Indian National Carbon Project – SDG goal 13

C S Jha & team

National Remote Sensing Centre
Indian Space Research Organisation
Hyderabad , India

"...the "environment" is where we live; and "development" is what we all do in attempting to improve our lot within that abode. The two are inseparable." – Our common future

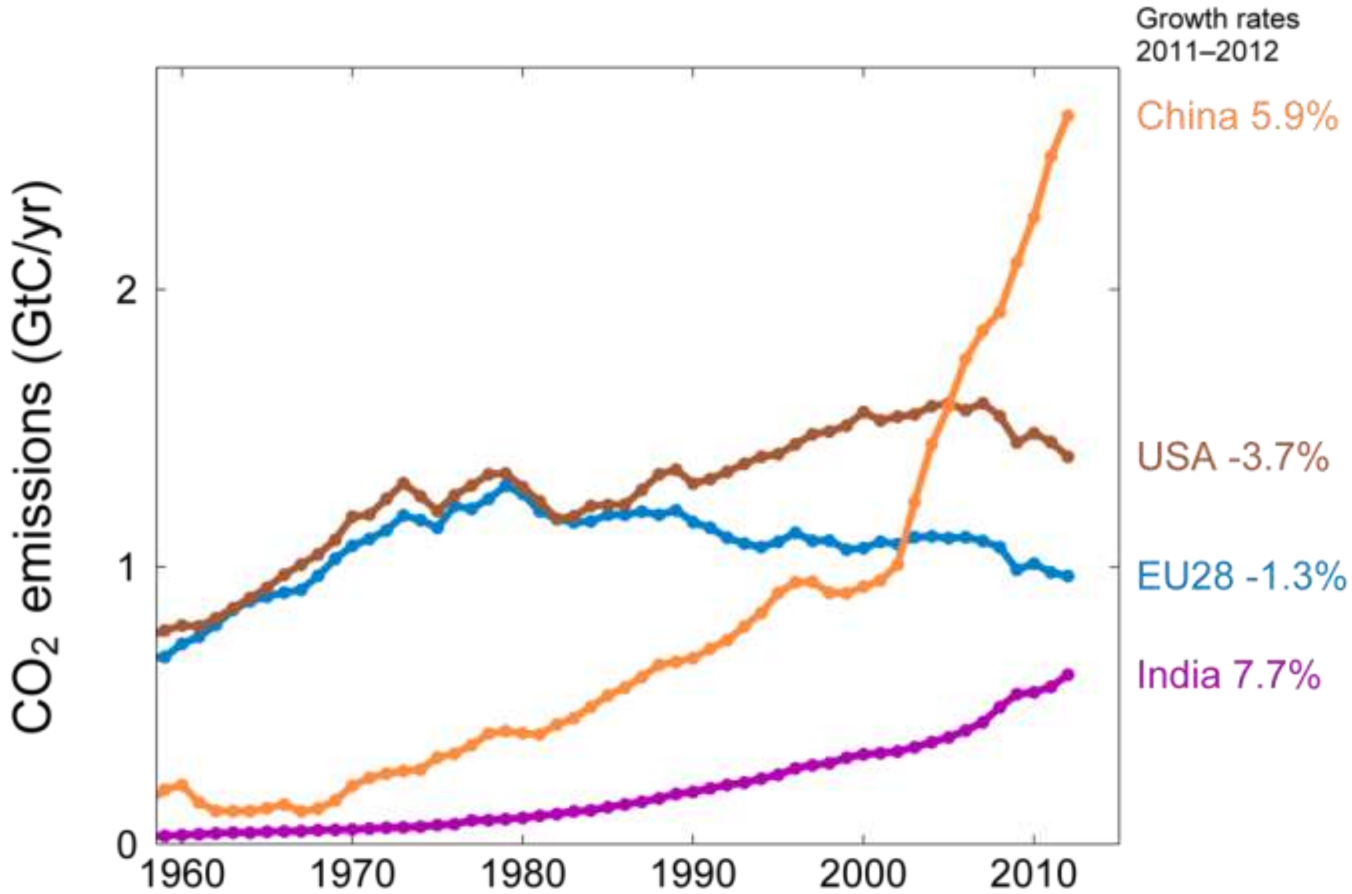
GEOSS-AP, *2017*

United Nations Bruntland report - 1987

In the middle of the 20th century, we saw our planet from space for the first time. Historians may eventually find that this vision had a greater impact on thought than did the Copernican revolution of the 16th century, which upset the human self-image by revealing that the Earth is not the centre of the universe. From space, we see a small and fragile ball dominated not by human activity and edifice but by a pattern of clouds, oceans, greenery, and soils. Humanity's inability to fit its activities into that pattern is changing planetary systems, fundamentally. Many such changes are accompanied by life-threatening hazards. This new reality, from which there is no escape, must be recognized - and managed.

Top Fossil Fuel Emitters (Absolute)

Top four emitters in 2012 covered 58% of global emissions
China (27%), United States (14%), EU28 (10%), India (6%)



With leap year adjustment in 2012 growth rates are: China 5.6%, USA -4.0%, EU -1.6%, India 7.4%.

