ISRO Activities on
Forest Biomass Mapping

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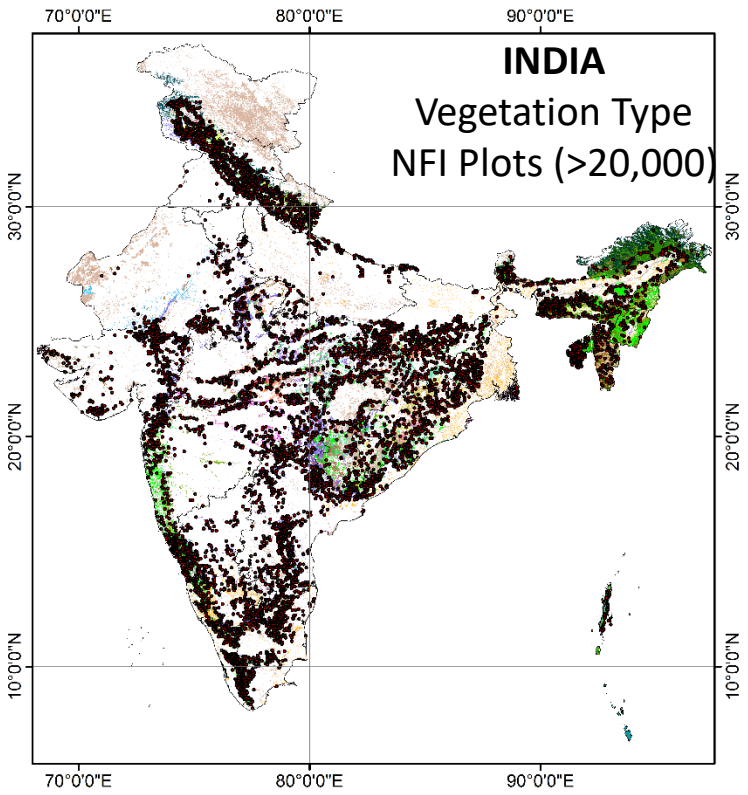
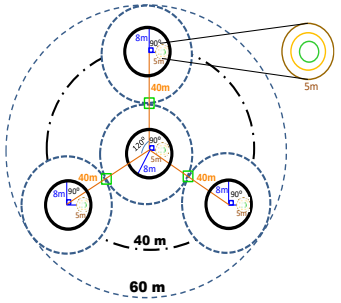
Background: Forest Carbon Estimation in India

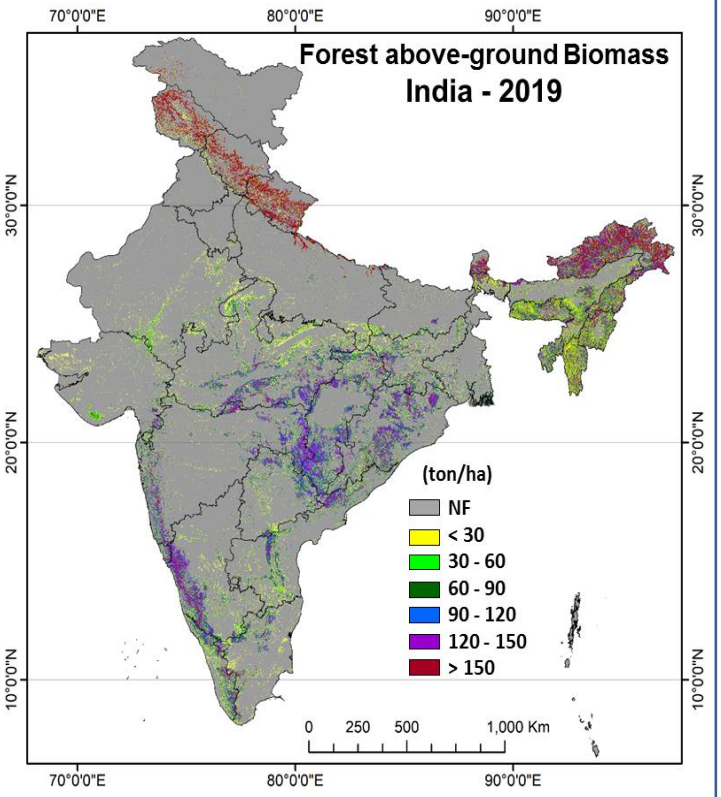
India Forest Cover: 713,789 Km^2 (21.71% GA) – Forest Survey of India (FSI, 2021)





India National Forest Inventory (NFI) design for ground data collection: 60m radius (1.13 ha) circular plot for qualitative information like – land use, crop composition, origin of stand, fire incidents, soil, regeneration, grazing etc. and cluster of 4 sub-plots of 8m radius are for tree measurements - like stem diameter at breast height, tree height, species name, crown-diameter etc.

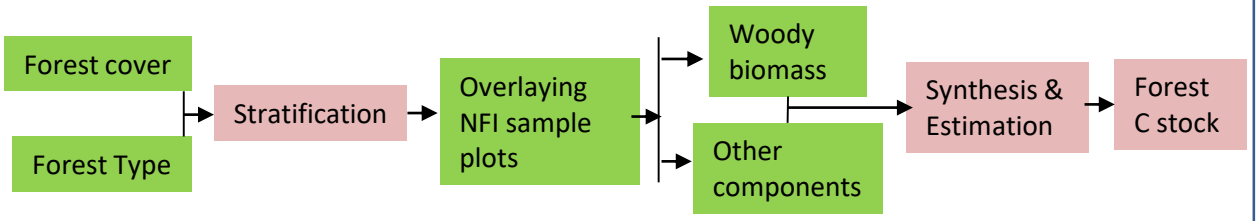
SAR based estimation of forest AGB (2019)



Reference: India State of Forest Report (ISFR), 2019
https://vedas.sac.gov.in/forest/index.html

Pools	2021	2019	Change
AGB	2319.9	2256.5	63.4
BGB	718.9	700.8	18.1
Deadwood	47.7	35.8	11.9
Litter	107.3	127.9	-20.6
Soil	4010.2	4003.6	6.6
Total	**7204.0**	**7124.6**	**79.4**

Forest C stock in India (million tons), FSI



Schematic diagram showing ground-based methodology of forest carbon assessment by the FSI (2011)

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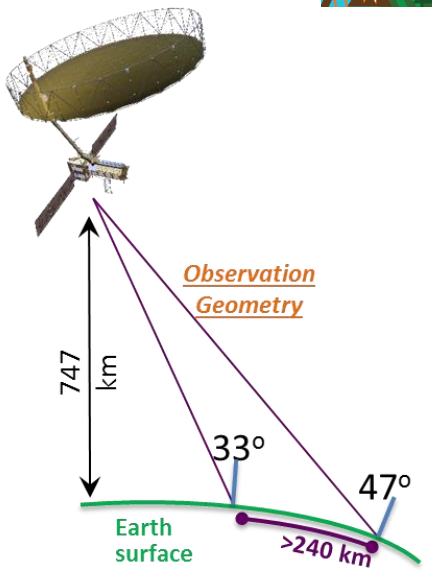
Planned AGB and Forest Disturbance Products from NISAR

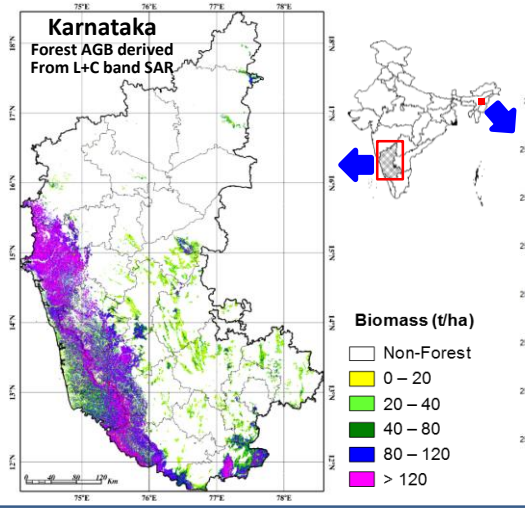
NASA-ISRO L&S band SAR Mission:

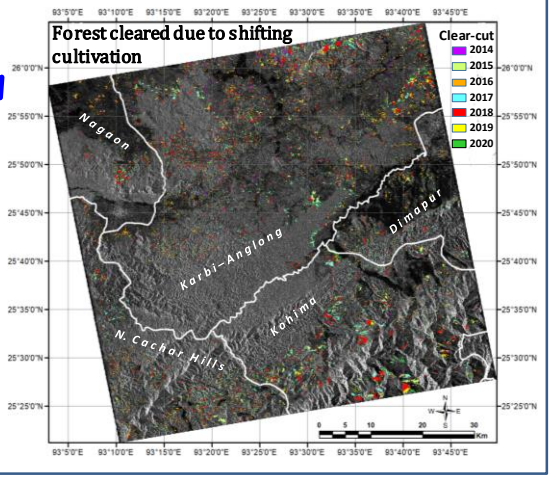
NISAR Characteristic:	Enables…
L-band (24 cm wavelength)	Low temporal decorrelation and good foliage penetration
S-band (9 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 50 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry (D-InSAR)
Orbit control < 500 meters	Short baseline D-InSAR
> 10% (S-band) & 50% (L-band) observation duty cycle	Complete land/ice coverage
Left-only pointing (Left/Right capability)	Uninterrupted time-series of Antarctic Rely on Sentinel-1 for Arctic



1. **Forest above-ground dry biomass** at hectare scale (1ha) generated annually within an RMSE of 20 Mg/ha over 80% of forest areas of biomass less than 100 Mg/ha over India.

2. **Vegetation disturbance** over Indian forests at 1-hectare grid size generated annually for areas losing at least 50% canopy cover with a classification accuracy of 80%.





