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Estimating Above Ground Biomass in Higher Altitude Eastern Himalayan Forests of India using Microwave Remote Sensing

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Biomass Estimation

- Vegetation biomass (*tonnes per hectare*) is used to estimate the amount of carbon stored in vegetation and emitted to the atmosphere when the vegetation is disturbed or harvested
- **Biomass is key to** understand the global carbon cycle and support in defining policies in the context of the UNFCCC REDD$^+$ initiative as a climate mitigation strategy

Biomass estimation through field methods

- Destructive sampling (*in situ*)
  - Harvesting sample trees, drying and weighing them.
- Non-destructive sampling (*in situ*)
  - Sampling measurements such as height and tree trunk diameter that are used in allometric relationships to extrapolate to biomass.

Biomass estimation through Remote Sensing

- Optical RS based spectral indices with biomass and found grazed sites was linearly related to GVI, NDVI, WI *etc.* indices (R^2= 0.62±0.67).
- Synthetic Aperture Radar (SAR) and light detection and ranging (LiDAR) technology is being predominantly used for biomass estimation, which is comparatively more sensitive to forest structures.

Study Area

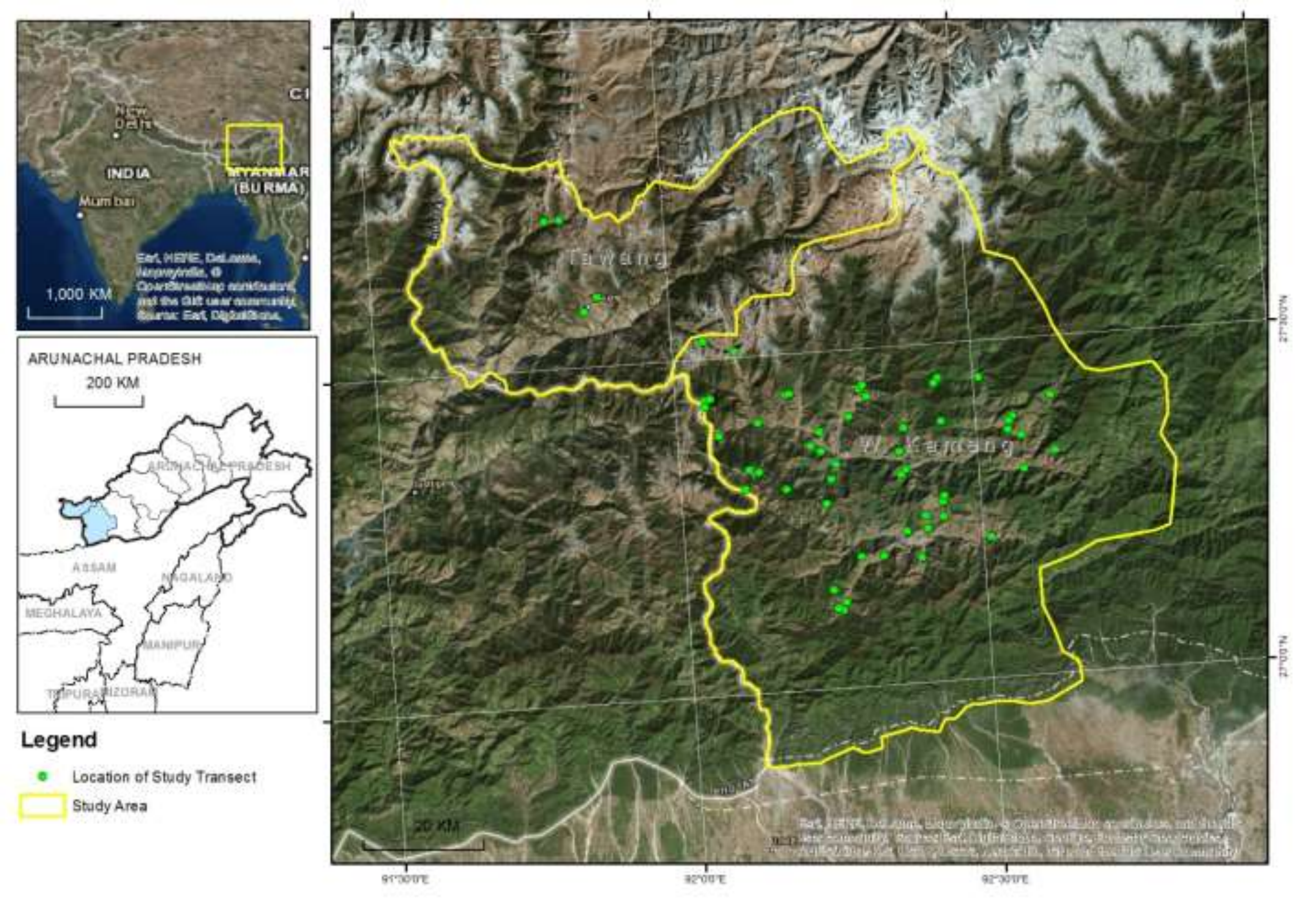


Figure 1: Map showing the study area and the locations of randomly selected transects in Tawang and West Kameng districts of Arunachal Pradesh

- The study area occupies *ca.* 16,226 km^2 (two districts occupy total area of *ca.* 9507 km^2).
- It lies approximately between 91°32' to 92°51' East longitudes and 26°53' to 27°52 North latitudes.
- Elevation ranges from 800m to 4400m
- A total of 182 grids present in the districts of West Kameng and Tawang, Arunachal Pradesh of which 57 grids (31.32 %) have been studied by laying 57 different belt transects each of 500m*10m (0.5 ha) size.

In a total of 57 randomly selected transects:

- 15 laid in Alpine climatic zone (2803 m to 4161 m)
- 24 laid in Temperate climatic zone (1824 m to 2788 m)
- 18 laid in Sub Tropical climatic zone (1047 m to 1800 m)