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

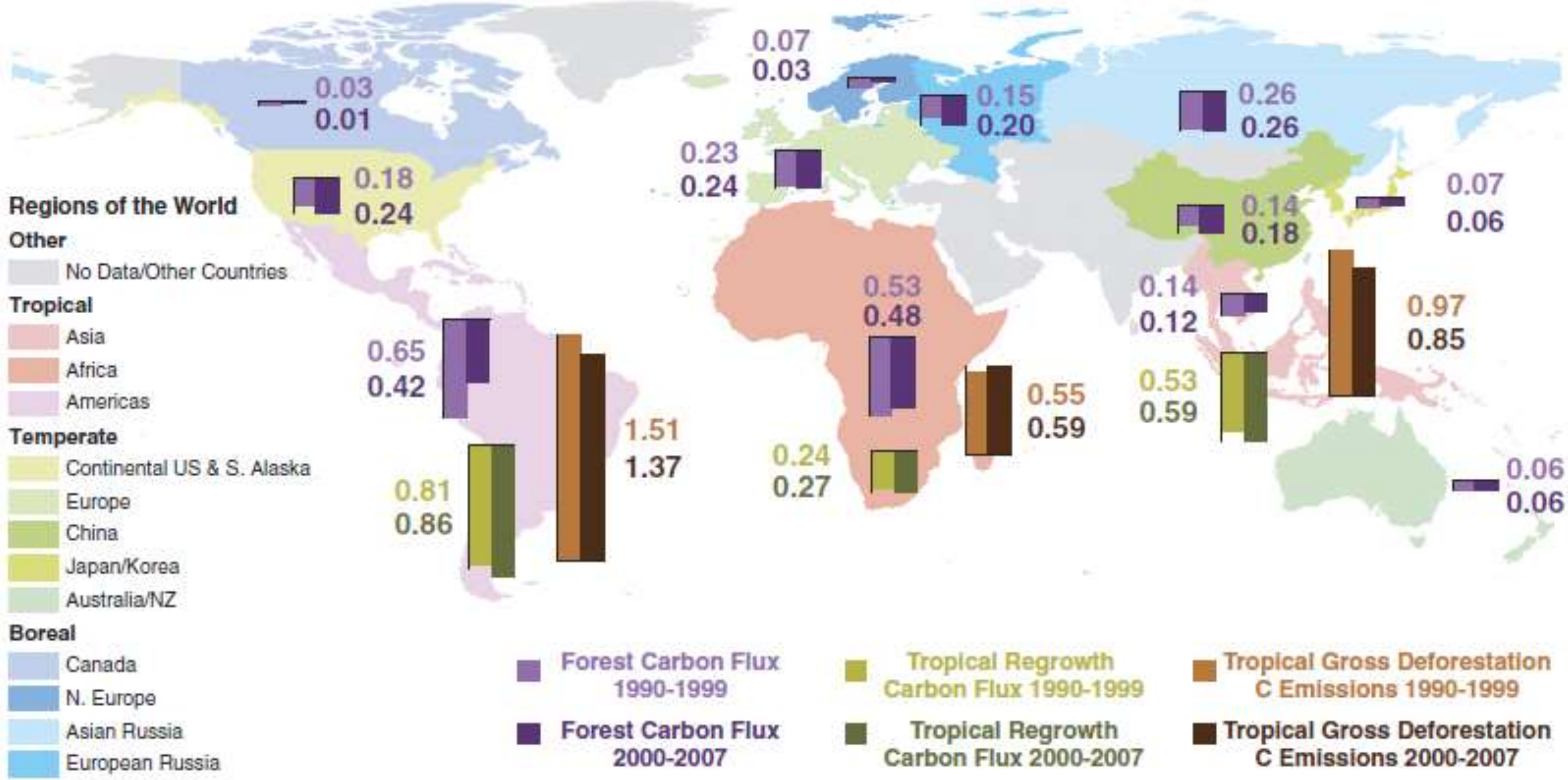


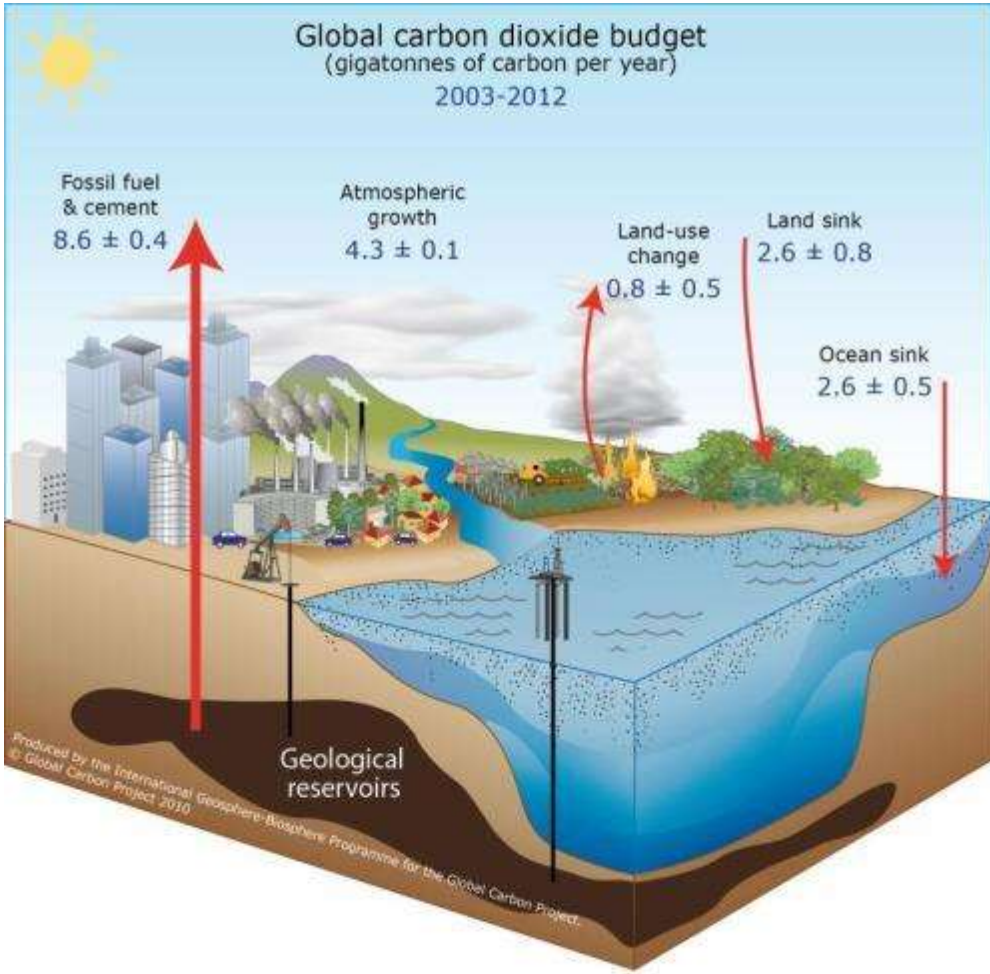
Fig. 1. Carbon sinks and sources (Pg C year^{-1}) in the world's forests. Colored bars in the down-facing direction represent C sinks, whereas bars in the upward-facing direction represent C sources. Light and dark purple, global established forests (boreal, temperate, and intact tropical forests); light and dark green, tropical regrowth forests after anthropogenic disturbances; and light and dark brown, tropical gross deforestation emissions.

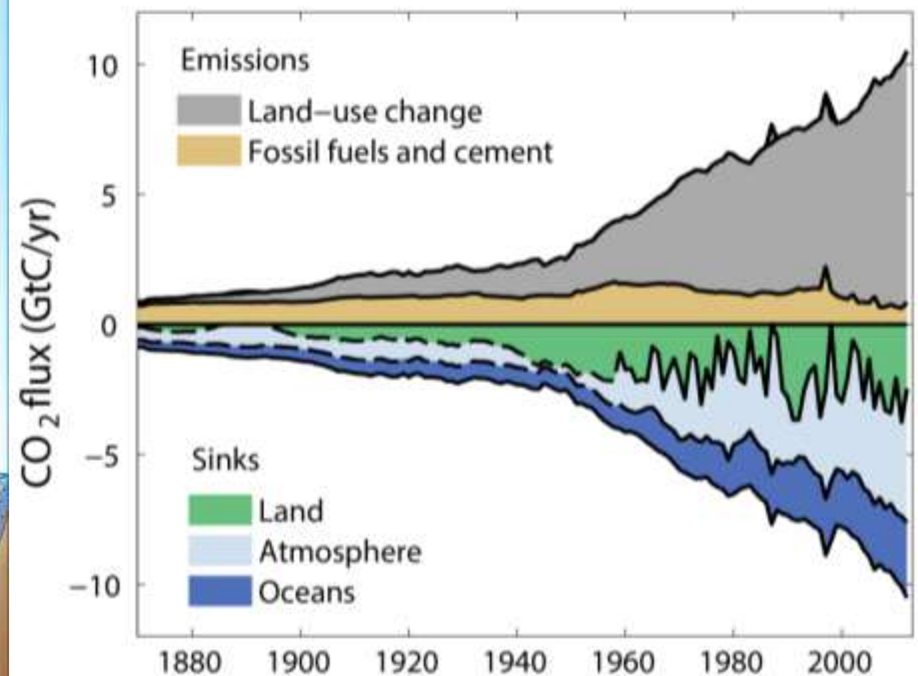
A Large and Persistent Carbon Sink in the World's Forests

AUGUST 2011 VOL 333 **SCIENCE** www.sciencemag.org

Yude Pan,[1]* Richard A. Birdsey,[1] Jingyun Fang,[2,3] Richard Houghton,[4] Pekka E. Kauppi,[5] Werner A. Kurz,[6] Oliver L. Phillips,[7] Anatoly Shvidenko,[8] Simon L. Lewis,[7] Josep G. Canadell,[9] Philippe Ciais,[10] Robert B. Jackson,[11] Stephen W. Pacala,[12] A. David McGuire,[13] Shilong Piao,[2] Aapo Rautiainen,[5] Stephen Sitch,[7] Daniel Hayes[14]