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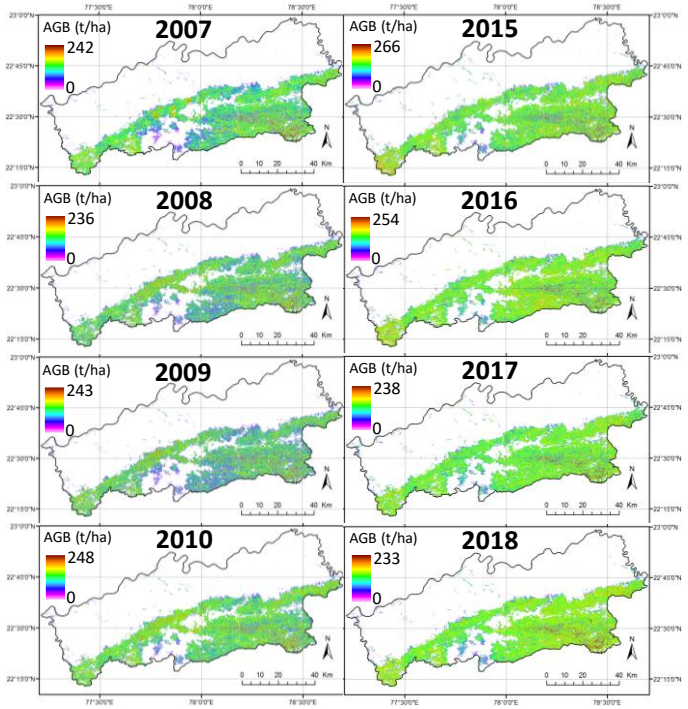
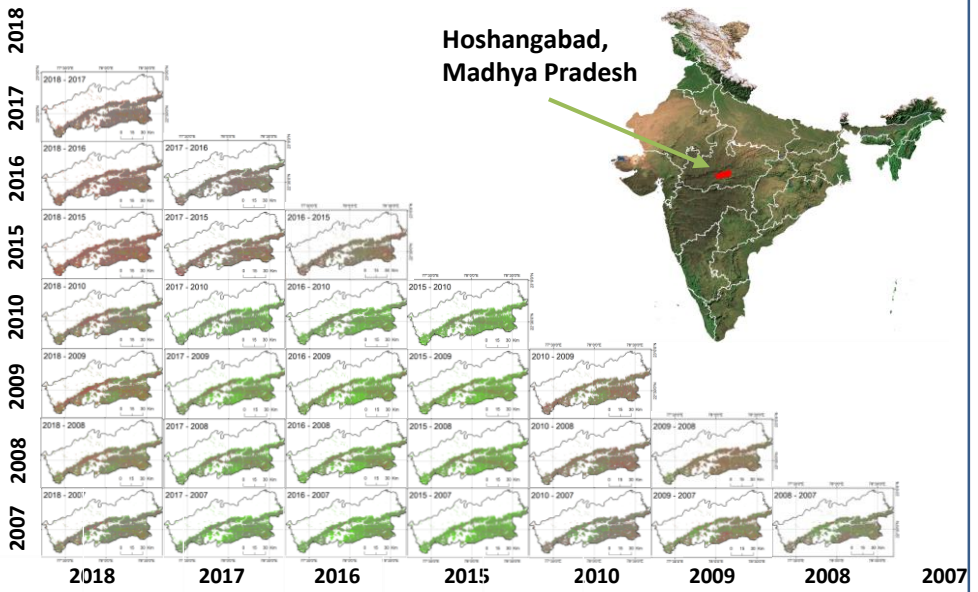
Forest Disturbance Monitoring

Forest Disturbance Monitoring : Selective logging /commercial harvesting

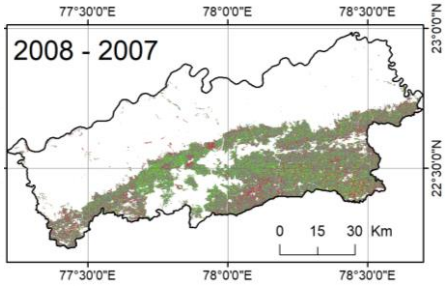


Forest AGB maps of Hoshangabad (MP) derived from ALOS PALSAR HH/HV data of 2007-2010 and 2015-2018.



Change (> ± RMSE) in forest AGB of Hoshangabad (MP) derived from ALOS PALSAR HH+HV polarization data of 2007-2010 and 2015-2018.

	2018	2017	2016	2015	2010	2009	2008	2007
2018								
2017	Un: 74.0 Loss: 21.8 Gain: 4.2							
2016	Un: 77.3 Loss: 16.9 Gain: 5.8	Un: 86.8 Loss: 7.5 Gain: 5.7						
2015	Un: 71.7 Loss: 21.4 Gain: 6.8	Un: 80.1 Loss: 12.2 Gain: 7.6	Un: 79.0 Loss: 11.7 Gain: 9.3					
2010	Un: 77.9 Loss: 10.3 Gain: 11.8	Un: 73.2 Loss: 1.9 Gain: 24.9	Un: 68.2 Loss: 2.4 Gain: 29.4	Un: 64.6 Loss: 2.5 Gain: 32.9				
2009	Un: 69.0 Loss: 14.9 Gain: 16.0	Un: 65.3 Loss: 5.1 Gain: 29.6	Un: 61.7 Loss: 5.3 Gain: 33.0	Un: 59.6 Loss: 5.0 Gain: 35.4	Un: 75.2 Loss: 12.6 Gain: 12.2			
2008	Un: 72.5 Loss: 14.3 Gain: 13.2	Un: 69.5 Loss: 4.3 Gain: 26.2	Un: 65.4 Loss: 4.7 Gain: 29.9	Un: 62.8 Loss: 4.6 Gain: 32.6	Un: 78.9 Loss: 11.8 Gain: 9.2	Un: 73.0 Loss: 14.7 Gain: 12.4		
2007	Un: 78.2 Loss: 8.3 Gain: 13.6	Un: 70.2 Loss: 1.4 Gain: 28.4	Un: 65.1 Loss: 1.7 Gain: 33.2	Un: 61.7 Loss: 1.6 Gain: 36.7	Un: 84.0 Loss: 6.1 Gain: 9.9	Un: 75.3 Loss: 9.8 Gain: 14.8	Un: 78.6 Loss: 7.2 Gain: 14.2	



AGB change Map: 2008-2007

Forest AGB change matrix: 2007-2010 and 2015-2018. Boxes with red shades indicate loss of biomass while boxes with green shades show gain in biomass (in % pixels).

Comparison of RMS Error (t/ha) obtained from estimation of AGB at 25m and 100m output grids over different years

Year	2007	2008	2009	2010	Average 2007-10	2015	2016	2017	2018	Average 2015-18
25m Grid	34.6	35.5	33.2	36.1	**32.2**	29.5	31.7	30.2	30.6	**28.5**
100m Grid	27.1	26.4	27.3	27.8	**25.4**	26.4	27.8	26.2	28.1	**24.3**

for RMSE N=35

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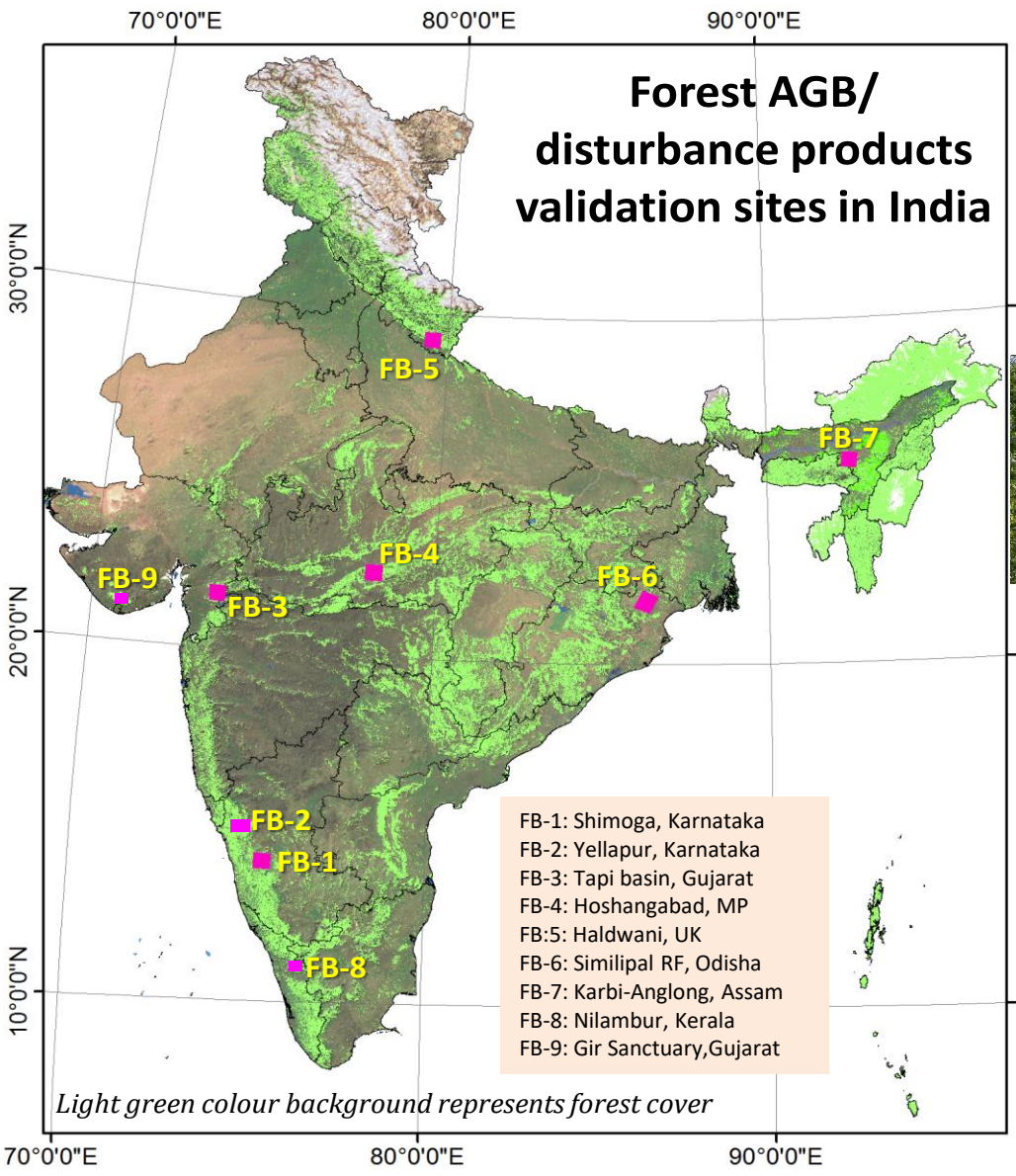
Forest AGB Validation Sites: INDIA