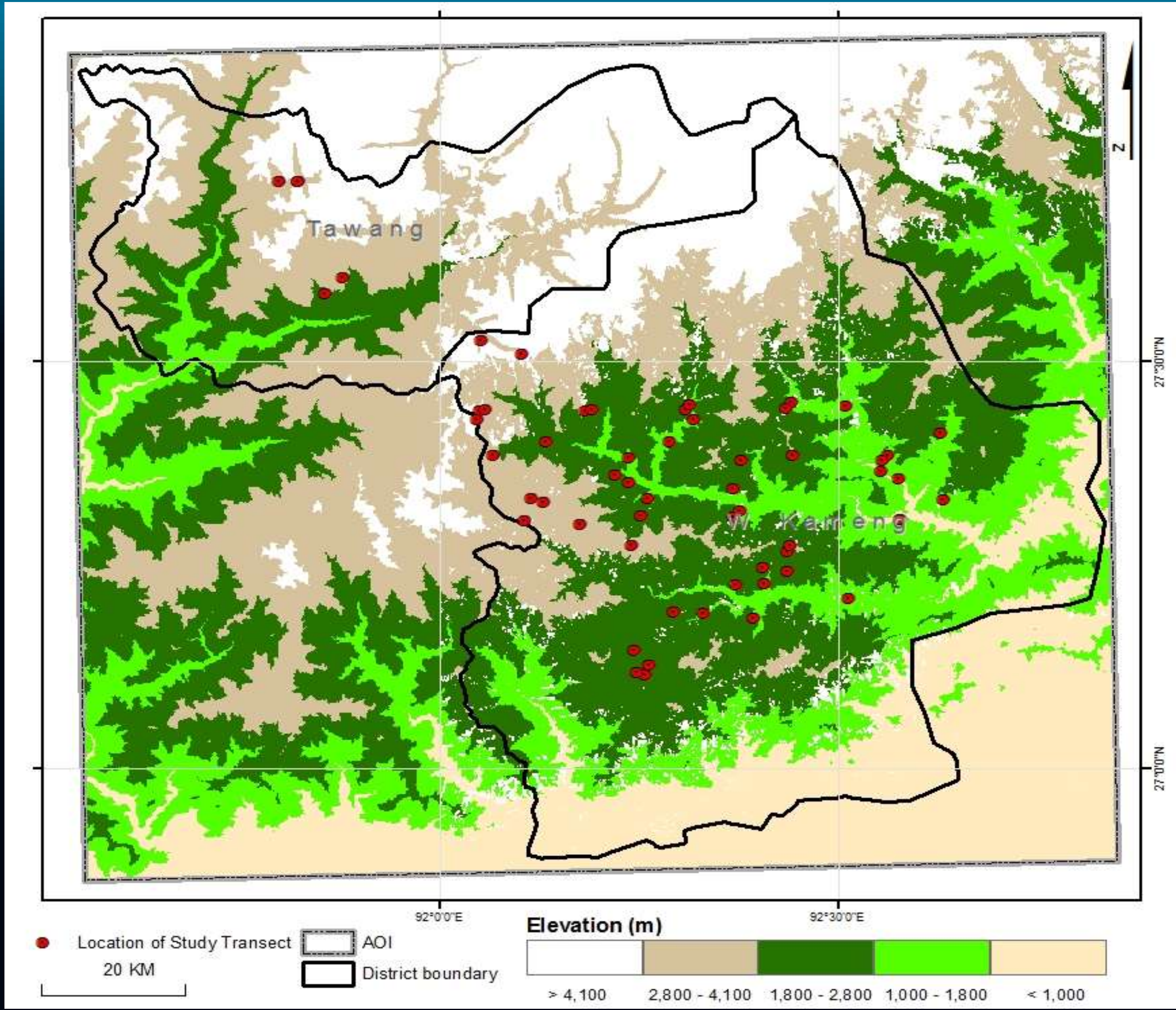


Figure 2: Map showing the spread of 57 transects in varied altitudinal range in Tawang and West Kameng districts of Arunachal Pradesh

Phytosociological compositions

Table 2: Phytosociology of higher altitude forests in different climatic zones of Eastern Himalayas.

Climatic zone	Alpine	Temperate	Sub-Tropical	Overall
No. of transects studied	15	24	18	57
Area sampled (ha)	7.5	12	9	28.5
Altitude Range (m)	2803 to 4161	1824 to 2788	1047 to 1800	1047 to 4161
Located Districts	Tawang, and West Kameng	Tawang, and West Kameng,	West Kameng	Tawang, and West Kameng
Tree diversity per transect (No.)	02 to 12 (mean 05±0.76 SE)	03 to 18 (mean 09±0.88 SE)	01 to 15 (mean 07±0.84 SE)	01 to 18 (mean 07±0.53 SE)
Tree density per transect (≥10 cm GBH) (individuals ha^{-1})	196 to 600 (mean 407±28.40 SE)	160 to 1216 (mean 421±45.13 SE)	178 to 902 (mean 455±37.64 SE)	160 to 1216 (mean 428±26.40 SE)
Basal cover per transect (m^2ha^{-1})	0.29 to 23.85 (mean 12.63±1.97 SE)	1.46 to 22.68 (mean 8.94±1.27 SE)	2.62 to 21.76 (mean 7.93±1.20 SE)	0.29 to 23.85 (mean 9.59±0.86 SE)
Total biomass per transect (ton ha^{-1})	0.04 to 0.77 (mean 0.26±0.06 SE)	0.07 to 30.75 (mean 2.72±1.27 SE)	0.56 to 10.17 (mean 2.49±0.68 SE)	0.04 to 30.75 (mean 2.00±0.59 SE)
Total tree diversity	27	45	21	68
Total tree density (individuals ha^{-1})	349	769	250	428
Total Basal cover (m^2ha^{-1})	1742.83	3144.77	2430.33	7658.63
Total biomass (ton ha^{-1})	3.95	65.35	44.82	114.12

- Total tree density ranged from 160 to 1216 individuals ha^{-1} .
- Per transect total basal cover ranged from 0.29 to 23.85 m2 ha^{-1} .
- Study recorded decreased mean tree density per transect with increase in altitude (subtropical > temperate > alpine forests).
- Higher altitude forests are always poor in terms of species diversity confirmed the present research by 67 species of trees

- Rhodendrons has the highest dominance with 14 species (in terms of diversity)
- Highest density was contributed by Pinus roxburghii (72 individuals ha^{-1}) followed by Quercus semicarpifolia (67 individuals ha^{-1}) and Abies alba (39 individuals ha^{-1}).
- Highest basal cover contributed by A. alba (1597 m2 ha-1) followed by P. roxburghii (1563 m2 ha-1) and Q. semicarpifolia (1149 m2 ha-1).

Specific Gravity & Volume eq.

Table 1: Specific gravity and volume equations of species present in the study area