Global Carbon Cycle (GtC/yr)



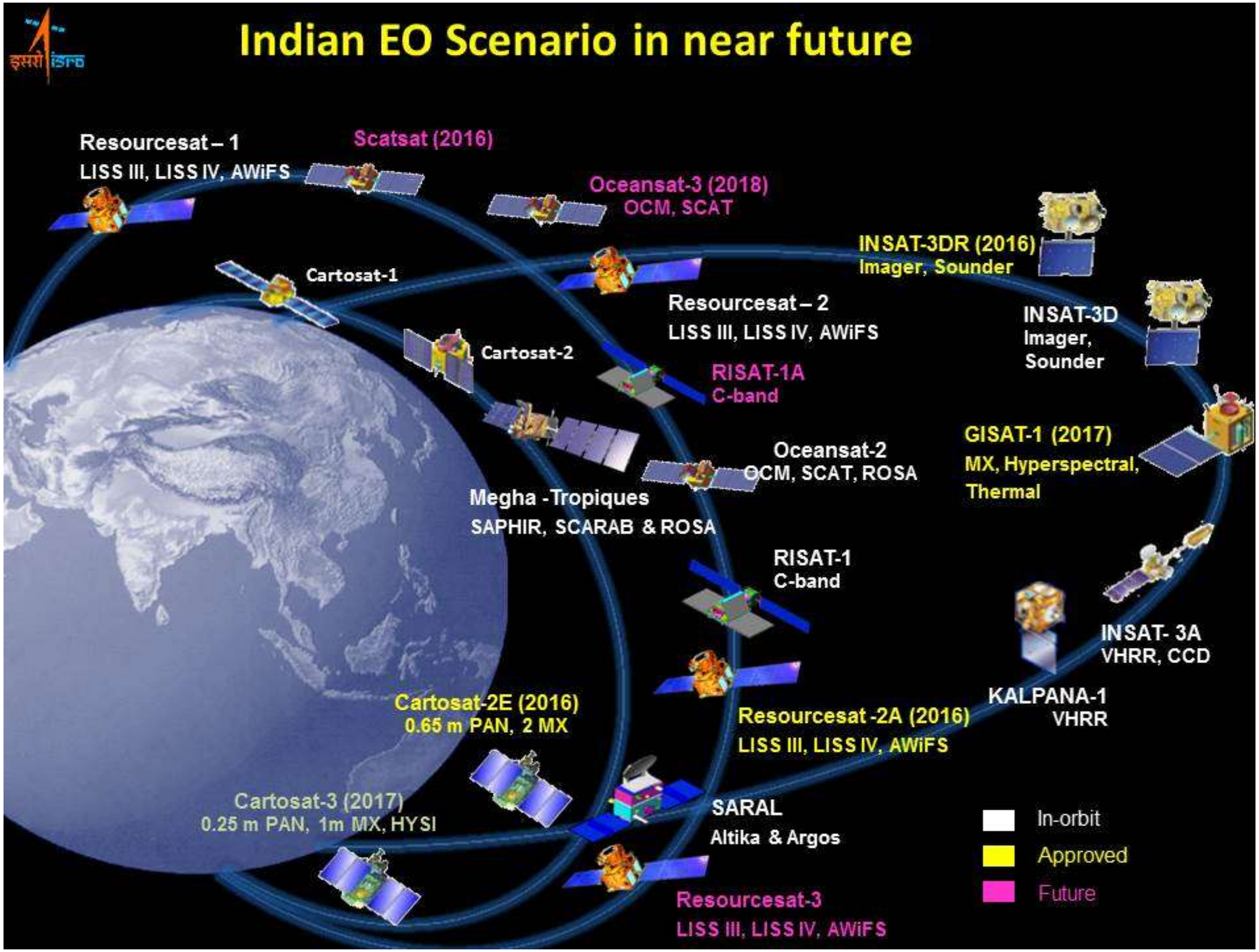


Source: Le Quéré et al 2013; CDIAC Data; NOAA/ESRL Data; Global Carbon Project 2013

- ✓ **Annual automated forest loss alert system**
- ✓ **Stubble burning in Indo-Gangetic plains**
- ✓ **Satellite monitoring of Pollutants**
- ✓ **SAR and LiDAR based forest biomass**
- ✓ **Biodiversity mapping at 1:10,000**

Energy and Environment

INDC – 2.5 b tons of CO2 – COP



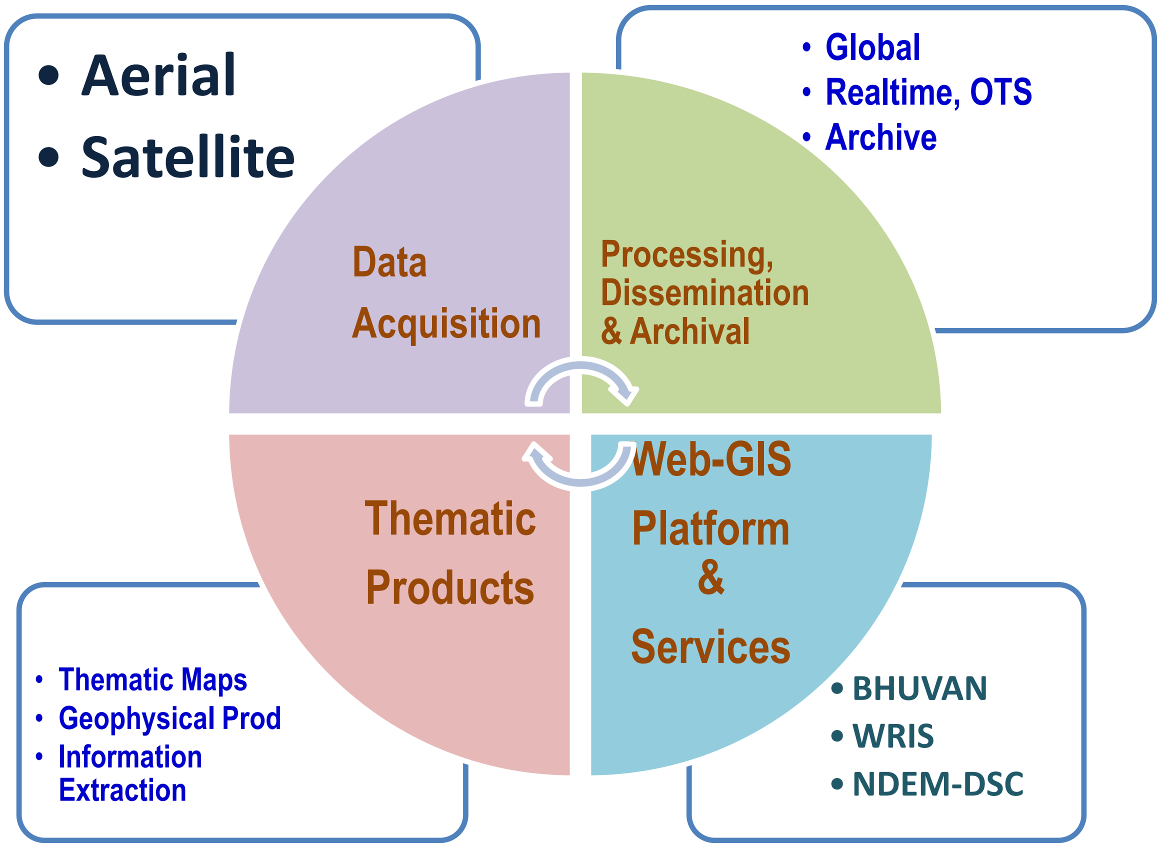
Indian EO Scenario in near future
Resourcesat – 1
LISS III, LISS IV, AWiFS
Scatsat (2016)
Oceansat-3 (2018)
OCM, SCAT
INSAT-3DR (2016)
Imager, Sounder
Cartosat-1
Resourcesat – 2
LISS III, LISS IV, AWiFS
INSAT-3D
Imager,
Sounder
Cartosat-2
RISAT-1A
C-band
GISAT-1 (2017)
MX, Hyperspectral,
Thermal
Oceansat-2
OCM, SCAT, ROSA
Megha -Tropiques
SAPHIR, SCARAB & ROSA
RISAT-1
C-band
INSAT- 3A
VHRR, CCD
KALPANA-1
VHRR
Cartosat-2E (2016)
0.65 m PAN, 2 MX
Resourcesat -2A (2016)
LISS III, LISS IV, AWiFS
Cartosat-3 (2017)
0.25 m PAN, 1m MX, HYSI
SARAL
Altika & Argos
Resourcesat-3
LISS III, LISS IV, AWiFS
In-orbit
Approved
Future