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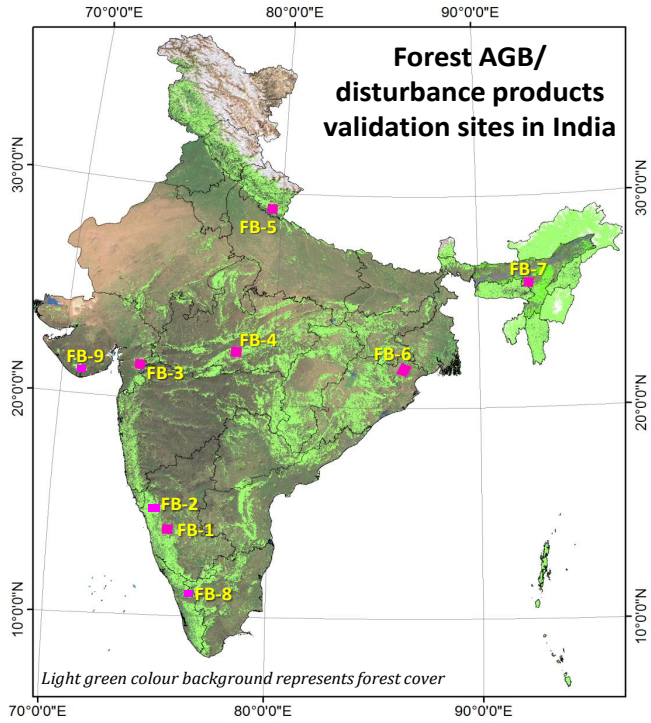
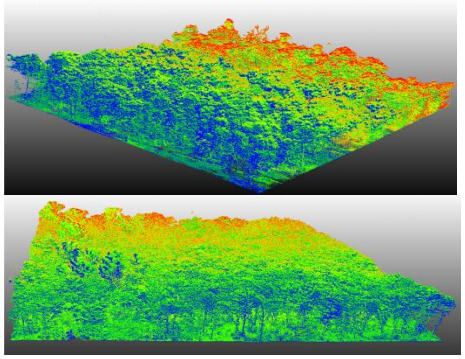
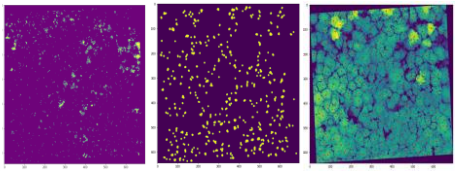
NISAR Forest Biomass product validation Plan

Establishment of Long-term 1ha sized forest inventory plots





Tree Trunk identification and Tree counting using LIDAR

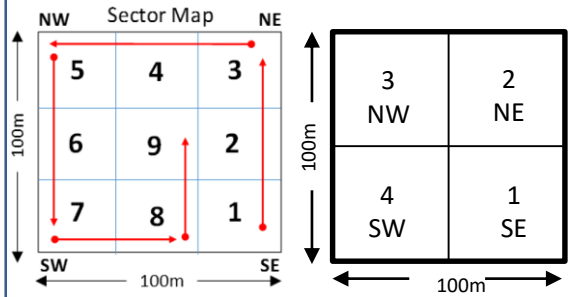


Forest biomass / disturbance (CEOS LPV protocol)

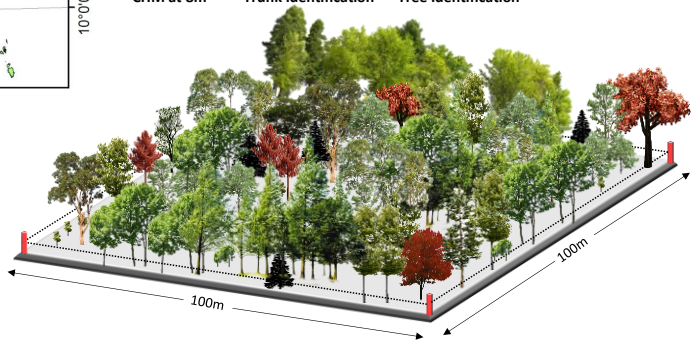
Parameters being measured over 1-ha inventory plots:

- Tree Height (mean, max, Lorey's ht.)
- Tree girth, Tree DBH
- Tree species, no. of stems
- Tree canopy density (LAI)
- Leaf size and formation
- Wood density and wood moisture
- Soil type and soil moisture

Collection of high resolution aerial colour photo and Lidar data sync to ground inventory



Plot layout for Deciduous and evergreen forests



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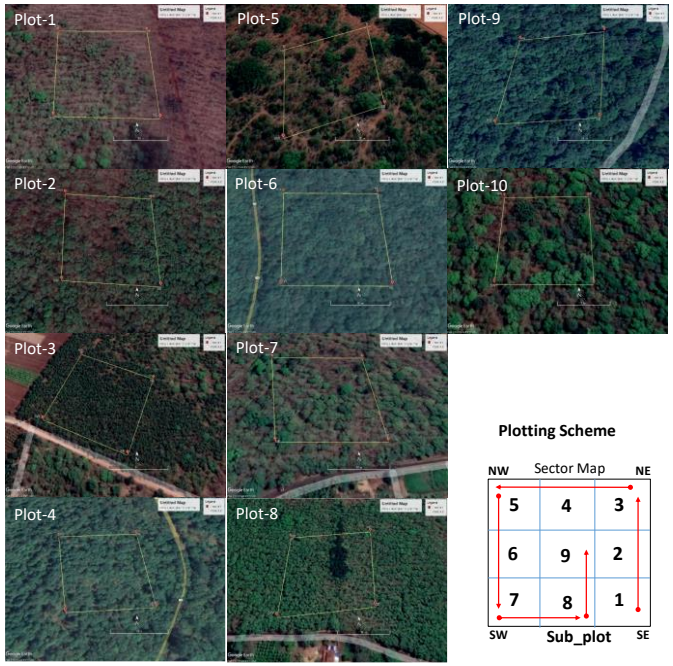
NISAR cal/val: Forest Inventory Plots at Shimoga, Karnataka

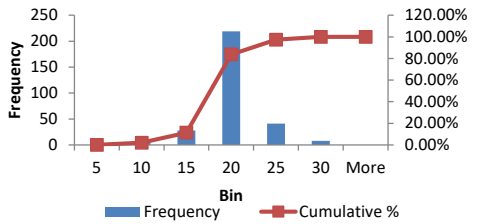
Establishment of 1ha Forest Inventory Plots
SHIMOGA, Karnataka



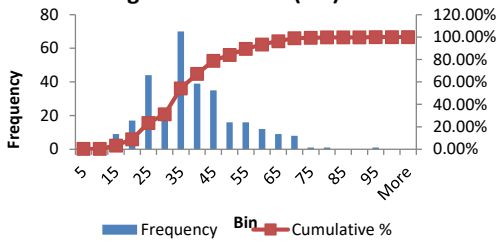
Plotting Scheme

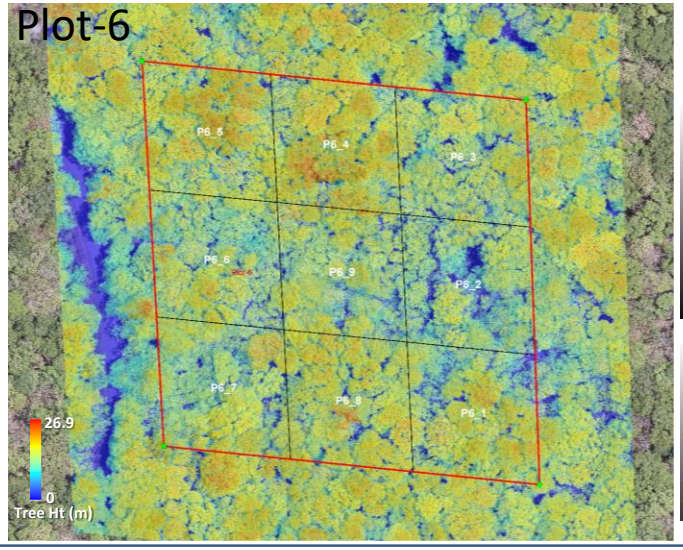
Plot-6

Histogram: : Tree Ht (m) - LIDAR

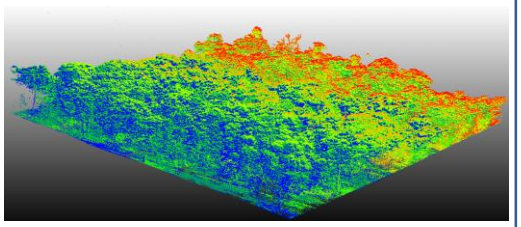


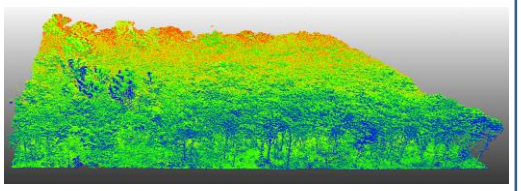
Histogram: Stem Dia (cm) - LIDAR





3D-View: LIDAR Point Cloud





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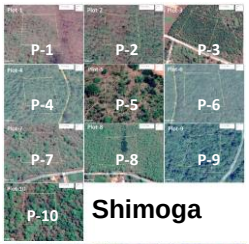
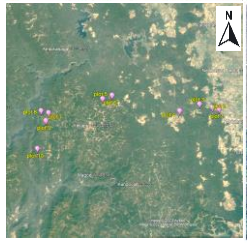
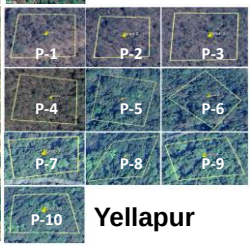
Forest AGB validation plots