Species	Specific Gravity*	Volume equation*
Abies alba Mill.	0.43	V=0.163269-2.232068 D +11.770869 D2+1.06041D3
Abies chensiensis Tiegh.	0.43	V=0.163269-2.232068 D +11.770869 D2+1.06041D3
Acer caesium Wall. ex Brandis	0.59	√V=-0.038730+0.362730D2H
Acer campbellii Hook. fil. & Thoms.	0.59	V=-0.0962-0.0145D+0.0008D2
Acer cappadocicum Gled.	0.59	√V=-0.038730+0.362730D2H
Acer sp.	0.59	√V=-0.038730+0.362730D2H
Alnus nepalensis D.Don	0.43	V=0.0741-1.3603D+10.9229D2
Bischofia javanica Blume	0.58	√V=-0.00273+2.56199D
Boehmeria depauperata Wedd.	0.54	V=0.00978-0.21005*D+5.62160*D*D
Cassia fistula L.	0.812	V=0.00978-0.21005*D+5.62160*D*D
Castanopsis indica (Roxb. ex Lindl.) A.DC.	0.51	V=0.05331-0.87098D+6.52533D2+1.74231D3
Coriaria nepalensis Wall.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Cornus capitata Wall.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Cupressus torulosa D. Don	0.5	V=0.00978-0.21005*D+5.62160*D*D
Daphne papyraceae	0.5	V=0.00978-0.21005*D+5.62160*D*D
Daphne retusa Hemsl.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Duabanga grandiflora (Roxb. ex DC.) Walp.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Dysoxylum excelsum Bl.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Elaeagnus sp.	0.51	V
Elaegnus parvifolia	0.5	V
Erythrina stricta Roxb.	0.5	V
Gymnocladus assamicus P.C.Kanjilal	0.3	V=0.00978-0.21005*D+5.62160*D*D
Hydrangea sp.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Illicium griffithii Hook. fil. & Thoms.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Juglans regia L.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Juniperus communis L.	0.61	√V=-0.207299+3.254007D
Lagerstroemia speciosa (L.) Pers.	0.5	V=0.11740-1.58941D+9.76464D2
Lindera sp.	0.53	V=0.00978-0.21005*D+5.62160*D*D
Litsea monopetala (Roxb. ex Baker) Pers.	0.5	V=0.00978-0.21005*D+5.62160*D*D
Litsea sp.	0.35	V=0.00978-0.21005*D+5.62160*D*D
Lyonia ovalifolia	0.677	V=0.00978-0.21005*D+5.62160*D*D
Lyonia ovalifolia (Wall.) Drude	[illegible]	V=0.00978-0.21005*D+5.62160*D*D
Machilus kurzii King ex Hook. fil.		
Mallotus phillipensis		
Morus alba L.		
Pieris formosa (Wall.) D. Don		
Pinus roxburghii Sarg.		
Pinus wallichiana A.B. Jacks.		
Pouzolzia rugulosa		
Pyrus malus		
Quercus baloot Griff.		
Quercus semicarpifolia		
Rhododendron arboreum var. delavayi		
Rhododendron arboreum Sm.		
Rhododendron barbatum Wall. ex G. Don	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron cinnabarinum Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron falconeri Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron fulgens Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron grande Wight	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron hodgsonii Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron keysii Nutt.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron lanatum Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron maddenii Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron nerifolium ssp. phaedropum	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron sp.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron thomsonii Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhododendron wallichii Hook. fil.	0.628	√V=0.306492+4.31536D-1.749908√D
Rhus javanica	0.5	V=0.00978-0.21005*D+5.62160*D*D
Sarcochlamys pulcherima	0.5	V=0.00978-0.21005*D+5.62160*D*D
Saurauia macrotricha Kurz ex Dyer	0.5	V=0.00978-0.21005*D+5.62160*D*D
Schima wallichii (DC.) Korth.	0.5	V=0.27609-3.68443D+15.86687D2
Schima wallichii var. khasiana (Dyer) Bloem.	0.5	V=0.27609-3.68443D+15.86687D2
Toxicodendron griffithii (Hook. fil.) Kuntze	0.5	V=0.00978-0.21005*D+5.62160*D*D
Unknown	0.5	V=0.00978-0.21005*D+5.62160*D*D
Viburnum cylindricum Buch.-Ham. ex D. Don	0.5	V=0.00978-0.21005*D+5.62160*D*D
Zanthoxylum armatum DC.	0.33	V=0.00978-0.21005*D+5.62160*D*D

* Source: Reyes et al. (1992), FSI (1996), FRI (1996), Raturi et al. (2002), Sheikh et al. (2011), FSI (2015).

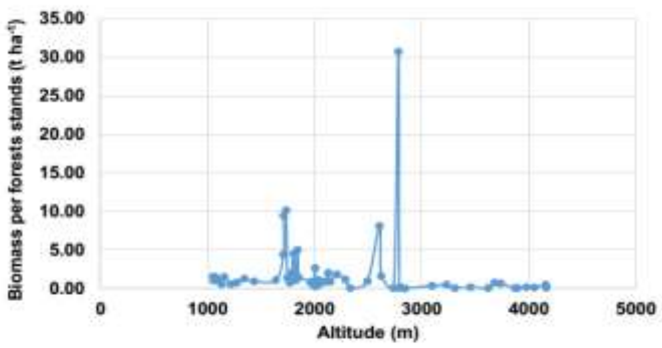


Figure 2: Distribution of biomass in different forests stands located in different elevation gradients.

Biomass estimation using Microwave Remote Sensing

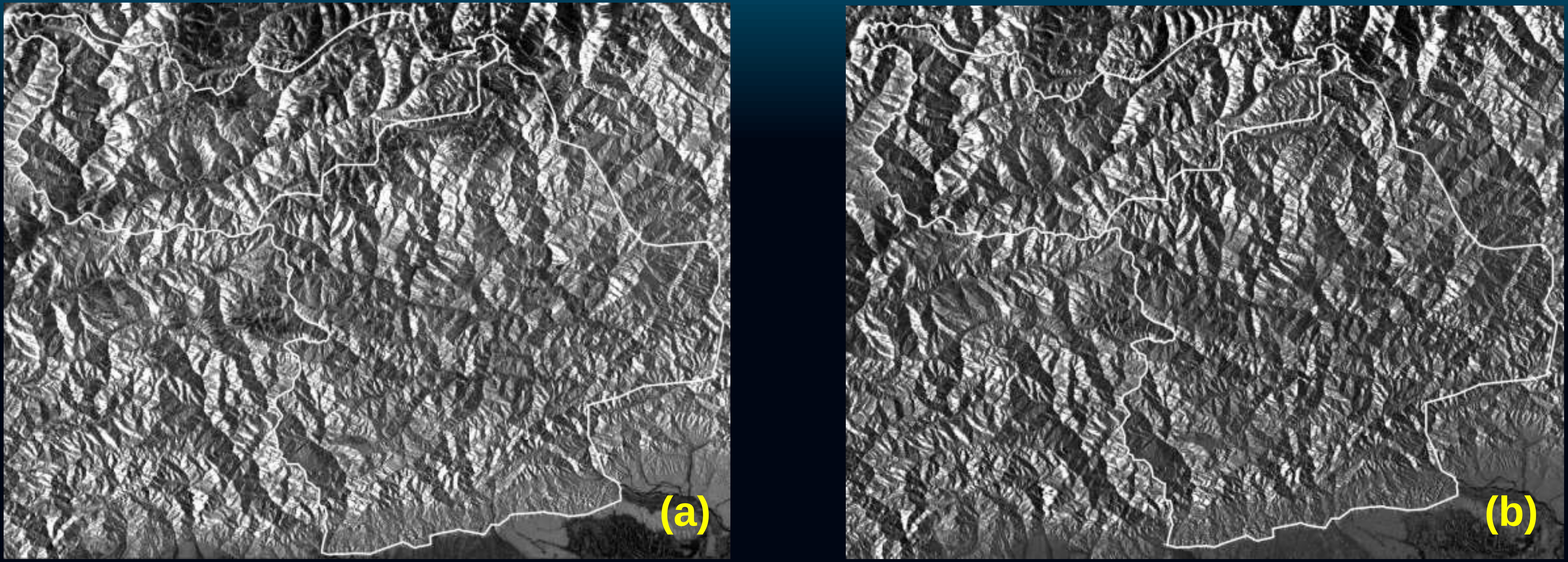
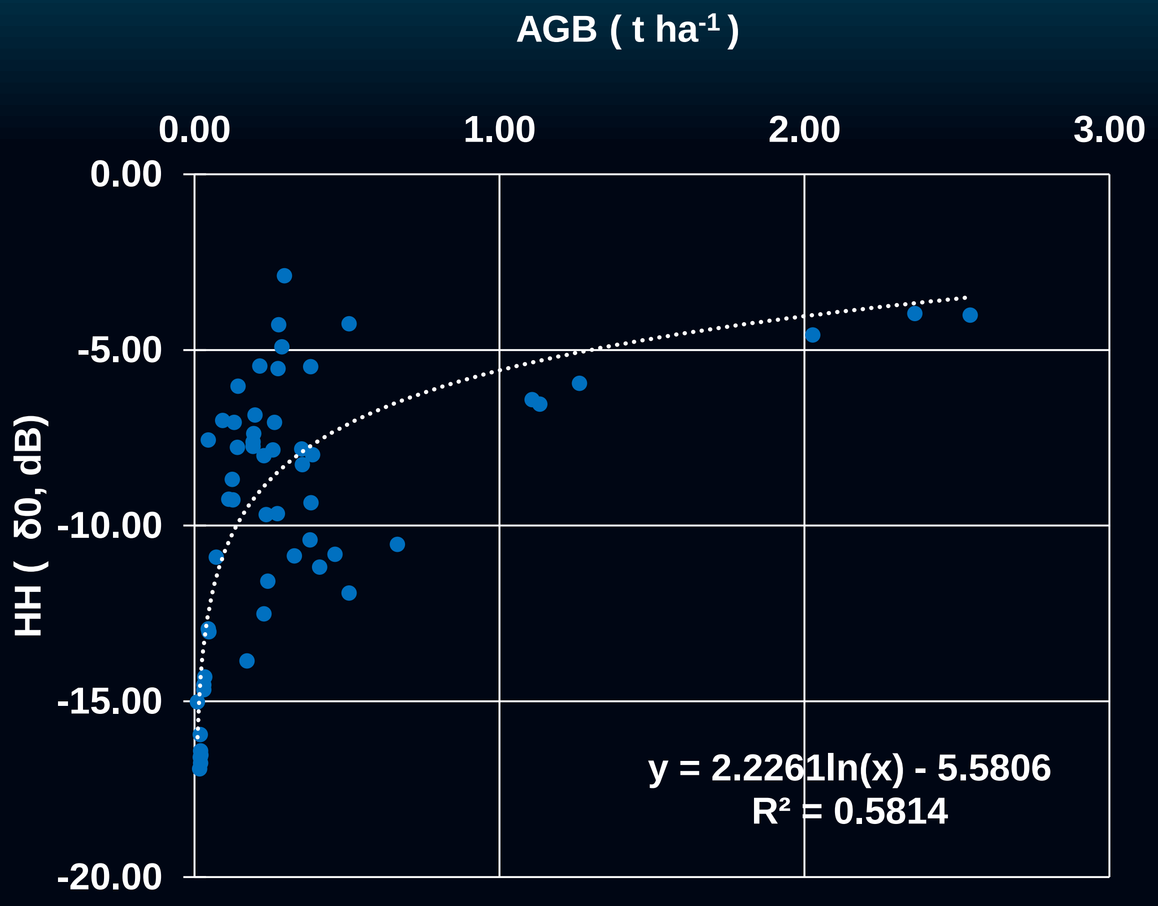