NRSC FACILITIES

Off Campus Technical Facilities

- **Satellite Data Reception, Larsemann Hills, Antartica**
- **Hangar Facilities for Aircraft at Begumpet Airport**
- **Field Observation Laboratories for Carbon & Water Fluxes at Betul (MP), Sunderbans (WB), ….**

Our Activities

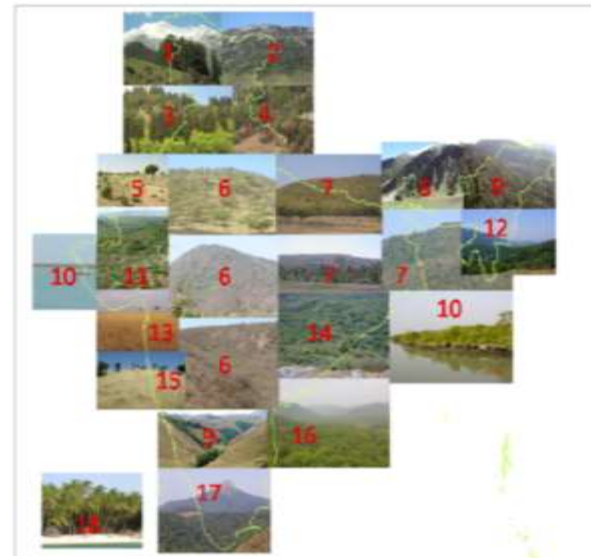


Presentation Outline

- Background – SDG and climate change
- Applications of RS by NRSC (ISRO) in
  - National Biodiversity Characterization
  - Vegetation and soil Carbon – pools & fluxes
  - Indian National Communications to the UNFCCC
  - Forest and Agriculture Fires inventory & Alert
  - National forest cover loss assessment
- Challenges and way forward

India – Vegetation Types

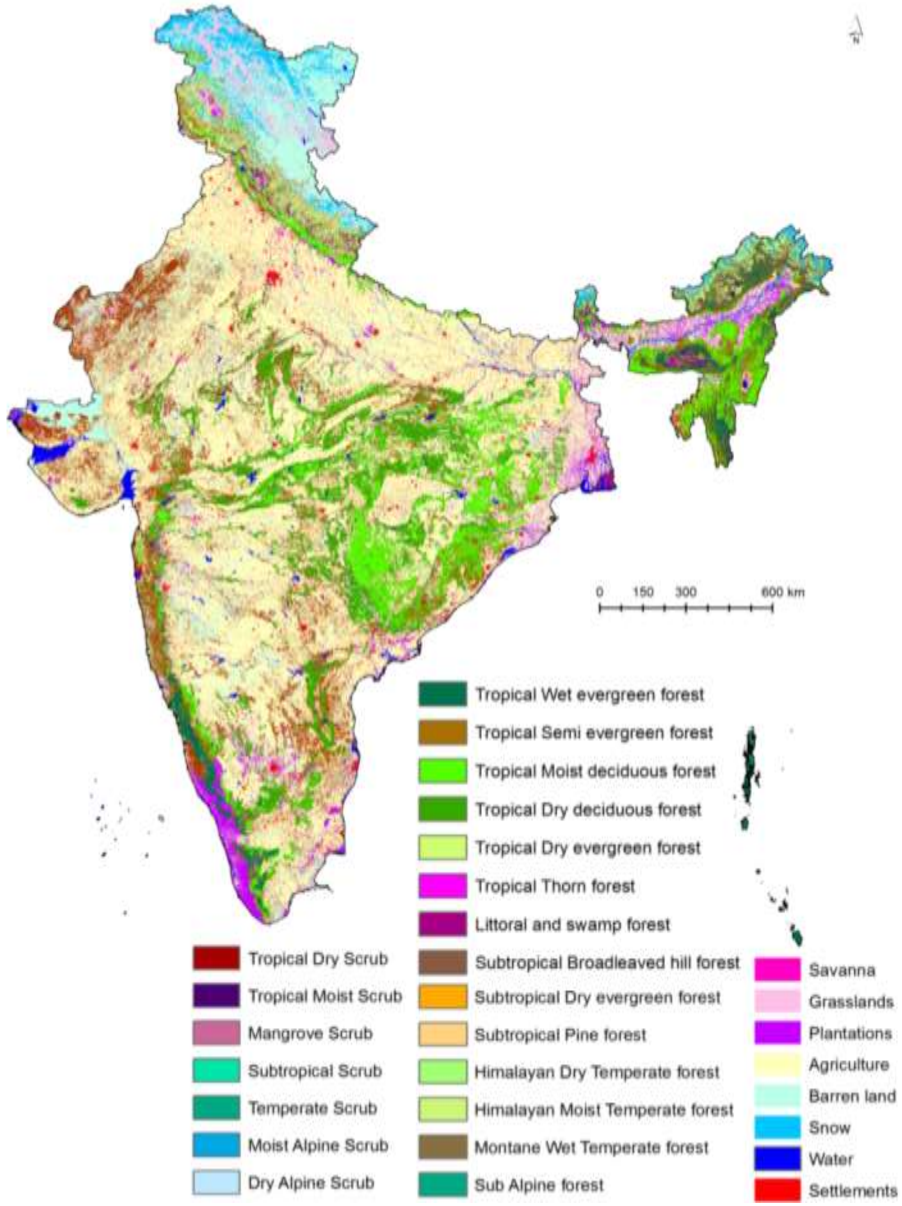
1. Himalayan Dry temperate forest 2. Moist Alpine Scrub 3. Himalayan Moist temperate forest
4. Subtropical Pine forest 5. Tropical dry scrub 6. Tropical Dry Deciduous forest
7. Tropical Moist Deciduous forest 8. Sub Alpine forest 9. Montane wet temperate forest
10. Littoral and Swamp forest (Mangroves) 11. Tropical Thorn forest 12. Subtropical broadleaved hill forest
13. Grassland 14. Tropical Semi evergreen forest 15. Savanna 16. Tropical Dry evergreen forest
17. Tropical Wet Evergreen forest 18. Plantations



✓ **Primary Database on Vegetation**

Reddy, C.S., Jha, C.S., Diwakar, P.G. & Dadhwal, V.K. 2015. Nationwide classification of forest types of India using remote sensing and GIS (*Environmental Monitoring and Assessment* DOI: 10.1007/s10661-015-4990-8).