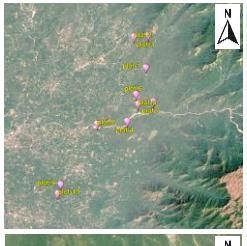


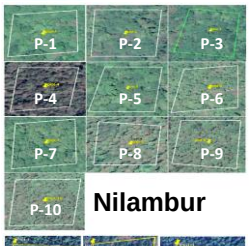
Shimoga



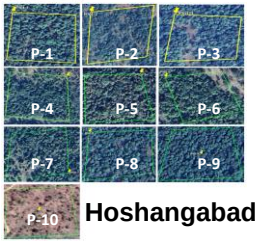


Yellapur





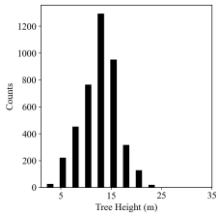
Nilambur

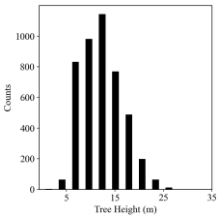


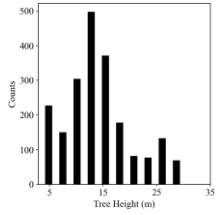
Hoshangabad

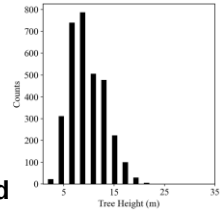
Haldwani
25 1ha plots

Distribution of Tree Height

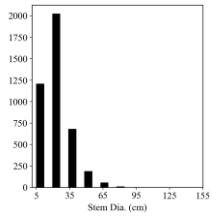


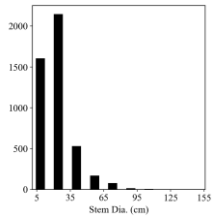


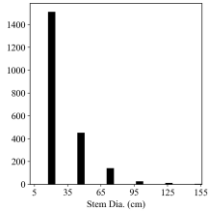


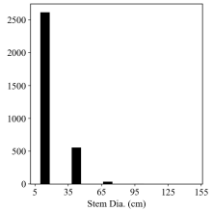


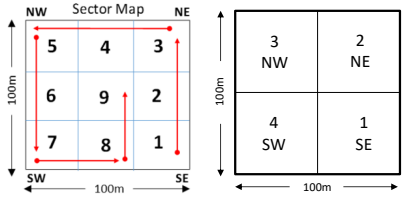
Distribution of Stem Dia.



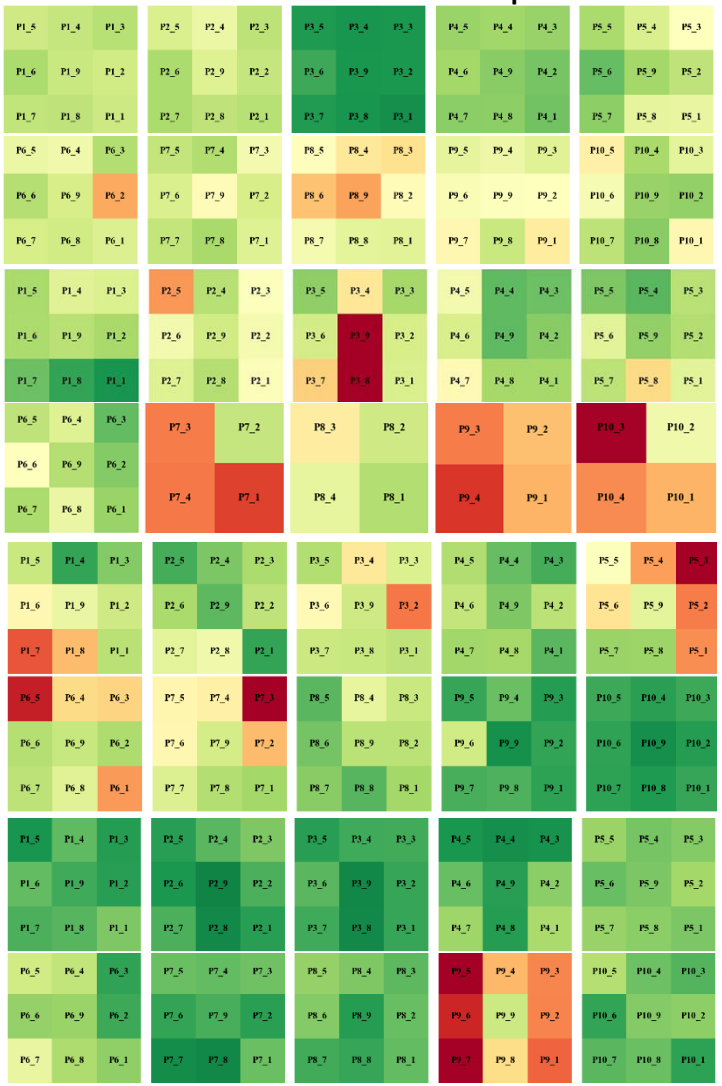




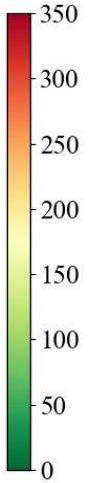




AGB distribution at sub-plots



AGB (ton/ha)



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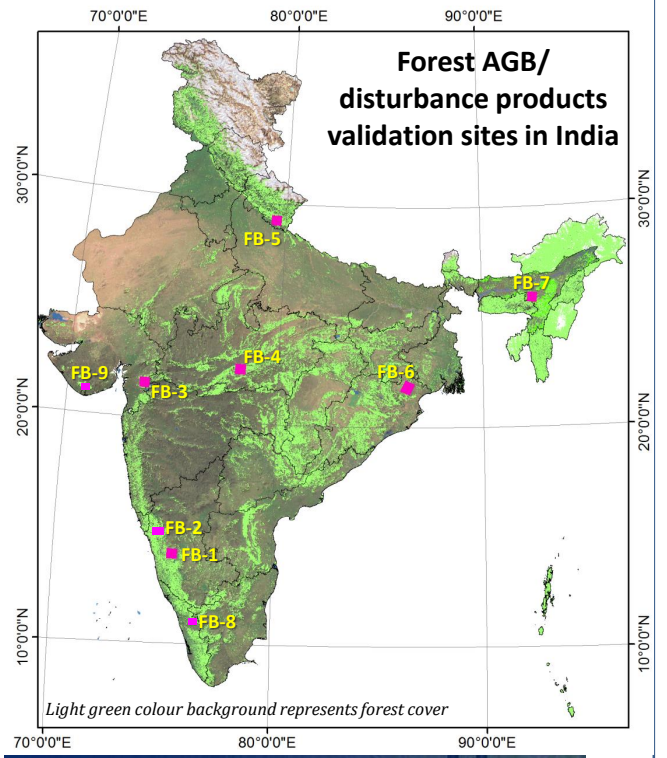
Current STATUS: Long-term 1-hectare inventory plots in India for the cal/val of forest biomass products

Site Name	Site characteristics	Activity	Schedule / Status
FB-1: Shimoga, Karnataka	Mix of tropical semi-evergreen and mixed deciduous forests	1 ha plots; plot level drone Lidar and RGB image; large area drone Lidar.	10 inventory plots + plot level Lidar with optical data acquired; Large-area Lidar planned
FB-2: Yellapur, Karnataka	Tropical deciduous, semi-evergreen and evergreen forests	- same as above -	- same as above -
FB-3: Tapi Forest, Gujarat	Dry deciduous to moist evergreen forest with mixed vegetation	1 ha plots; large area drone based Lidar + Optical data	Planned during Oct 2023 -March 2024
FB-4: Hoshangabad, MP	Tropical dry deciduous and tropical dry evergreen forests	1 ha plots; plot level drone Lidar and RGB image; large area drone Lidar.	10 inventory plots + plot level Lidar with optical data acquired; Large-area Lidar planned.
FB-5: Haldwani, Uttarakhand	Sub-tropical moist deciduous, plantation forests dominated by Teak and Eucalyptus sp	1 ha plots; large area drone based Lidar + Optical data	25 1ha plots inventory data acquired; Large-area Lidar planned.
FB-6: Simlipal, Odisha	Northern tropical moist deciduous forest with patches of semi-evergreen forests	1 ha plots; large area Lidar data	Planned in 2023-24
FB-7: Karbi Anglong, Assam	Sub-tropical moist semi-evergreen forests and moist mixed deciduous forests	1 ha plots; large area drone based Lidar + Optical data	Planned during Oct - Dec 2023
FB-8: Nilambur, Kerala	Part of Nilgiri biosphere reserve, famous for Nilambur Teak. Mix of deciduous and evergreen forests.	1 ha plots; plot level drone Lidar and RGB image; large area drone Lidar.	10 inventory plots + plot level Lidar with optical data acquired; Large-area Lidar planned
FB-9: Gir Forests Gujarat	Dry deciduous mixed with thorn forests / shrub lands	1 ha plots; large area drone based Lidar + Optical data	Planned during Oct 2023 -March 2024



