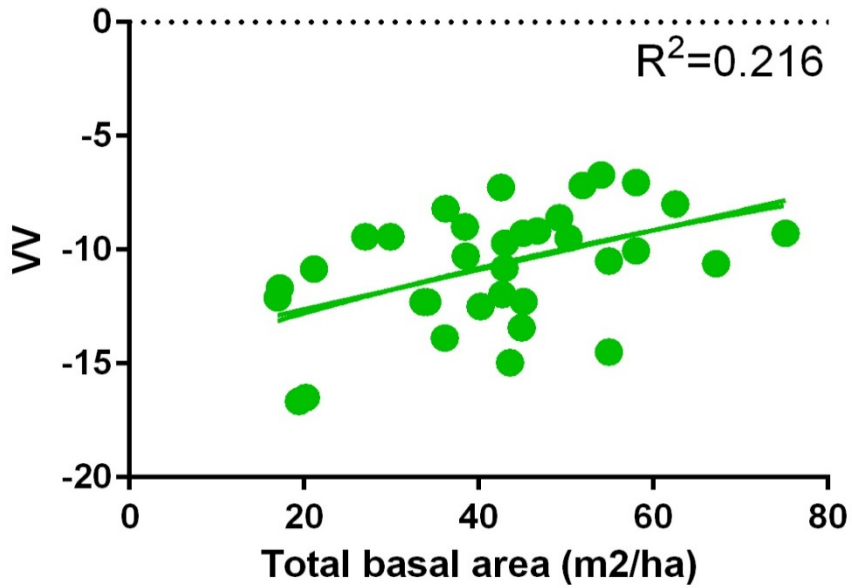
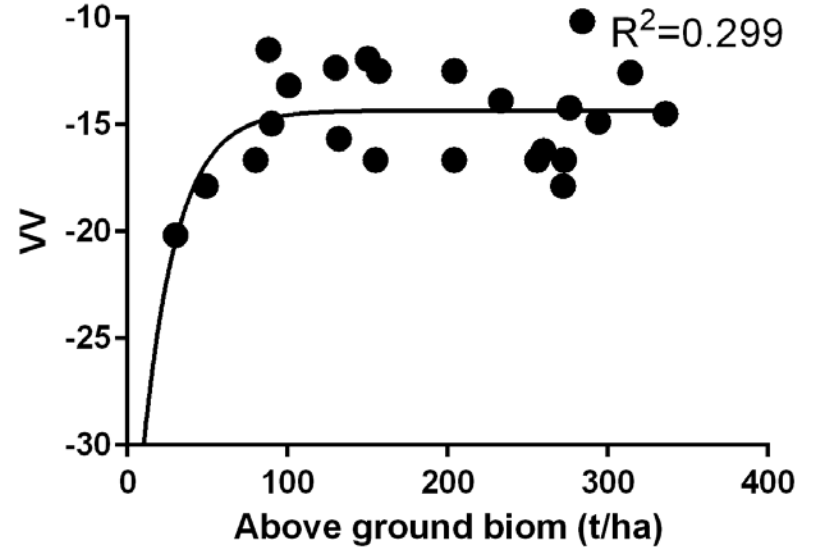
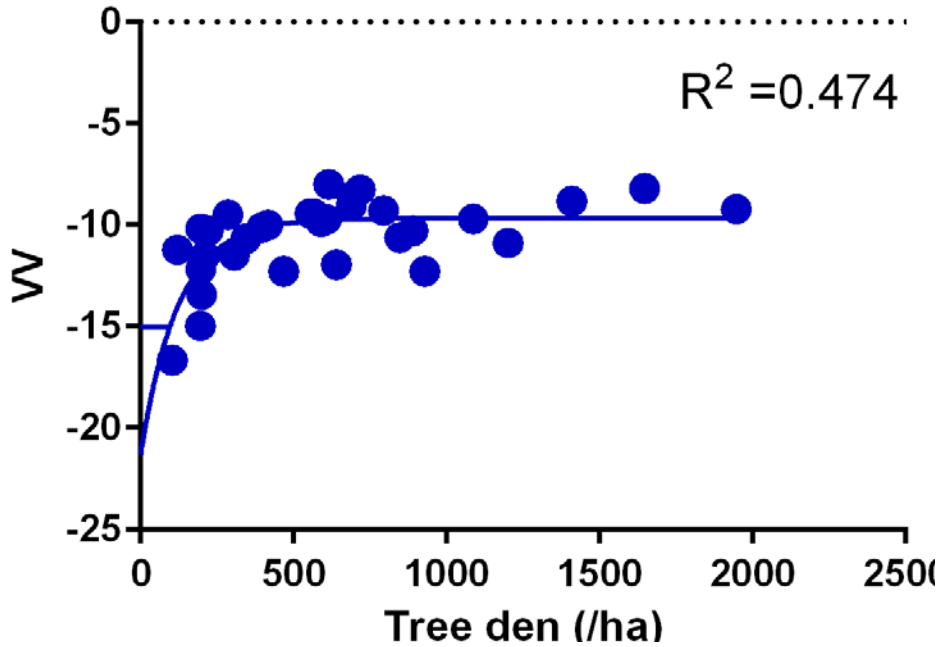
# VH (Sigma) over different forest types