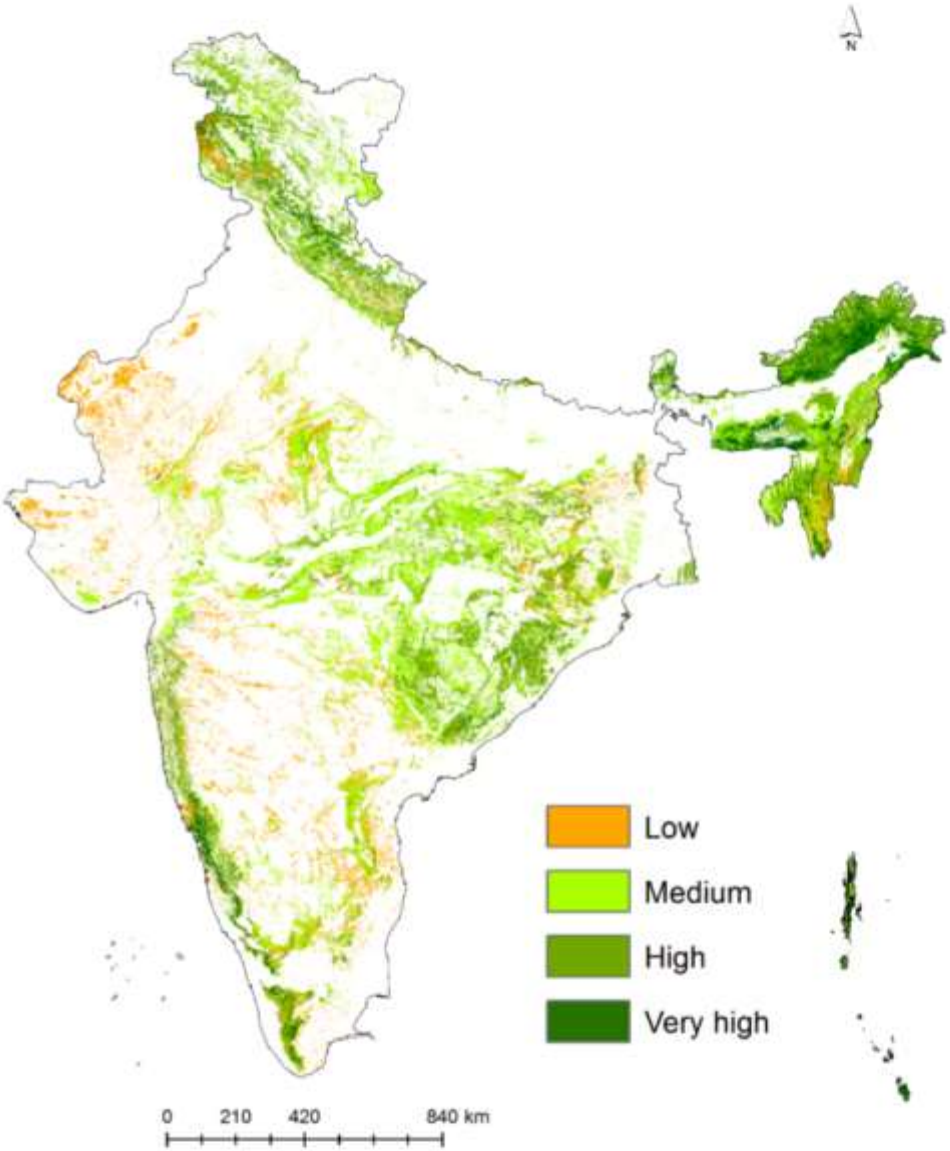
Vegetation type and land cover map



Class	Area (km²)	% of Area
Tropical wet evergreen forest	47192	1.44
Tropical dry evergreen forest	378	0.01
Subtropical broad leaved hill forest	20623	0.63
Subtropical dry evergreen forest	354	0.01
Montane Wet Temperate forest	7457	0.23
Tropical Semi evergreen forest	48295	1.47
Tropical moist deciduous forest	20,7,649	6.32
Tropical dry deciduous forest	21,7,713	6.62
Tropical thorn forest	8166	0.25
Subtropical Pine forest	22880	0.70
Himalayan Moist Temperate forest	27510	0.84
Himalayan Dry Temperate forest	7634	0.23
Sub Alpine forest	5774	0.18
Littoral and swamp forests	3940	0.12
Tropical moist scrub	19614	0.60
Subtropical scrub	4415	0.13
Temperate scrub	553	0.02
Moist Alpine scrub	4278	0.13
Dry Alpine scrub	10400	0.32
Mangrove scrub	853	0.03
Tropical dry scrub	212364	6.46
Grasslands	81494	2.48
Savanna	5592	0.17
Agriculture	17,49,076	53.21
Plantations/Orchards	95586	2.91
Barren land	267837	8.15
Water bodies	84801	2.58
Snow	62314	1.90
Settlements	62521	1.90
Grand total	32,87,263	100.00

Reddy, C.S., Jha, C.S., Diwakar, P.G. & Dadhwal, V.K. 2015. Nationwide classification of forest types of India using remote sensing and GIS (*Environmental Monitoring and Assessment* DOI: 10.1007/s10661-015-4990-8).

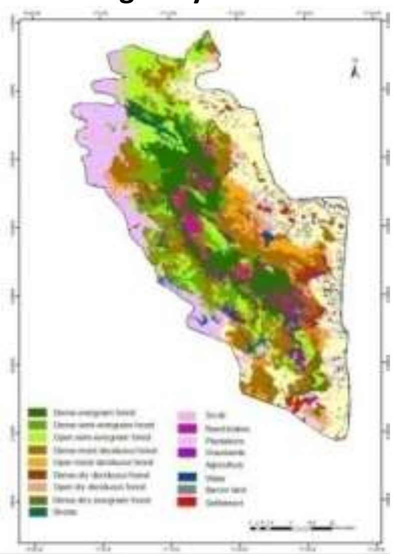
Biological Richness



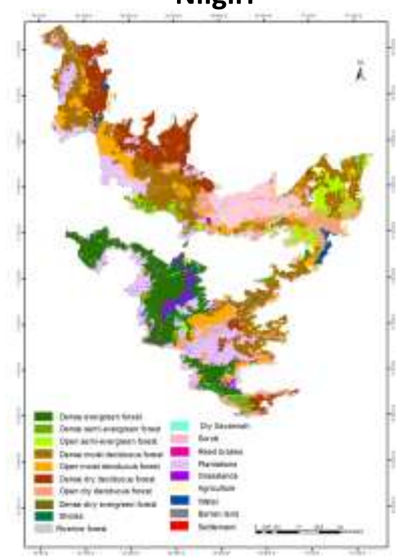
Biologically rich areas delineated using geospatial techniques……..Provides baseline for conservation prioritization and monitoring