Nextcore Lumus XT100

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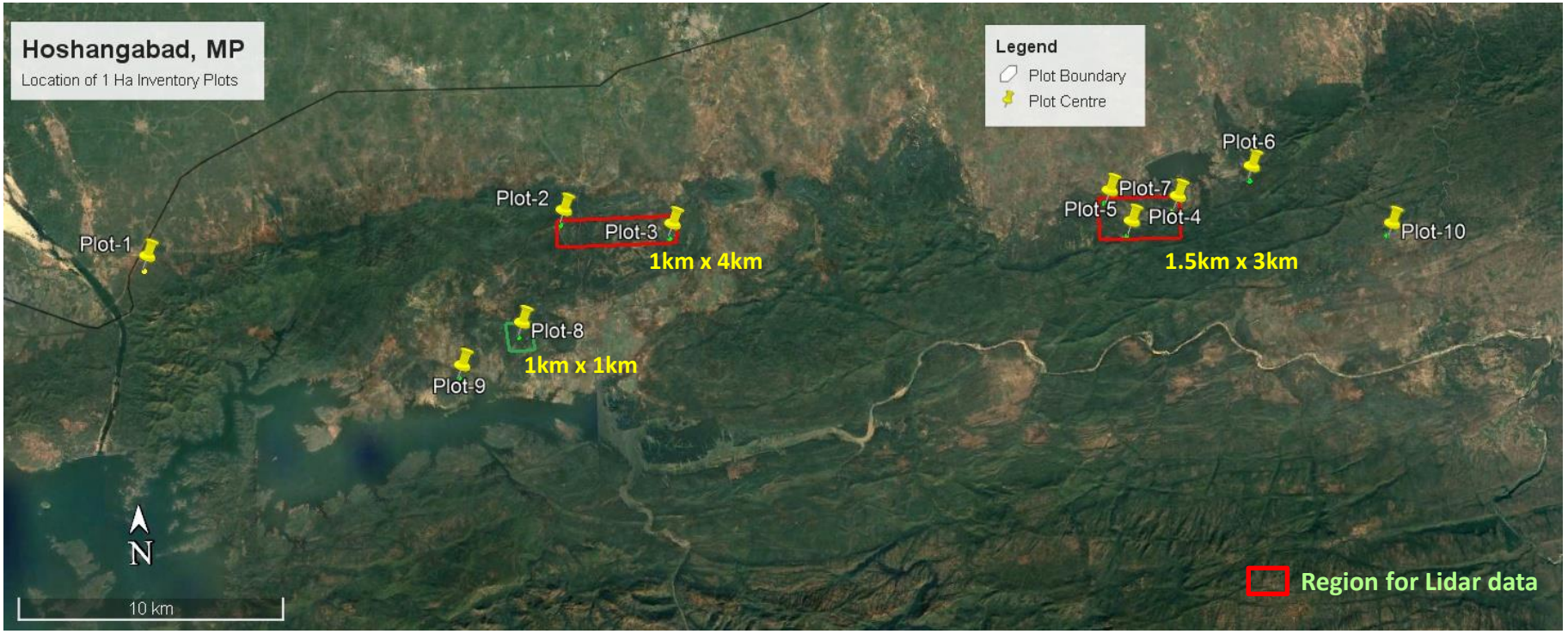
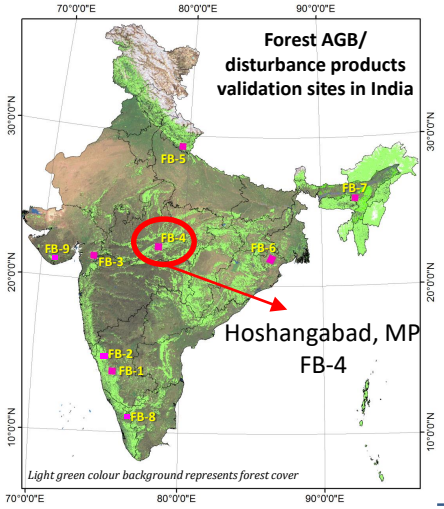
Hoshangabad, MP





tropical dry deciduous and tropical dry evergreen vegetation.

		PLOT-1	PLOT-2	PLOT-3	PLOT-4	PLOT-5	PLOT-6	PLOT-7	PLOT-8	PLOT-9	PLOT-10
HOSHANGABAD	No. of Trees	265	400	261	447	486	323	296	318	390	475
	No. of Species	12	14	12	20	16	19	16	18	21	12
	Tree Height (m)	8.68	7.39	9.39	8.24	11.94	8.93	8.50	10.47	13.77	6.59
	DBH (cm)	23.41	19.13	23.95	18.6	20.23	25.24	20.39	23.34	25.85	15.51
	AGB (t/ha)	**63.0**	**54.0**	**45.7**	**61.4**	**107.2**	**101.4**	**54.7**	**71.0**	**294.3**	**73.3**

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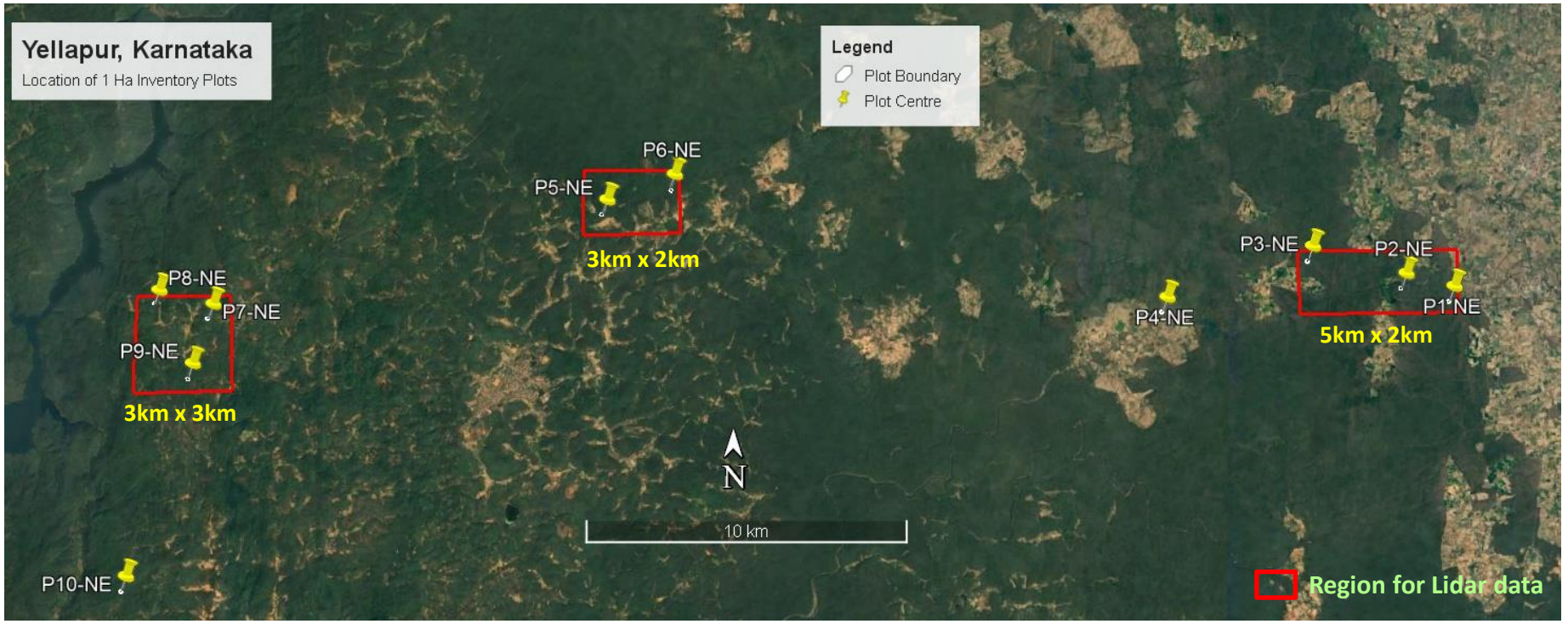
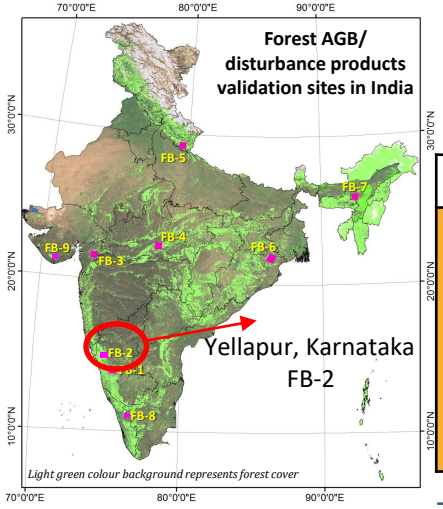
Yellapur, Karnataka