*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?*

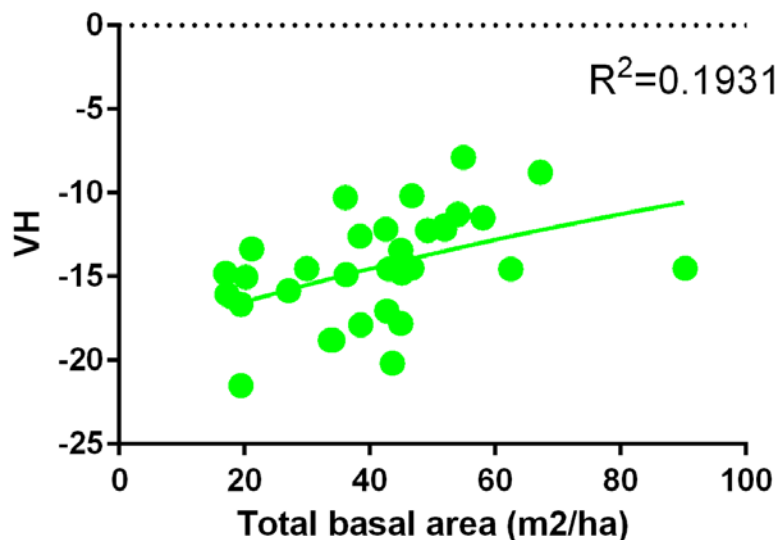
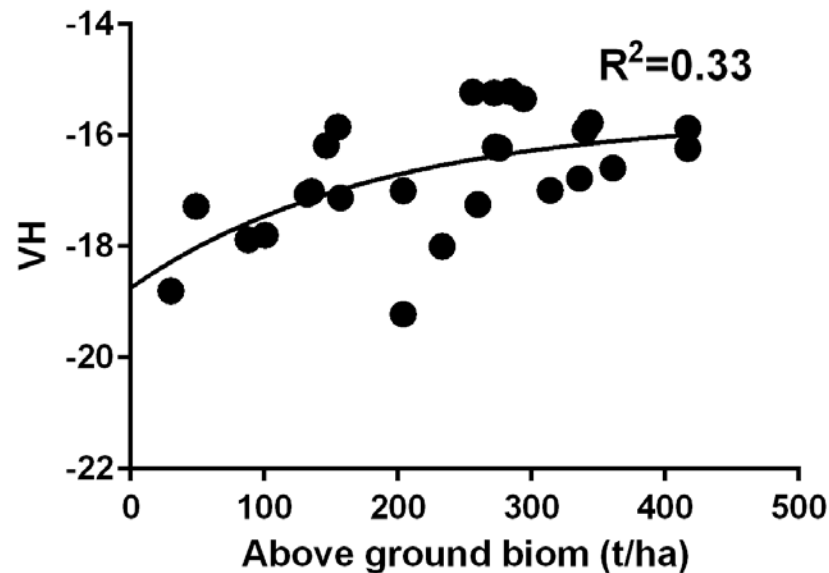
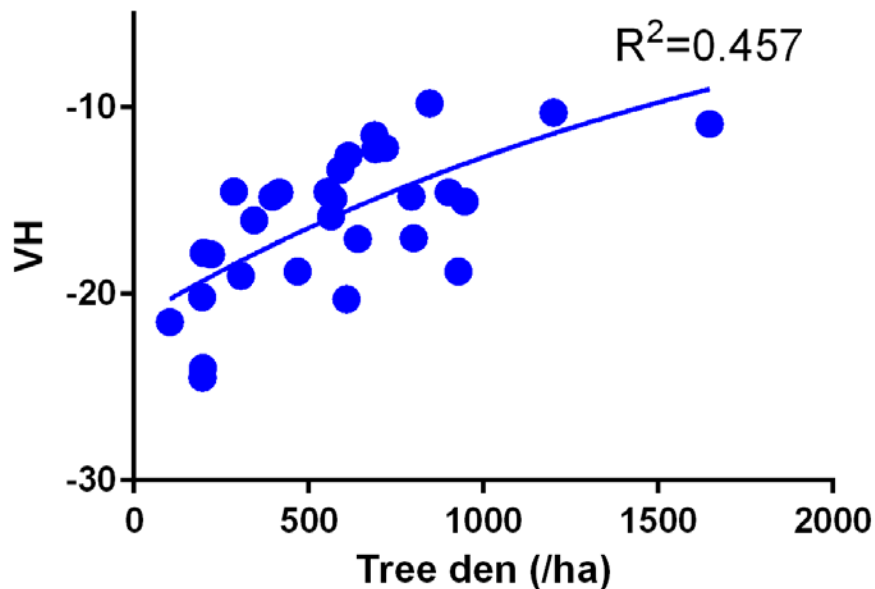


# Variance Explained (VV)



*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 -  $VV \sim VH$
  - 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.