Figure 4: ALOS PALSAR 50m Orthorectified data (a) HH polarization and (b) HV polarization

Regression Analysis

(a) Plot level AGB vs. δ0 of HH



(b) Plot level AGB vs. δ0 of HV

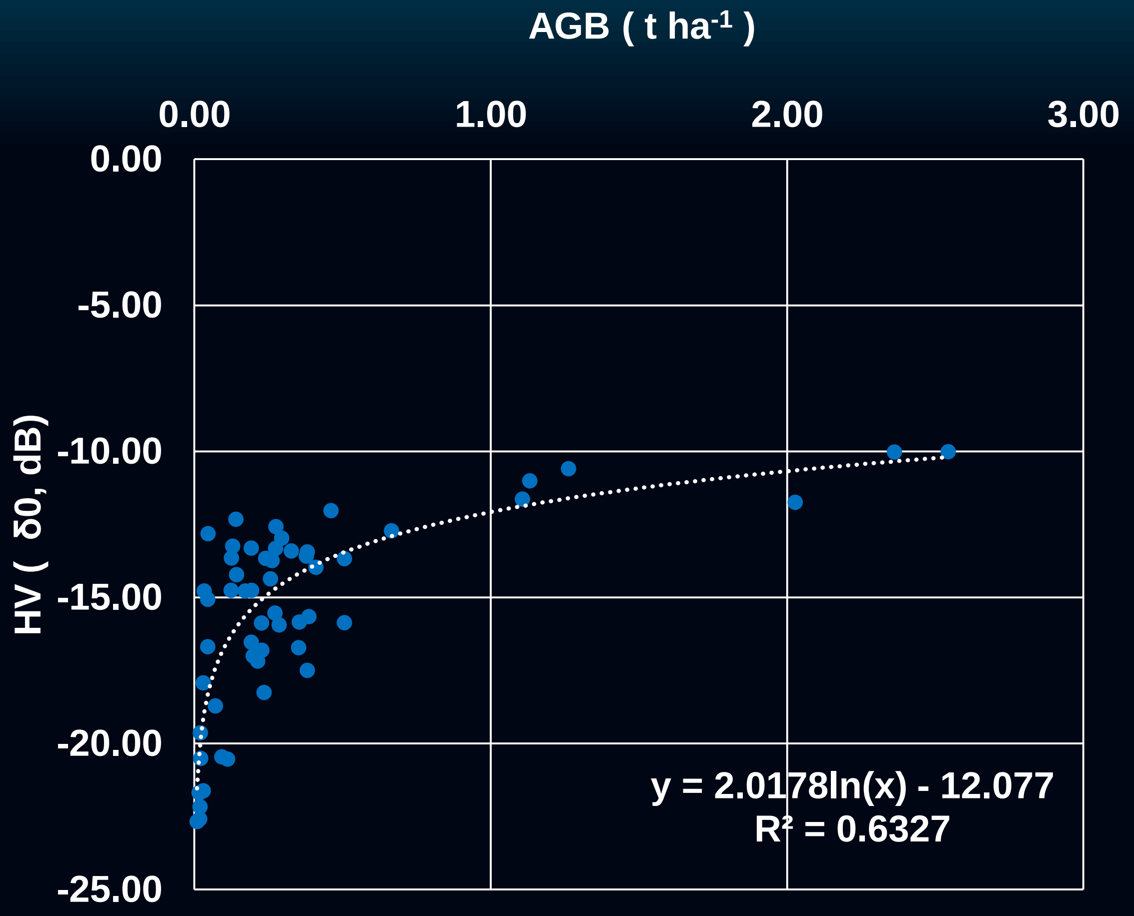


Figure 5: Scatter plots of transect level AGB estimates with (a) HH and (b) HV polarization of ALOS PALSAR 50m Orthorectified Mosaic Product