Inventorisation and Monitoring of Biosphere Reserves

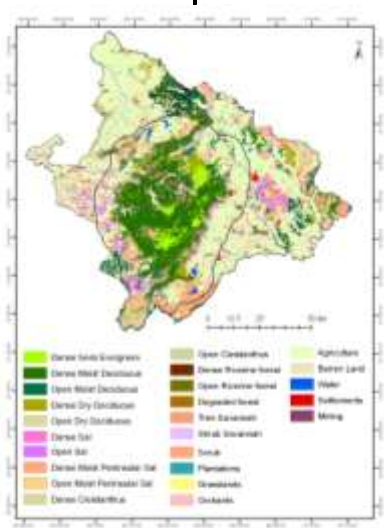
Agasthyamalai



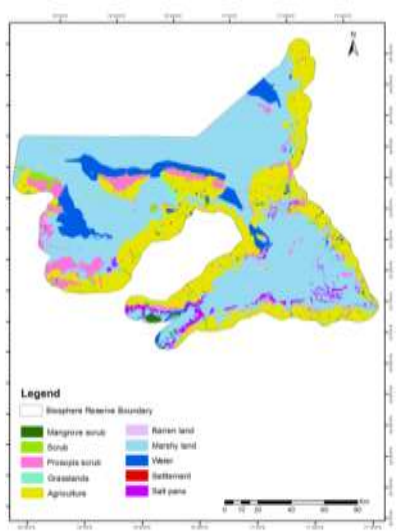
Nilgiri



Similipal



Kachchh



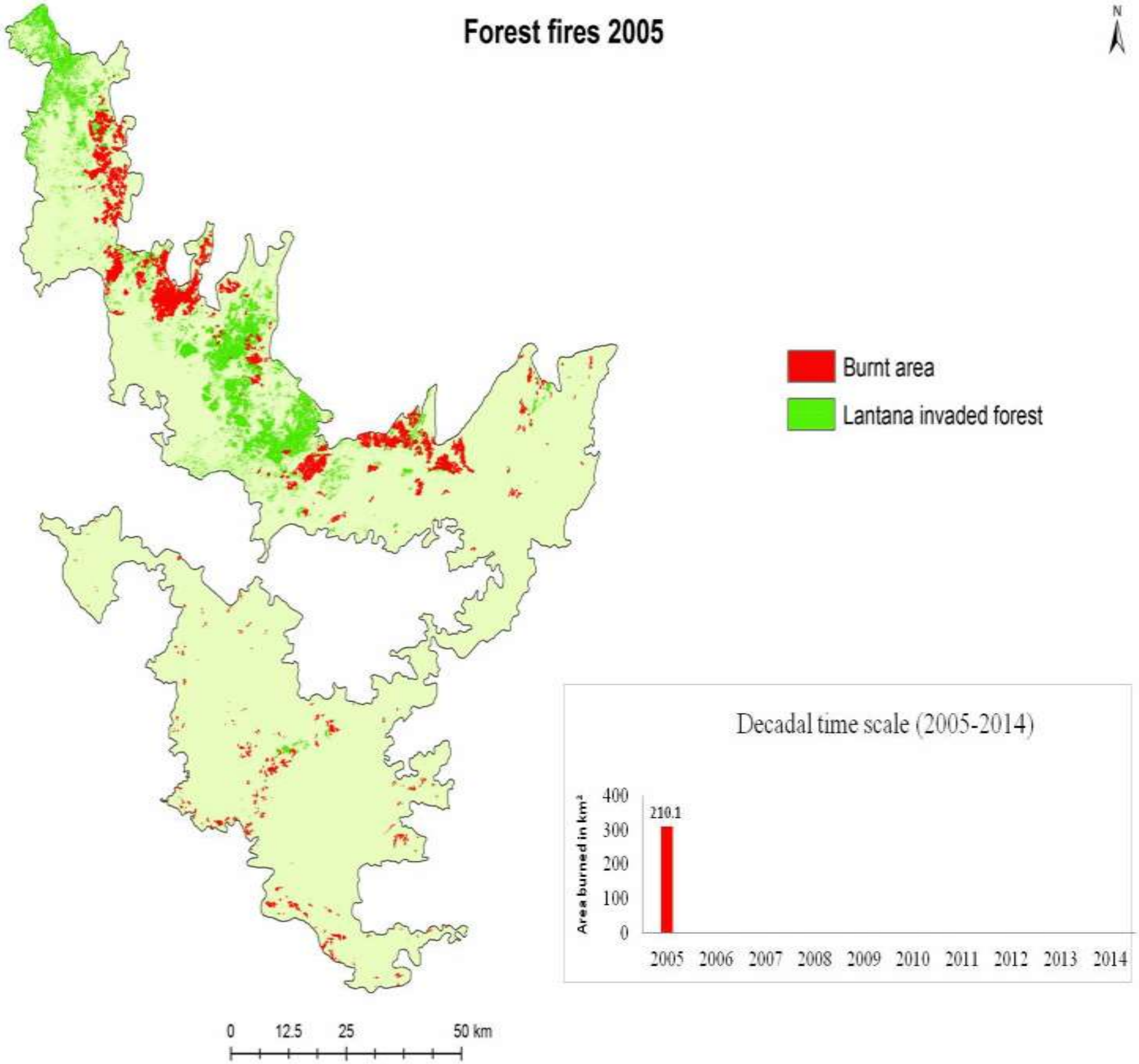
Biosphere monitoring under MAB is critical for verifying conservation efficacy.

Long term satellite records help to clarify issues better.

Study requested by MoEnF aims at create NR database for analysing Land use / land cover in four major biospheres of the country viz., Simlipal, Nilgiri, Rann and Agasthymalai.

Assess temporal changes in land use dynamics (at 5 year interval, starting from date of notification) using IRS Dataset.

Datasets correspond to 1990,1995,2000,2005 and 2010 periods in tandem with current phytosociology.



Forest fires 2005
N
Burnt area
Lantana invaded forest
Decadal time scale (2005-2014)
Area burned in km²
400
300
200
100
0
210.1
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
0
12.5
25
50 km

National Carbon Project (NCP)
ISRO's Geosphere Biosphere Programme (ISRO-GBP)

- **NCP was initiated as a major integrated project under ISRO-GBP in 2007 with major goals on**
  - ***Assessment of Carbon Pools, Fluxes and Net Carbon balance for terrestrial biosphere in India***
  - ***To establish a observational network and remote sensing-based spatial databases for modeling and periodic assessment of carbon balance***
  - ***To provide support to national activity with respect to carbon balance under National Communication to UNFCCC***
- **Achieved through implementation of 3 sub-projects, namely**
  - ***VCP : Vegetation Carbon Pool – National integrated sampling***
  - ***SCP : Soil Carbon Pool – National Integrated sampling***
  - ***SVF : Soil & Vegetation - Atmosphere Fluxes – Flux Towers, RS-based modeling***
  - ***Atmospheric Carbon Observations & Hydro-geochemistry***

IGBP-NCP Terrestrial Carbon Cycle Component Studies

- **Soil-Vegetation-Atmosphere fluxes (SVAF)**
  - **Flux towers, Forests & Agriculture**

    eddy flux based observation network to monitor net carbon exchange in forests & agriculture

    Upscaling flux measurements to regional scale using remote sensing
- **Vegetation Carbon Pools (VCP)**
  - **Phytomass**
  - **Long term forest cover change**

    National, spatially explicit Tier-III based forest carbon pool and change assessment over India through conjunctive use of remote sensing, and field data (with revisit measurement)
- **Soil Carbon Pools (SCP)**
  - **Soil Carbon Pools dataset**