Tropical deciduous, semi-evergreen and evergreen forests

		PLOT-1	PLOT-2	PLOT-3	PLOT-4	PLOT-5	PLOT-6	PLOT-7	PLOT-8	PLOT-9	PLOT-10
YELLAPUR	No. of Trees	190	170	170	353	120	129	176	137	460	597
	No. of Species	12	8	16	6	42	28	34	34	28	34
	Tree Height (m)	8.72	13.91	12.42	16.68	12.89	13.75	11.44	12.26	13.66	13.04
	DBH(cm)	16.88	30.99	22.27	31.87	21.47	25.00	22.35	22.26	28.13	28.00
	AGB (t/ha)	**102.0**	**160.4**	**197.4**	**110.9**	**121.1**	**120.1**	**247.7**	**148.4**	**279.4**	**252.9**

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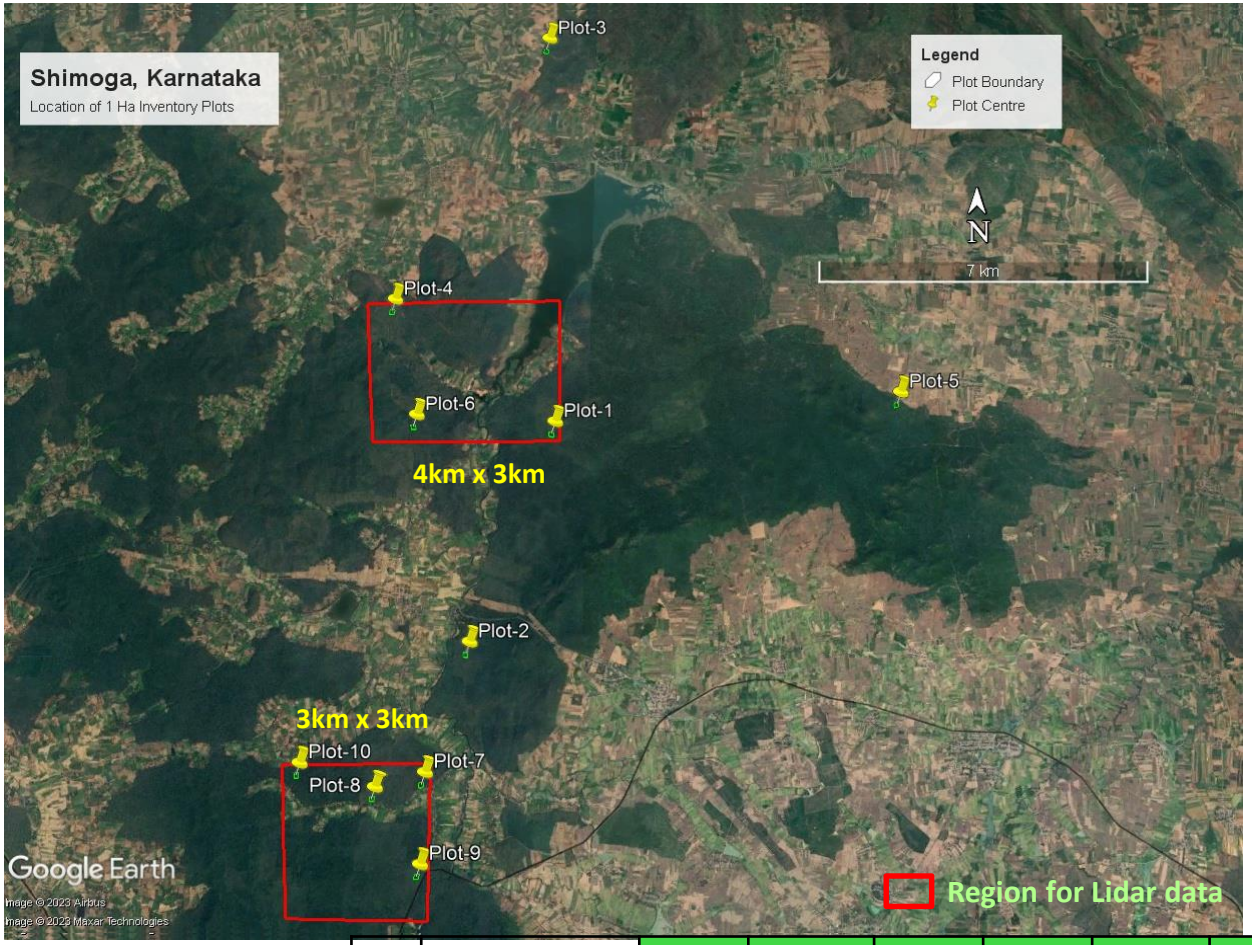
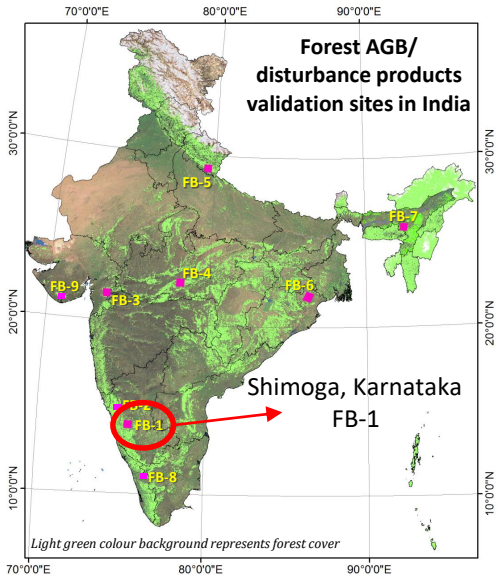
Shimoga, Karnataka



10 1Ha Plots



tropical moist deciduous, tropical dry deciduous and semi-evergreen vegetation

		PLOT-1	PLOT-2	PLOT-3	PLOT-4	PLOT-5	PLOT-6	PLOT-7	PLOT-8	PLOT-9	PLOT-10
SHIMOGA	No. of Trees	483	257	645	313	590	477	324	881	229	293
	No. of Species	4	7	2	4	15	10	8	3	9	10
	Tree Height (m)	15.1	17.8	8	11.7	7.8	12.7	13.5	13.7	15.3	11.3
	DBH(cm)	24	37	15	26	19.6	25.2	31.1	21.4	40.5	28.6
	AGB (t/ha)	**162.8**	**166.3**	**58.8**	**120.6**	**160.8**	**195.3**	**179.2**	**247.2**	**214.4**	**174.0**

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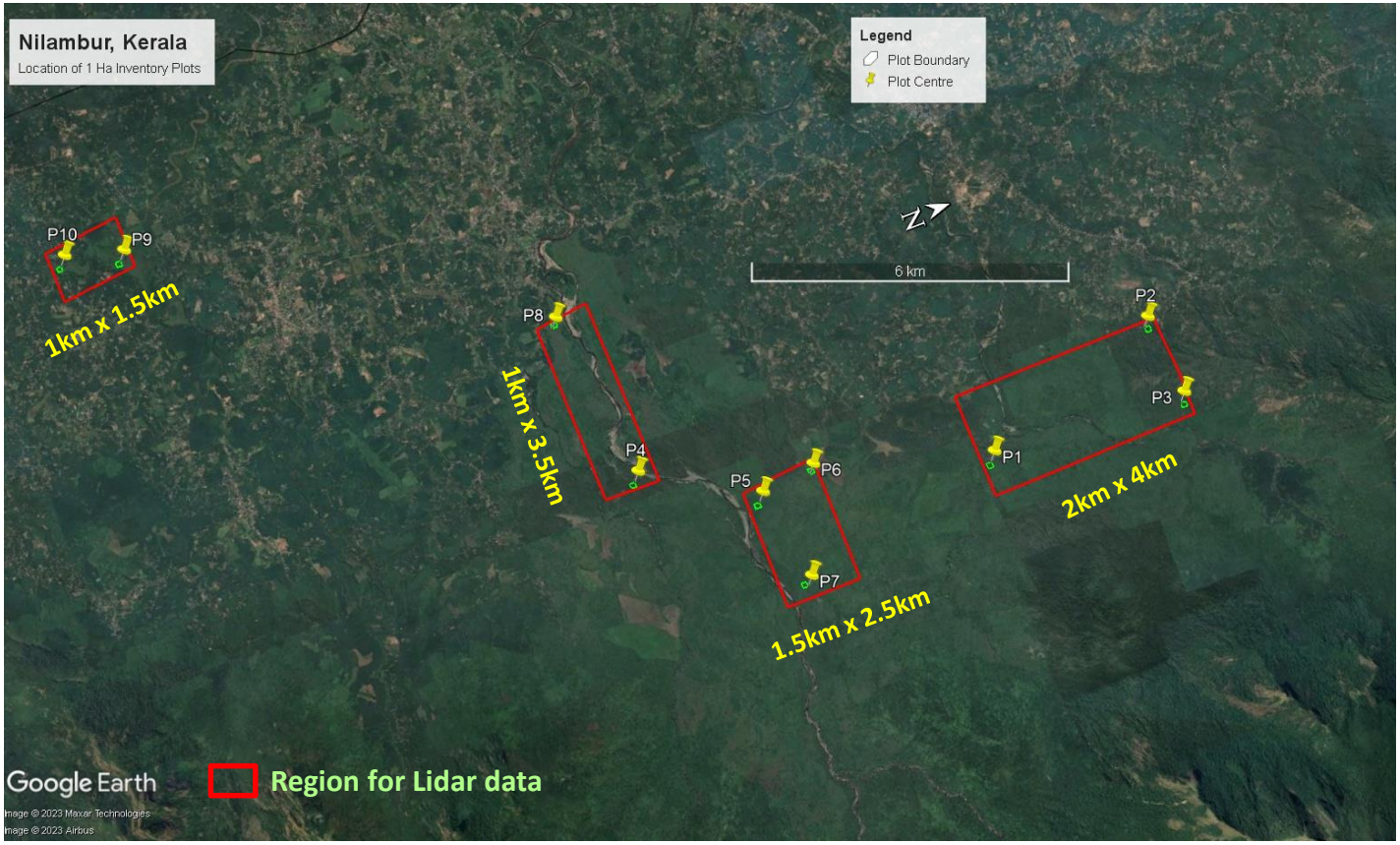
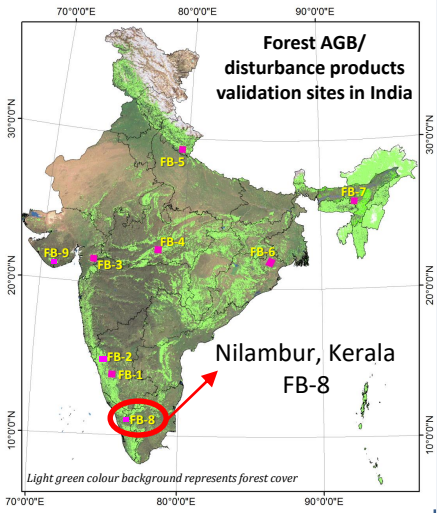
Nilambur, Kerala