Spatial Biomass Map

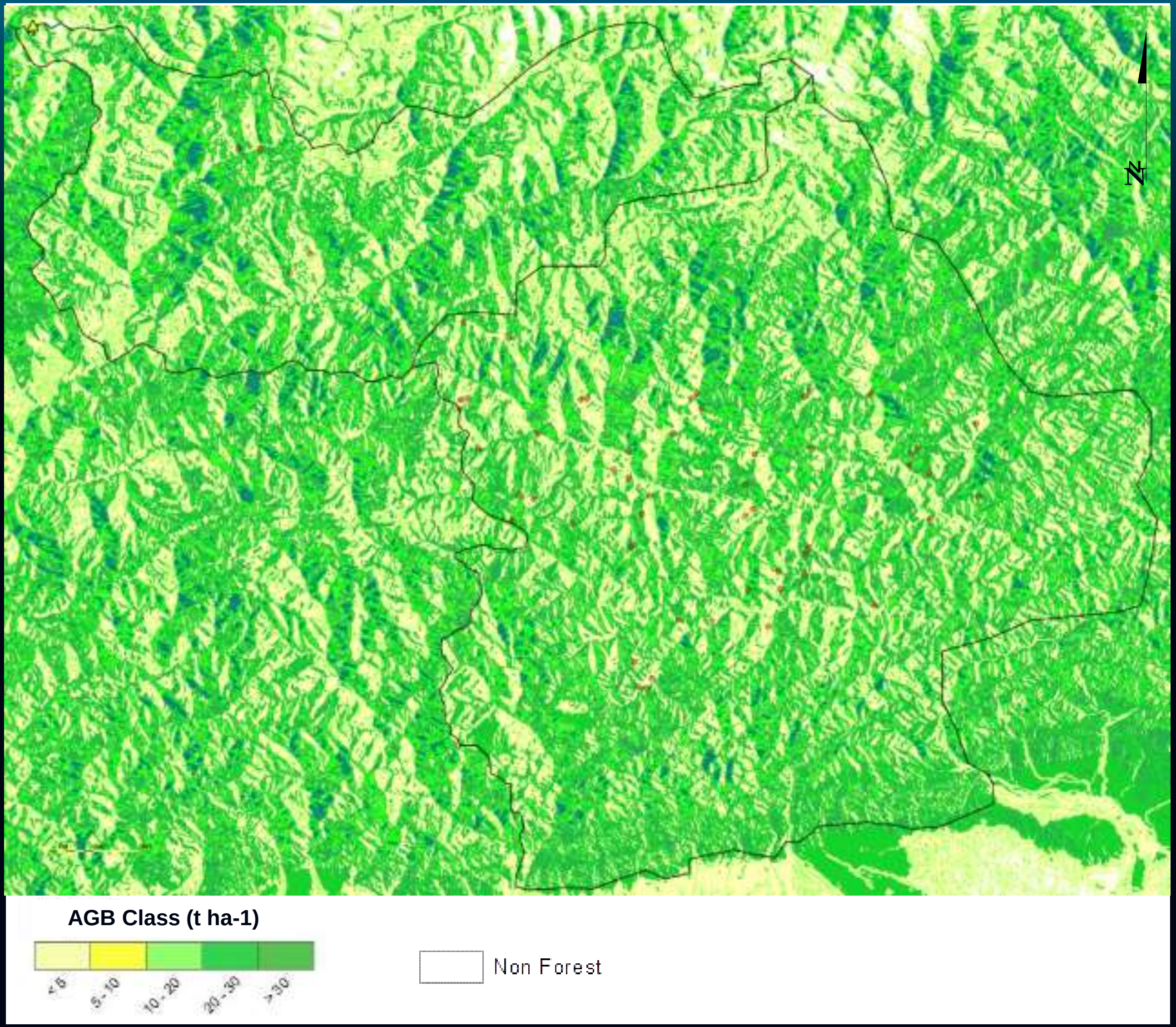


Figure 6: Estimated above ground biomass (AGB) map prepared using backscattering coefficients of HV polarization

The majority of area was under very low (<5 t ha^{-1}) AGB class (covering 55.8% in HV to 58.3% in HH polarizations), followed by low (26.8% in HV to 28.8% in HH) and moderate (11.4% in HH to 12.1% in HV) AGB classes

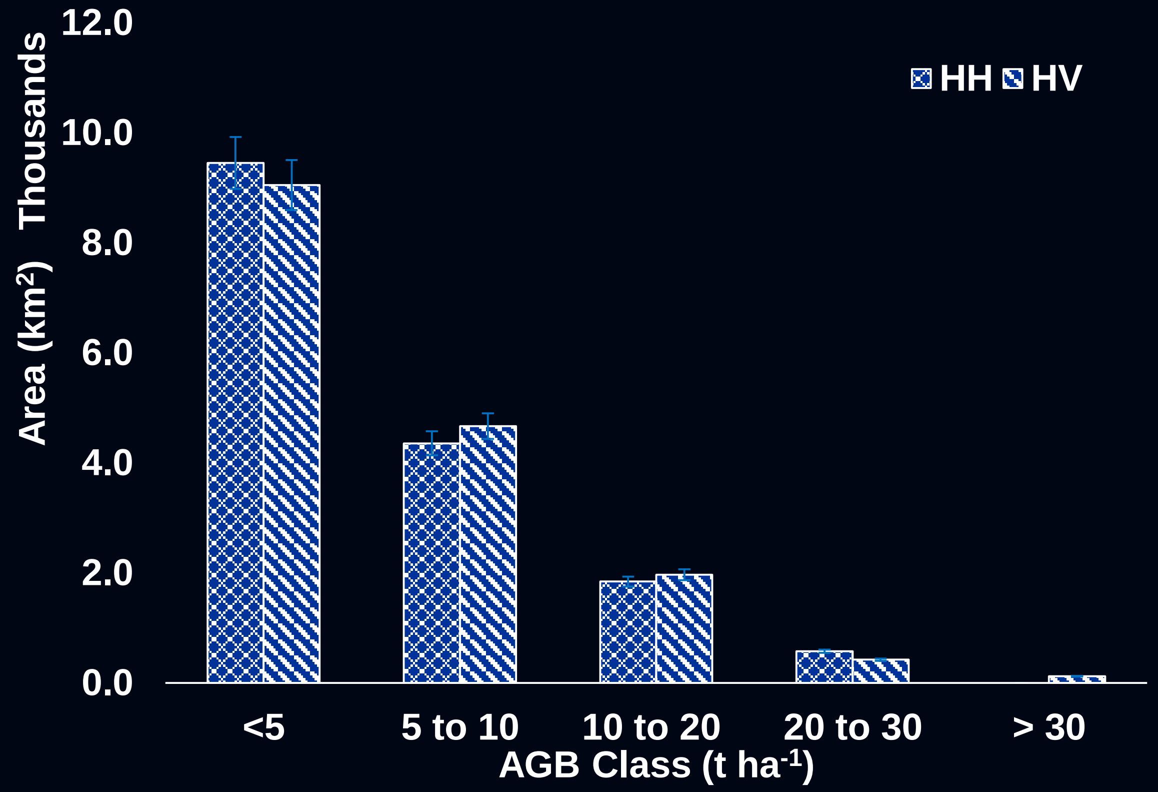


Figure 7: Bar diagram representing the area coverage of varied AGB classes in HH and HV polarizations

Sentinel 1A GRD Processing

- AGB estimation is also done using the Sentinel 1A GRD data of recent time (17th Aug 2017). The raw data is first set for pre processing like radiometric calibration, speckle correction and terrain correction and finally the sigma0 values are converted to decibels.

- The regression analysis between transect based AGB and backscatter coefficient retrieved in VH and VV polarizations, VV exhibit higher correlation of transect AGB with VH (R^2=0.054) as compared to HH (R^2= 0.044; Figure 10)