    National spatial estimates of organic and inorganic soil carbon stocks

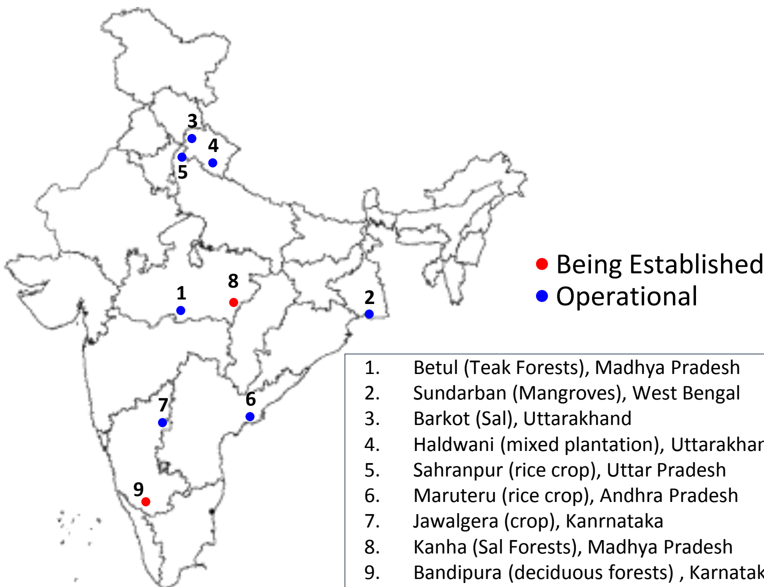
Soil-Vegetation-Atmosphere Fluxes (SVAF)
Flux towers - Objectives

- Establish eddy flux based observation network to monitor net carbon exchange
- Measurement and modeling of soil respiration / emission fluxes
- Up-scaling of carbon assimilation fluxes to regional scale using satellite remote sensing
- Modeling C-fluxes in forest ecosystem using forest cover change, forest growth models and inventory data
- Evaluation of spatial terrestrial carbon model for long-term simulation of carbon cycle over India

Sub Project: Soil-Vegetation-Atmosphere fluxes (SVAF)
Forest & Agriculture Ecosystems

Objectives

- To establish eddy flux tower based observation network for monitoring net carbon exchange.
- Up-scaling flux measurements to regional scale using remote sensing



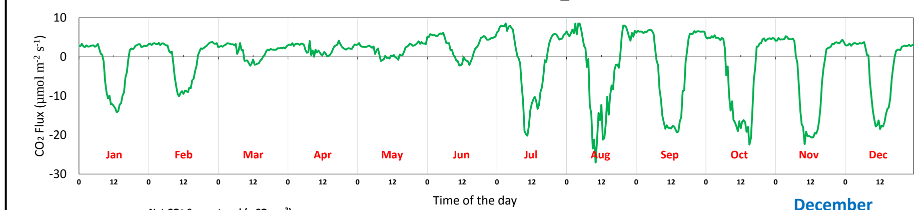
1. Betul (Teak Forests), Madhya Pradesh
2. Sundarban (Mangroves), West Bengal
3. Barkot (Sal), Uttarakhand
4. Haldwani (mixed plantation), Uttarakhand
5. Sahranpur (rice crop), Uttar Pradesh
6. Maruteru (rice crop), Andhra Pradesh
7. Jawalgera (crop), Kanrnataka
8. Kanha (Sal Forests), Madhya Pradesh
9. Bandipura (deciduous forests) , Karnataka

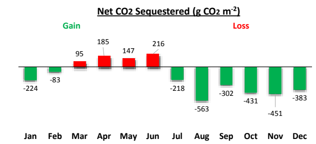
Betul, Teak Forests, MP

Sundarbans, WB

Kanha flux tower

Diurnal Average variation of CO_2 Flux – Betul, M.P



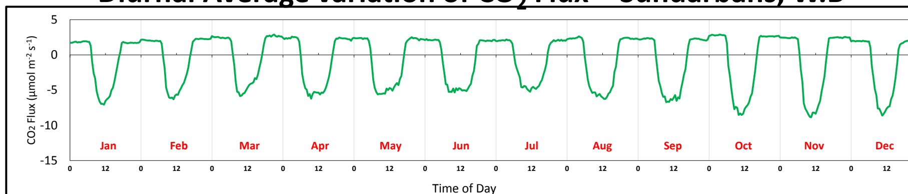


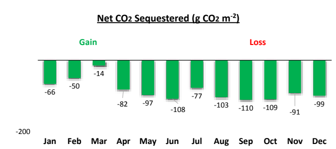
Net Annual Production

2012.87 g CO_2 m^{-2}
(or)
548.46 g C m^{-2}.

December

Diurnal Average variation of CO_2 Flux – Sundarbans, W.B





Net Annual Production

1005.32 g CO_2 m^{-2}
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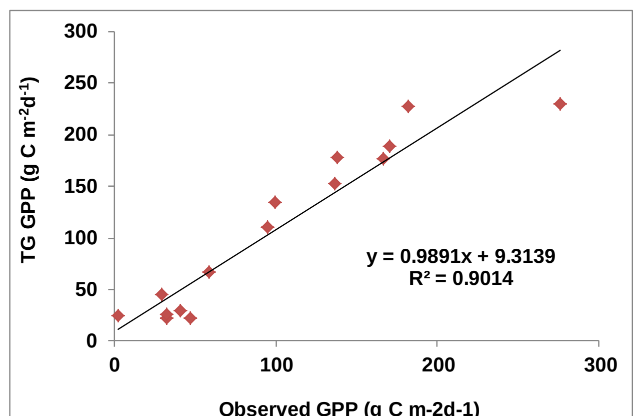