10 1Ha Plots



Mix of deciduous and evergreen forests. Part of Nilgiri biosphere reserve, famous for Nilambur Teak

		PLOT-1	PLOT-2	PLOT-3	PLOT-4	PLOT-5	PLOT-6	PLOT-7	PLOT-8	PLOT-9	PLOT-10
NILAMBUR	No. of Trees	190	170	170	353	120	129	176	137	460	597
	No. of Species	13	9	19	15	14	7	14	5	7	3
	Tree Height (m)	11.20	8.70	14.19	12.79	17.81	17.91	15.20	24.98	12.88	13.28
	DBH(cm)	39.58	24.88	38.49	24.69	54.05	46.77	41.15	43.75	18.84	16.84
	AGB (t/ha)	**154.1**	**100.5**	**158.3**	**93.7**	**198.8**	**181.9**	**188.1**	**102.4**	**59.5**	43.6

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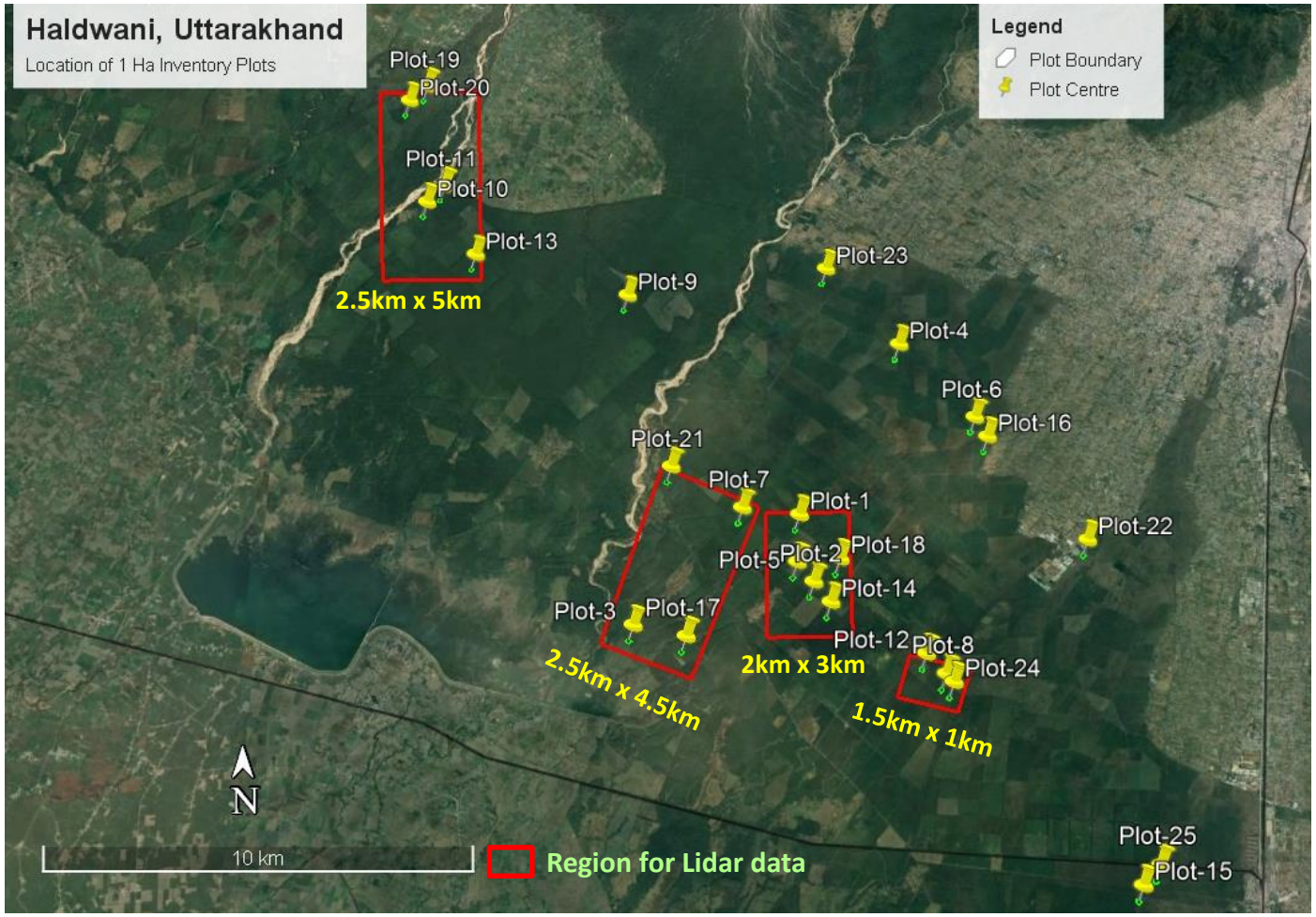
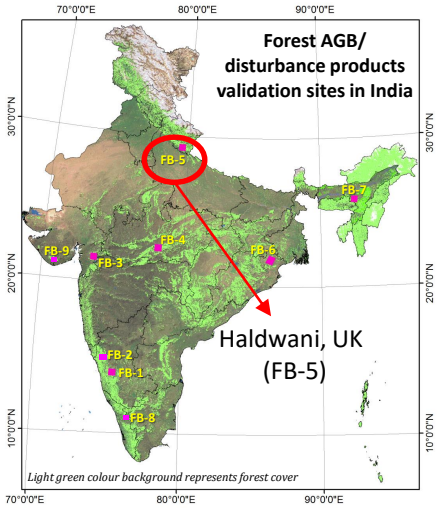
Haldwani, Uttarakhand



25 1Ha Plots



Plantation forests with major species:

Eucalyptus hybrid, *Tectona grandis, Populus deltoides, Acacia catechu, Cassia fistula and Dalbergia sissoo*

Plot Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of Trees	582	630	549	233	1227	302	459	542	250	702	291	268	207	241	541	1299	811	294	387	221	307	179	172	1556	382
Mean Ht. (m)	15.3	14.9	15.6	18.7	9.95	24.1	14.7	17.1	24.1	12.2	16.1	16.1	23.7	14.0	13.7	7.83	18.4	15.2	20.3	20.5	21.8	19.5	25.9	7.9	17.2
GBH (cm)	63.7	47.3	50.8	107.	24.1	92.5	60.9	70.5	100.	50.5	86.1	87.2	112	95.8	49.4	28.2	41.4	45.8	71.4	78.8	82.4	77.7	121.	16.1	76.4
AGB (t/ha)	**147**	**73.2**	**75.7**	**205**	**22.1**	**190**	**76.3**	**159.**	**195.**	**43.6**	**79.7**	**144**	**201**	**134**	**74.6**	**16.9**	**58.6**	**21.8**	**127.**	**93**	**149.**	**90.4**	**202**	**20.1**	**168.**