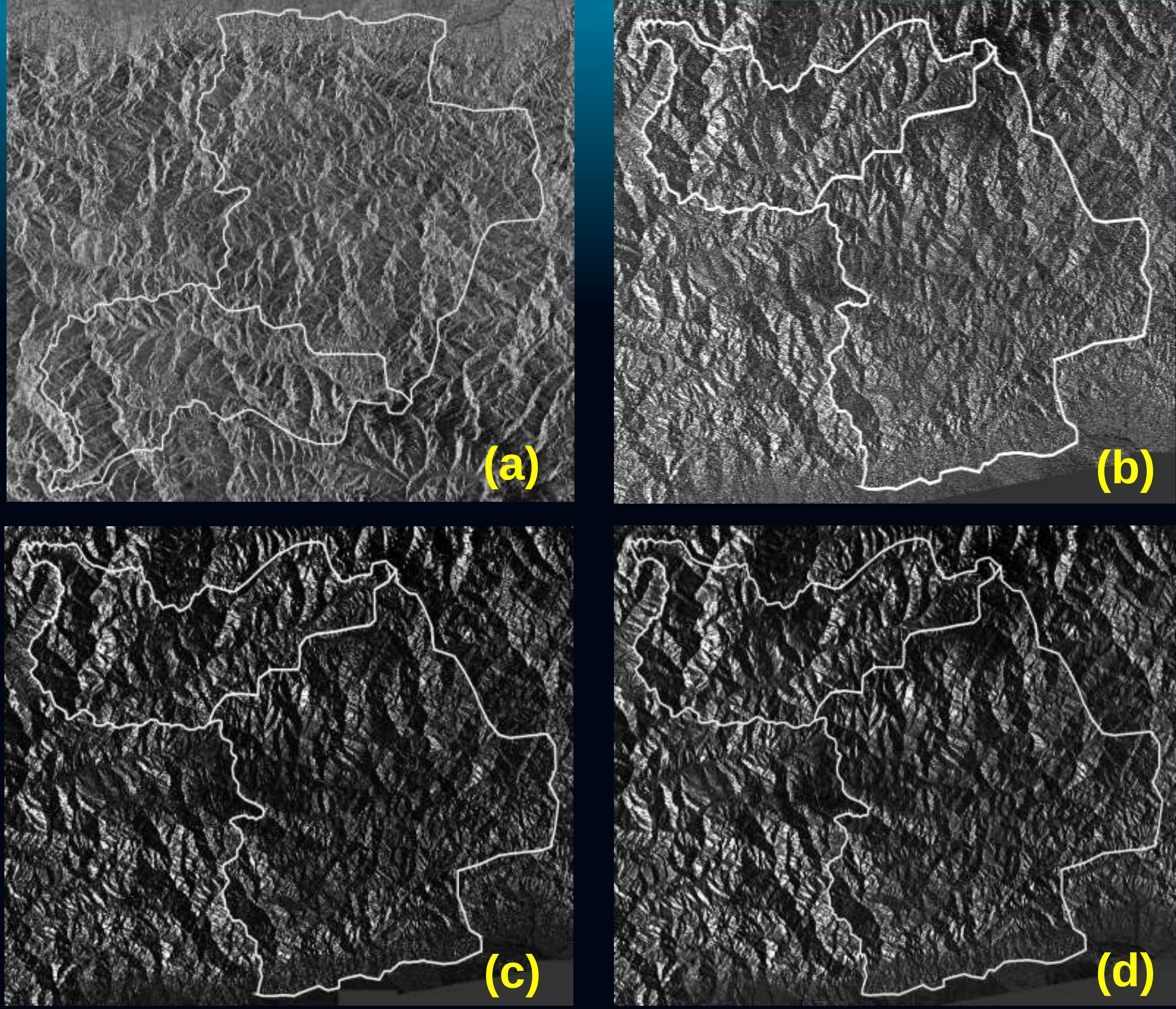
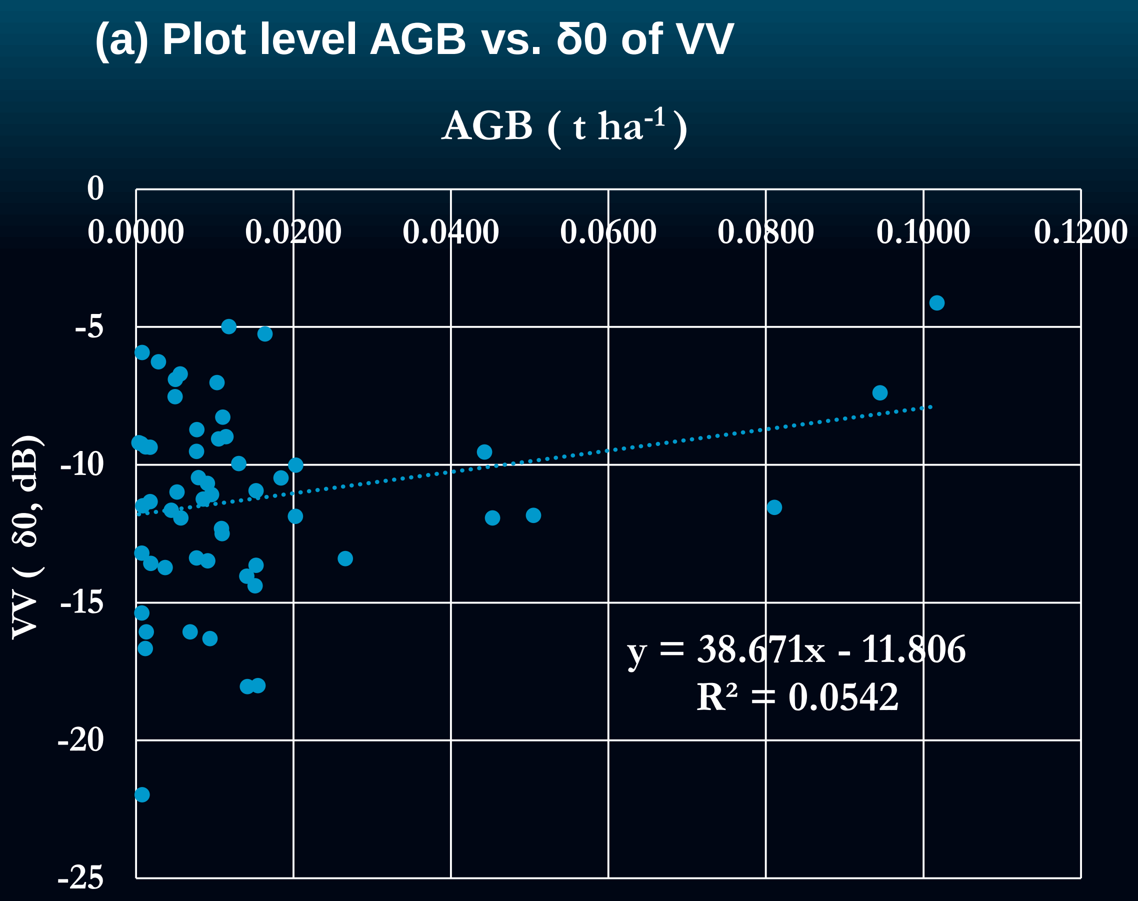


Figure 8: Sentinel 1A GRD VV polarization (a) subset of raw data, (b) terrain corrected, (c) radiometric calibration and (d) speckle corrected

Regression Analysis



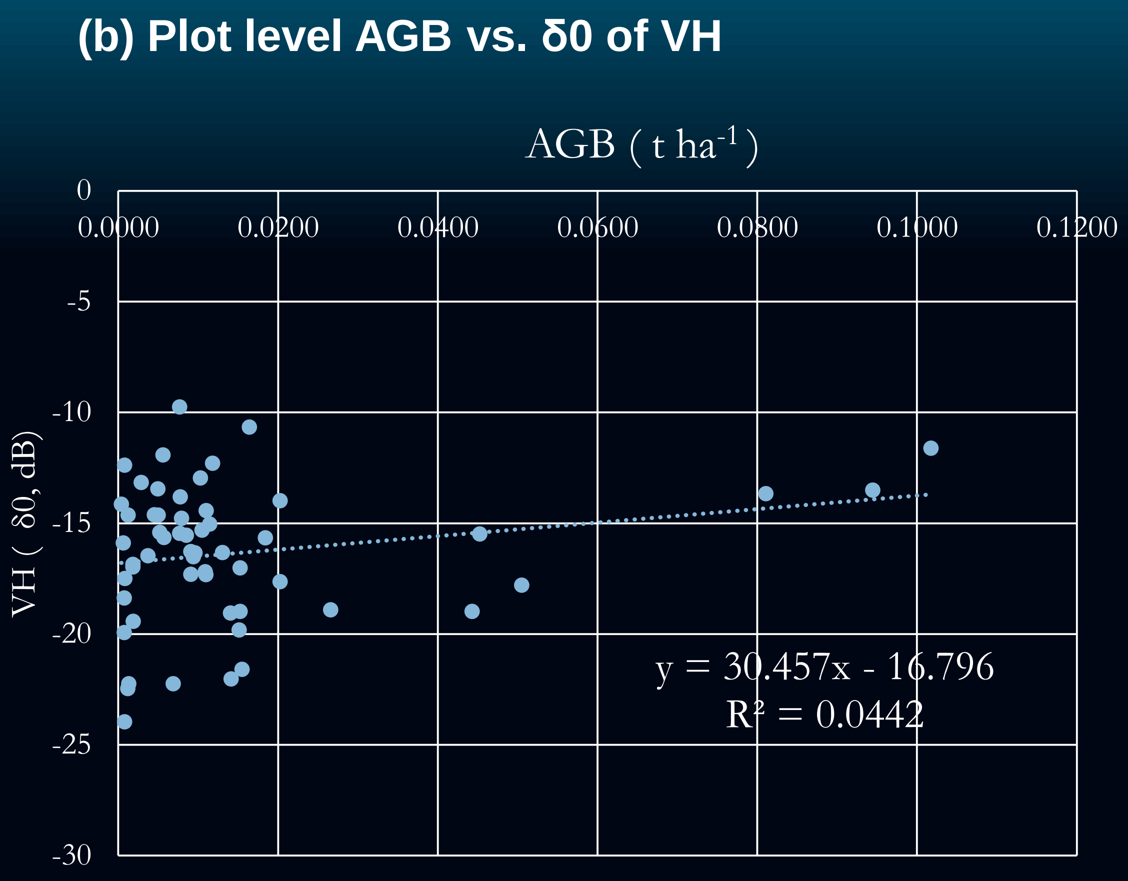


Figure 10: Scatter plots of transect level AGB estimates with (a) VV and (b) VH polarization of Sentinel 1A

Spatial Biomass Map

The majority of area was under very low (<5 t ha^{-1}) AGB class (covering 28.5% in VV to 35.6% in HH polarizations), followed by low (24.4% in VH to 27.5% in VV) and moderate (19.3% in VH to 22.18% in VV) AGB classes

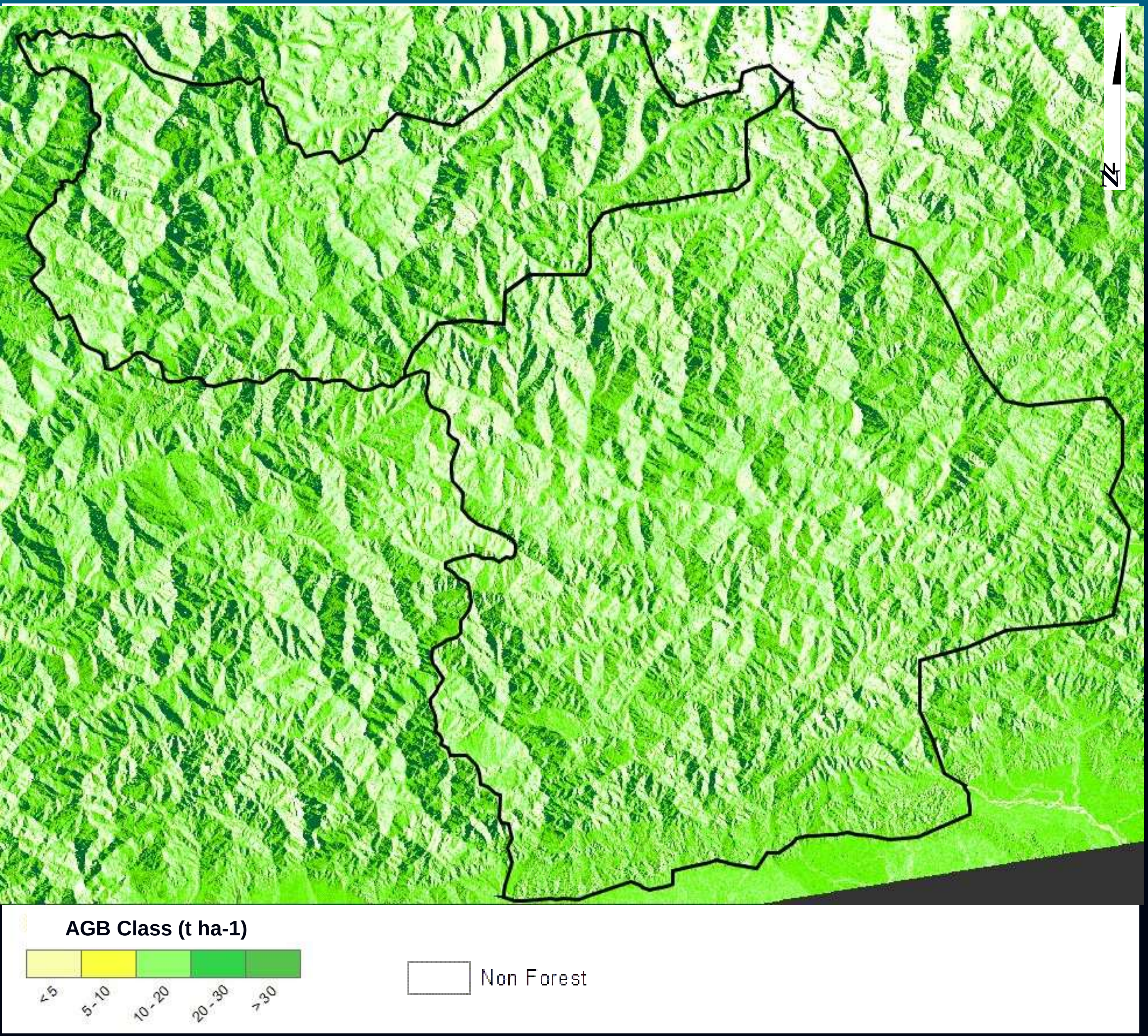


Figure 11: Estimated above ground biomass (AGB) map prepared using backscattering coefficients of VV polarization