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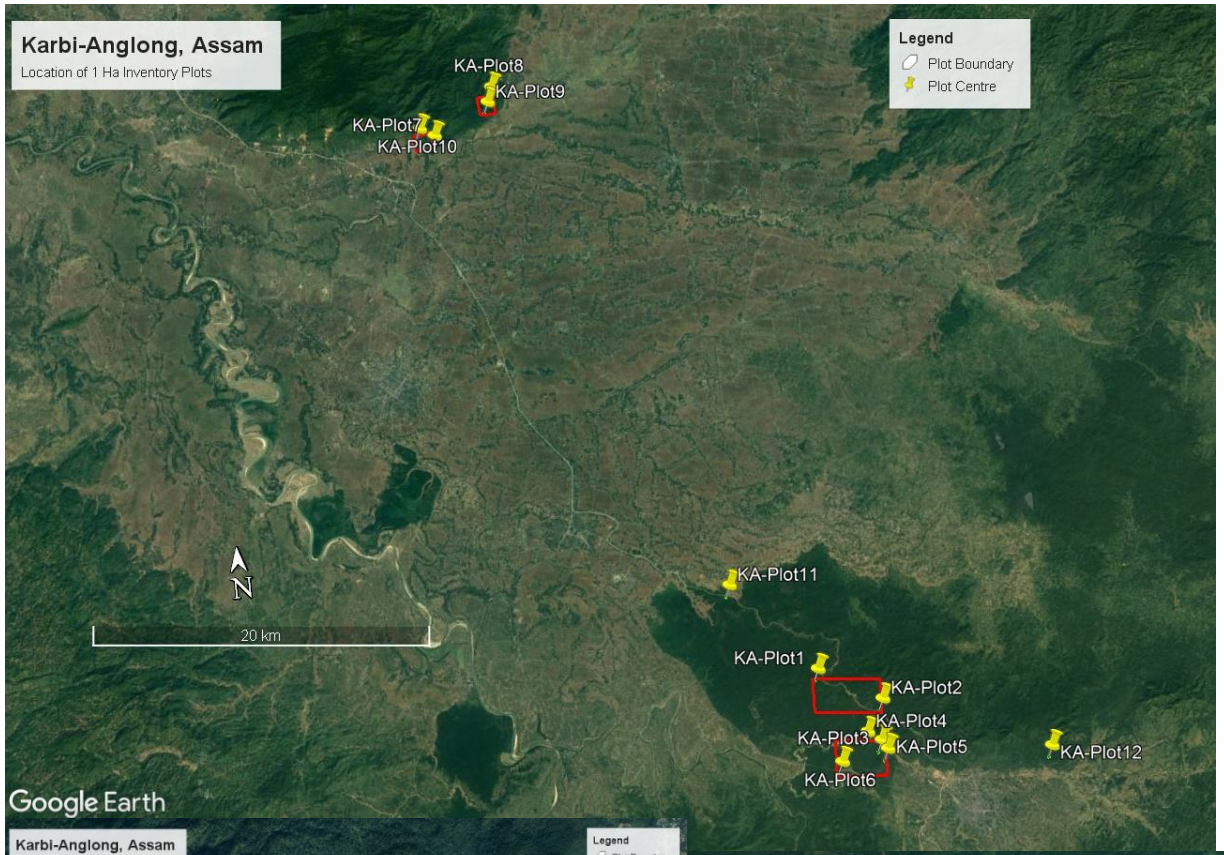
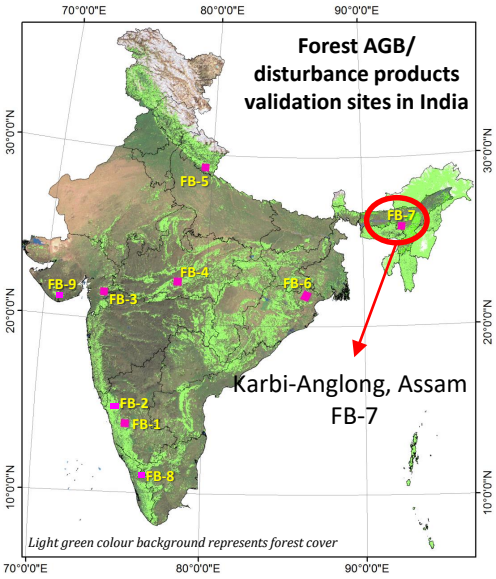
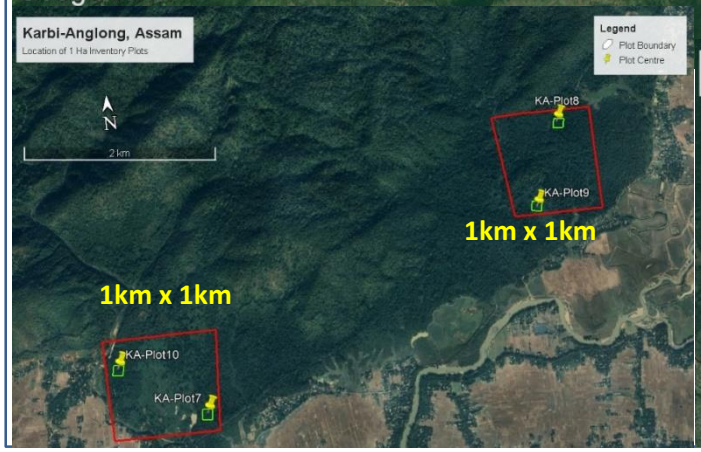
Karbi-Anglong, Assam

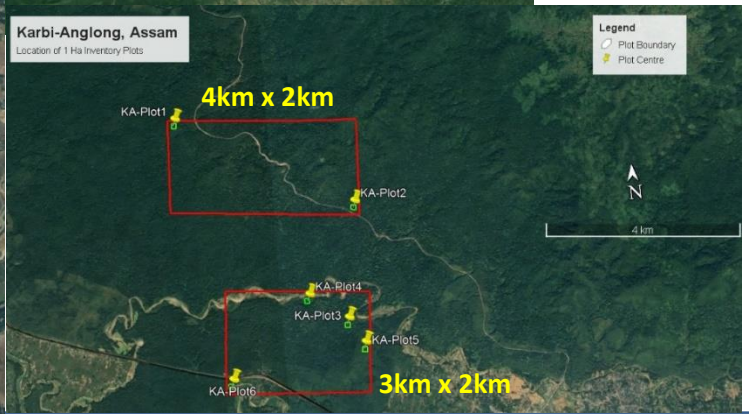


12 1Ha Plots



Moist semi-evergreen forests, Moist mixed deciduous forests, Riverine vegetation and bamboos





Region for Lidar data

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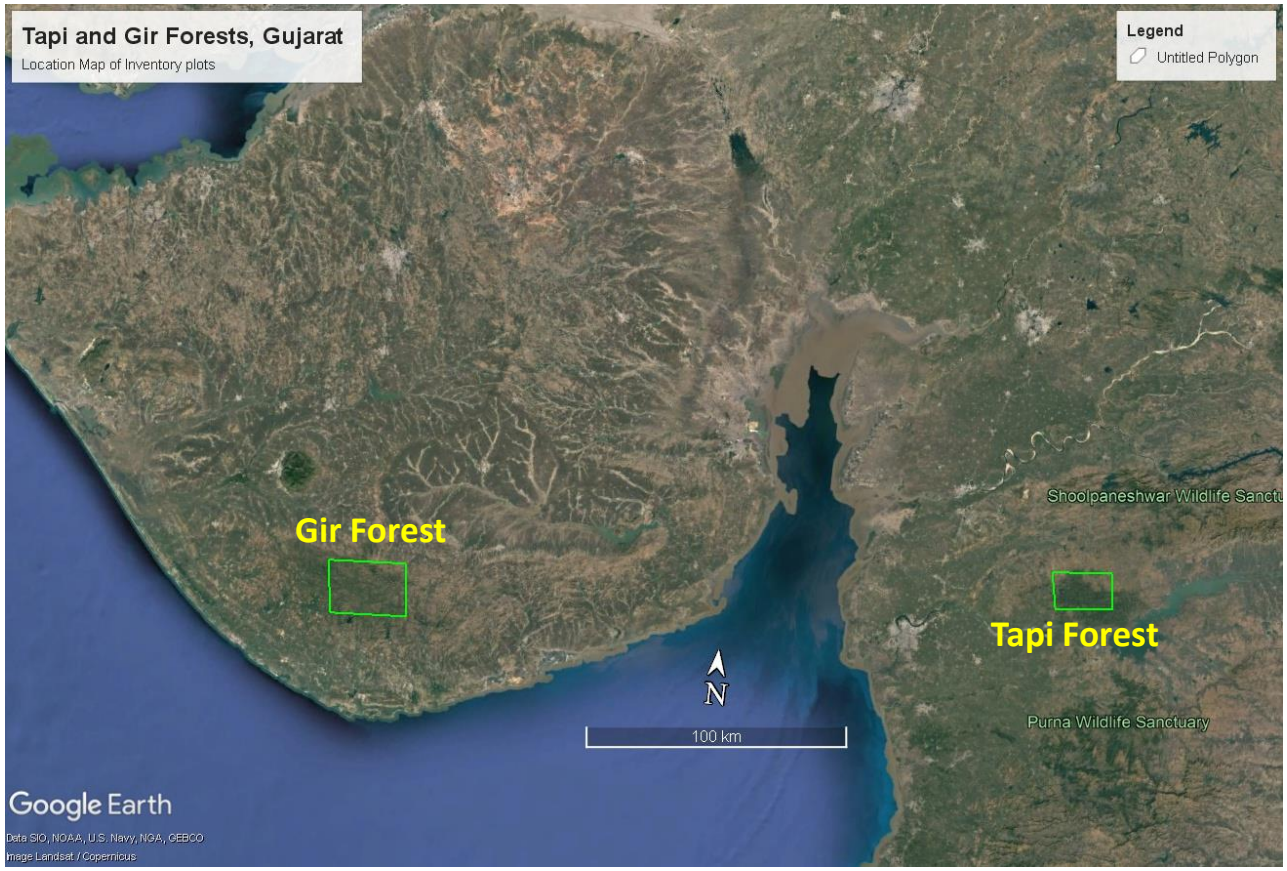
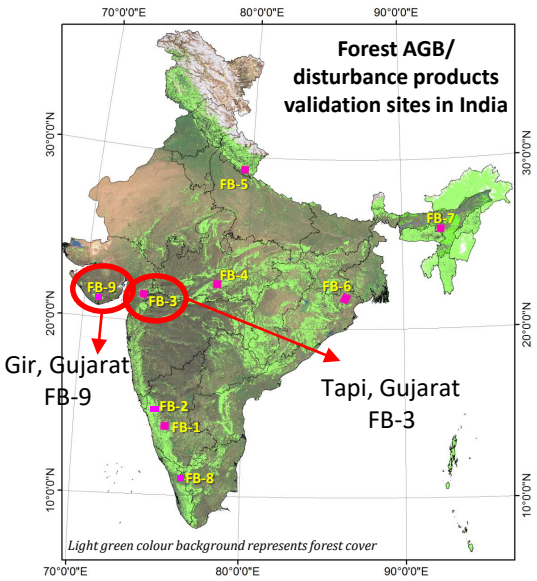
Tapi and Gir Forests, Gujarat



12 + 12 1Ha Plots



Plot level inventory (1ha plots) and collection of large-swath drone-based Lidar and Optical data is planned during Oct 2023 – Mar 2024.

Tapi Forests (FB-3): Dry deciduous to moist evergreen forest with mixed vegetation

Gir Forests (FB-9): Dry deciduous mixed with thorn forests / shrub lands

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ISRO – GEO-TREES Partnership

Thank You

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