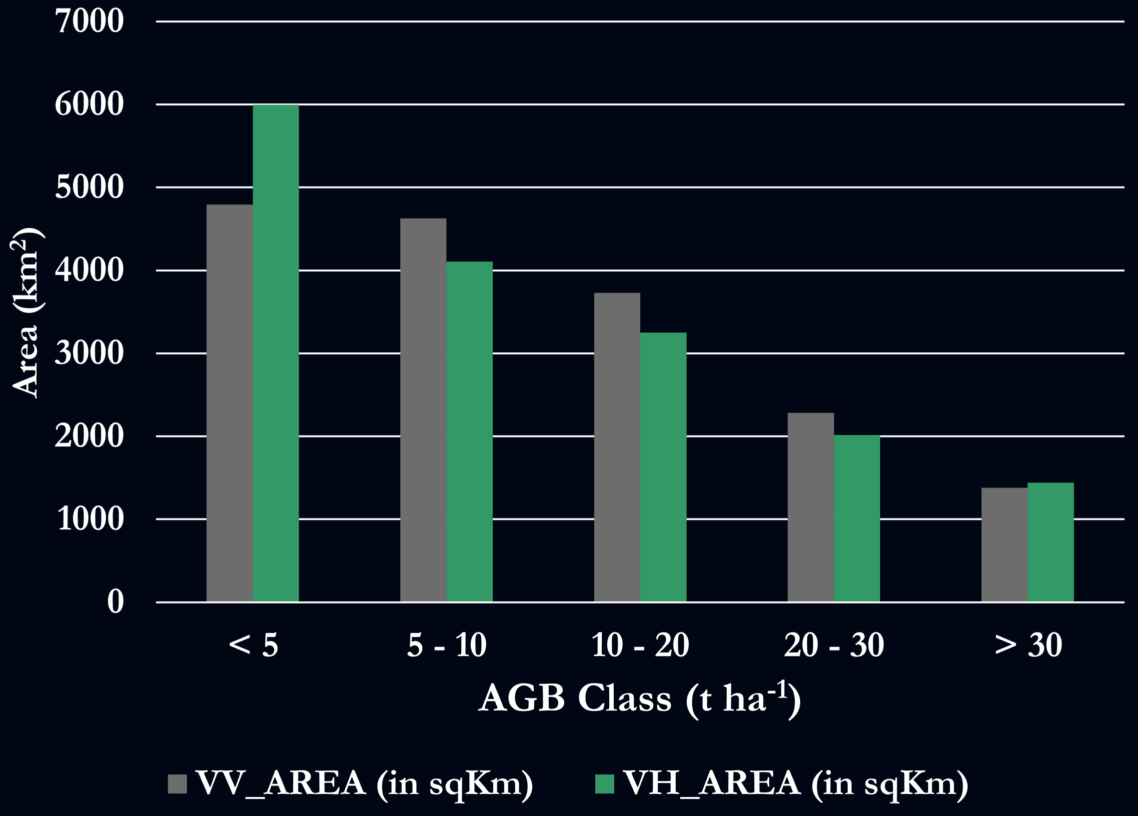


Figure 12: Bar diagram representing the area coverage of varied AGB classes in VV and VH polarizations

Field photographs & their location over LANDSAT TM satellite image

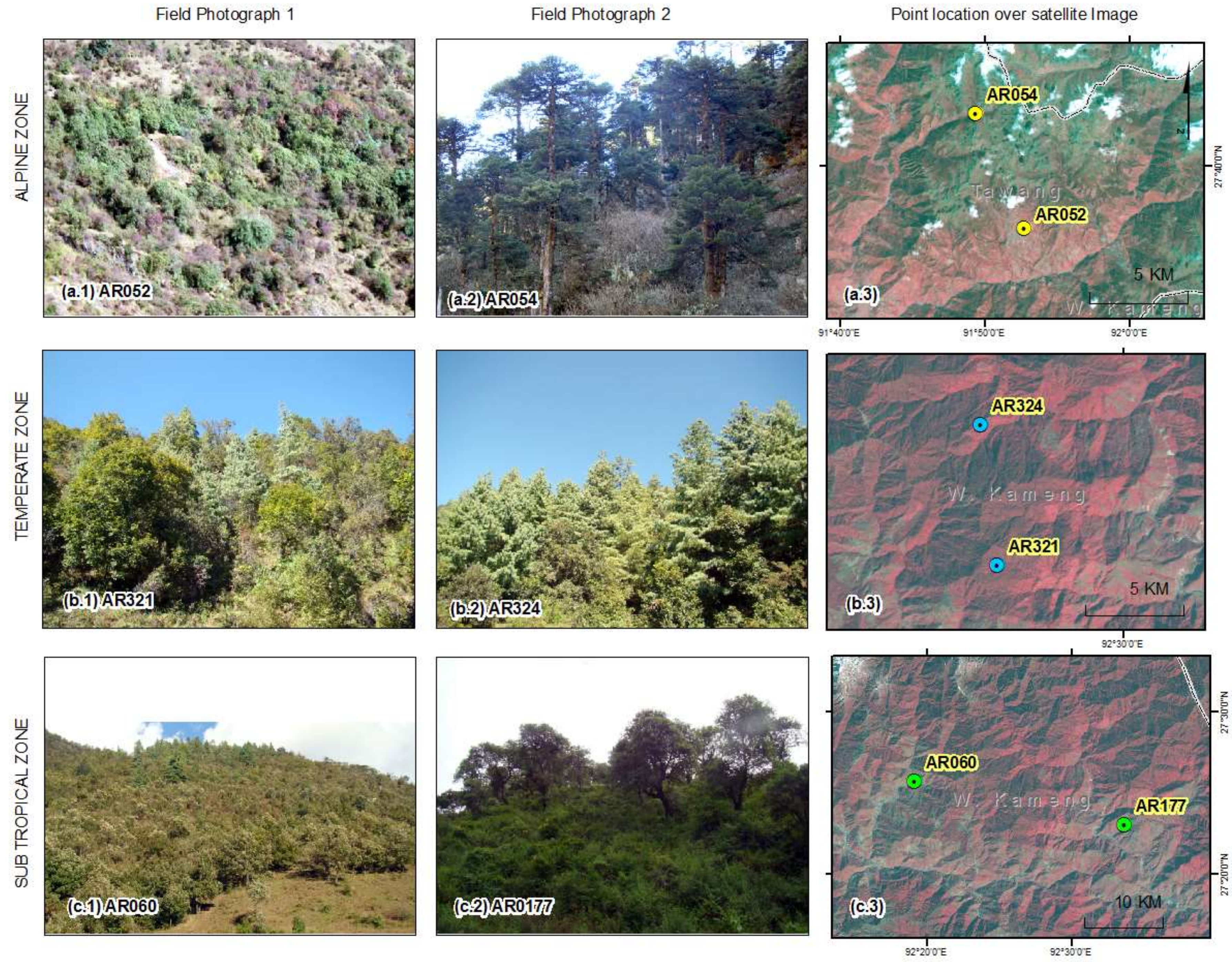


Figure 13: Field photographs of alpine forest (a.1 and a.2), temperate forests (b.1 and b.2) and Sub tropical forests (c.1 and c.2) and locations of respective transects in LANDSAT TM satellite image (a.3, b.3 and c.3)

Conclusion

- The present study reported that altitudinal gradients has significant impact over forests above ground biomass. Maximum AGB recorded in the forests stands located at 1700 to 2800 m altitude range.
- The trend in AGB in the Eastern Himalayan forests exhibits an increase in AGB level with increase in elevation up to 2800 m and thereafter it decreases.
- The decrease in mean tree density per transect with increase in altitude (subtropical > temperate > alpine forests) was observed but, mean tree diversity and biomass per transect highest in temperate forests followed by subtropical and in alpine forests.

Conclusion cont…

- The study shown that ALOS PALSAR L band (HV pol.) has better correlation with AGB then Sentinal 1A C band due to higher penetration of L band.
- The time difference of satellite data acquisition and field measurement, pixel size and field transect size are the major limitations
- The study exhibited the poor species diversity due to high altitudinal variations although contributing comparatively higher AGB. This may be attributed to due to favourable environmental conditions as well as less biotic interferences.

Research Team

Thank You

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