Upscaling of tower based fluxes to regional level using remote sensing

Temperature-Greenness Model

Flux Tower Measurement: Status

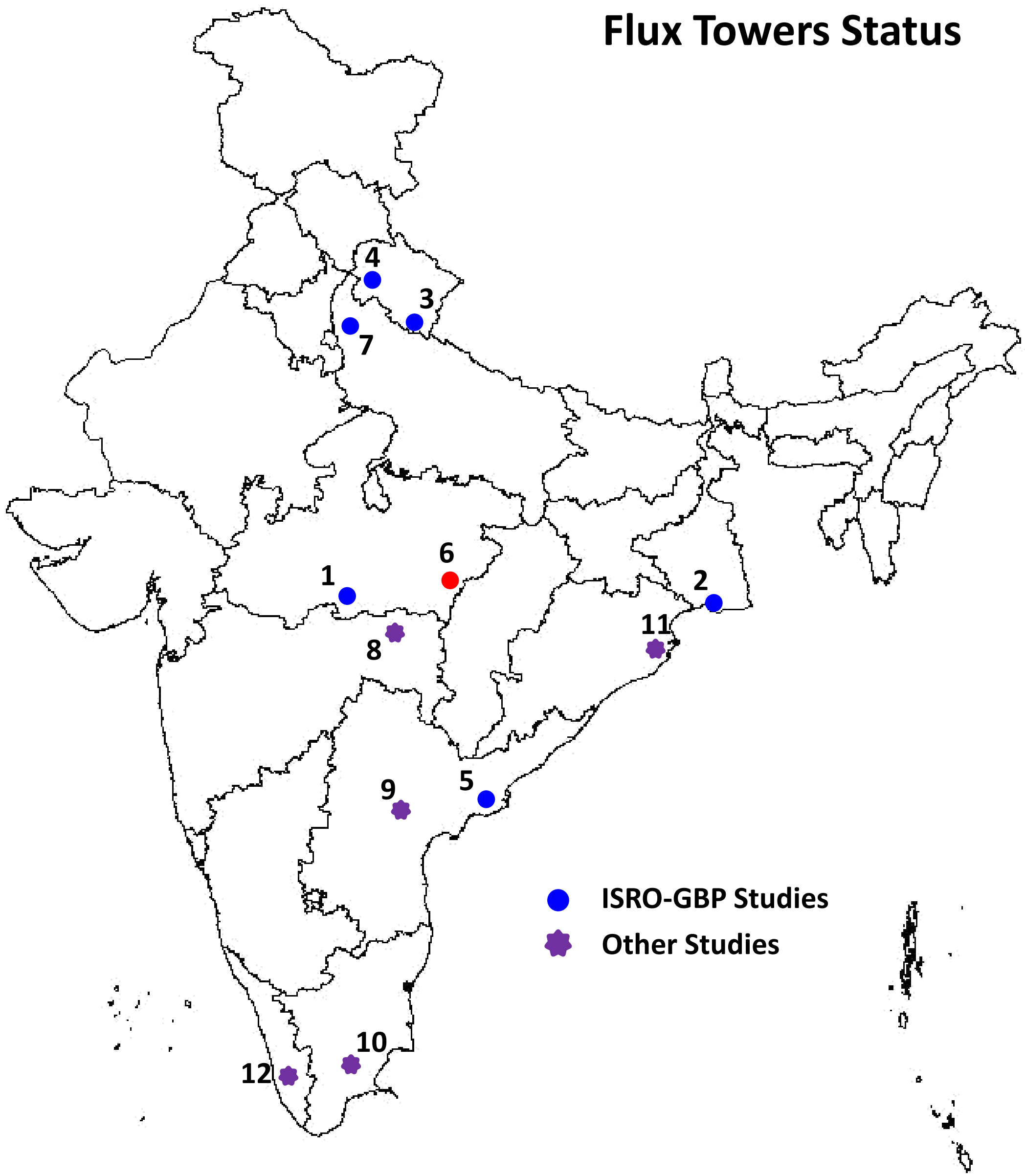
Implementation Steps

- Site Selection
- MOU / Forest Dept
- AAI/DGCA Approval
- Site Infrastructure
- Tower Establishment
- Instrument installation
- Operational with field data

Flux Tower Status

1. Betul , teak forests
2. Sundarbans, mangroves
3. Haldwani, mixed plantation
4. Barkot, sal forests
5. Maruteru, rice crop
6. Kanha, Sal Forests
7. Rice Crop, Meerut
8. Gumngaon (NEERI)
9. Mahabubnagar (By IITM)
10. Grasslands, Madurai
11. Rice crop, CRRI, Cuttack
12. Rubber Plantation, RRI, Kottayam

Flux Towers Status



Sensors on Betul Flux Tower

CO_2, H_2O Flux

Fast Response – IRGA & Ultrasonic Anemometer
Frequency of Measurement: 10 Hz

Sap Flow

Sap Flow Meter (HRM Sensor)
Frequency of Measurement: 15 min

Phenology Camera

Phenocam (CC5MPX)
Frequency of Measurement: 30 min

Data Logger

Data Logger – Campbell Sci. CR3000

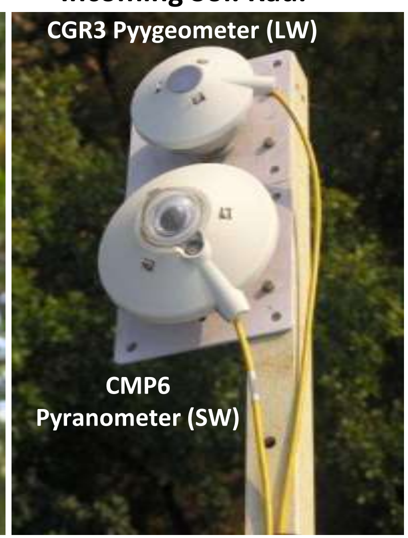
Wind Speed & Dir.

RM YOUNG - 5103

RH & Air Temp.

Rotoronic Hygroclips S3

Incoming Sol. Rad.



CGR03, CMP6

Soil Moist.

Delta-T PR2 - 6

Soil Temp.

Komoline KDS-037

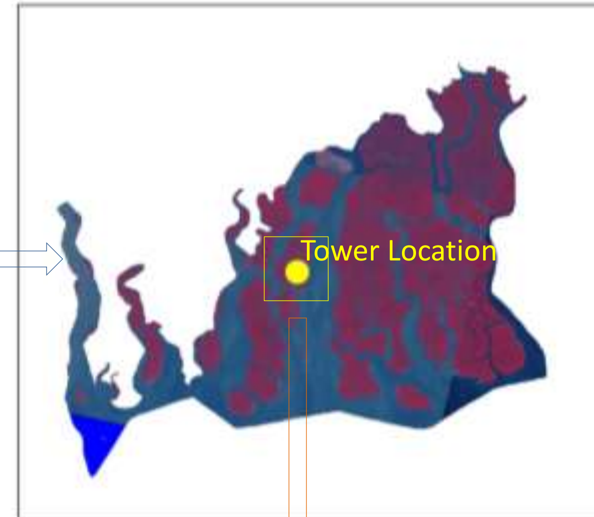
Automated Soil CO_2

LI-8100A

Sunderban Carbon Flux Tower Location

India

Sunderban Biosphere Reserve

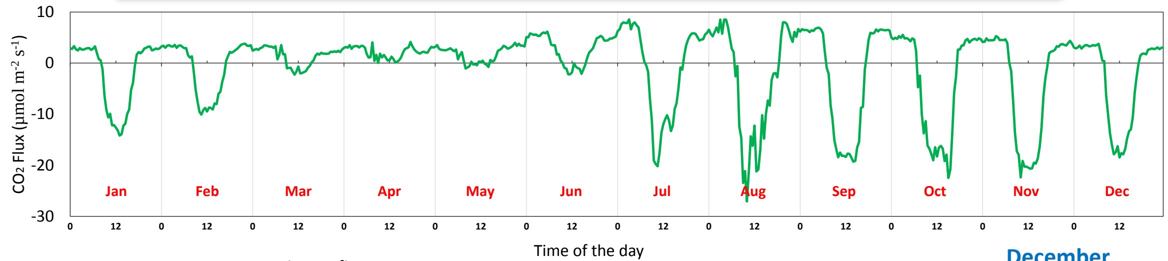


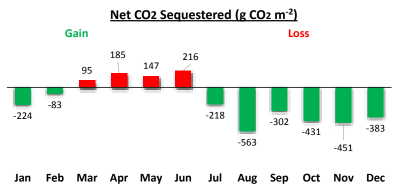
Creeks

Canopy Walkway

Carbon Flux Tower Location

Seasonal Diurnal Average variation of CO_2 Flux – Betul, M.P





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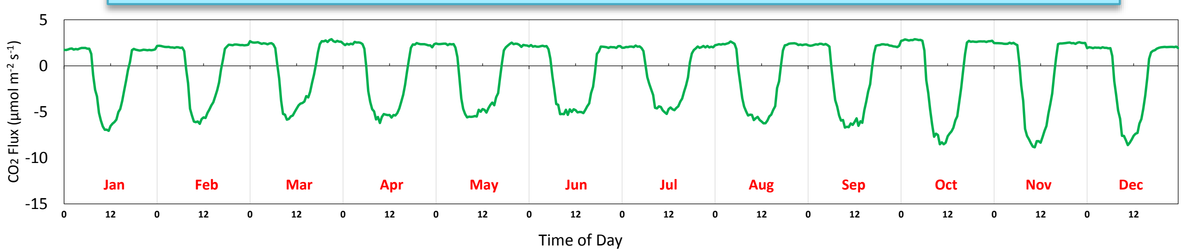
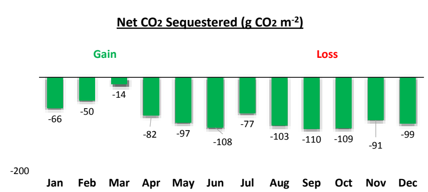
December

May

Seasonal Diurnal Average variation of CO_2 Flux – Sundarbans, W.B.





Net Annual Production

1005.32 g CO_2 m^{-2}
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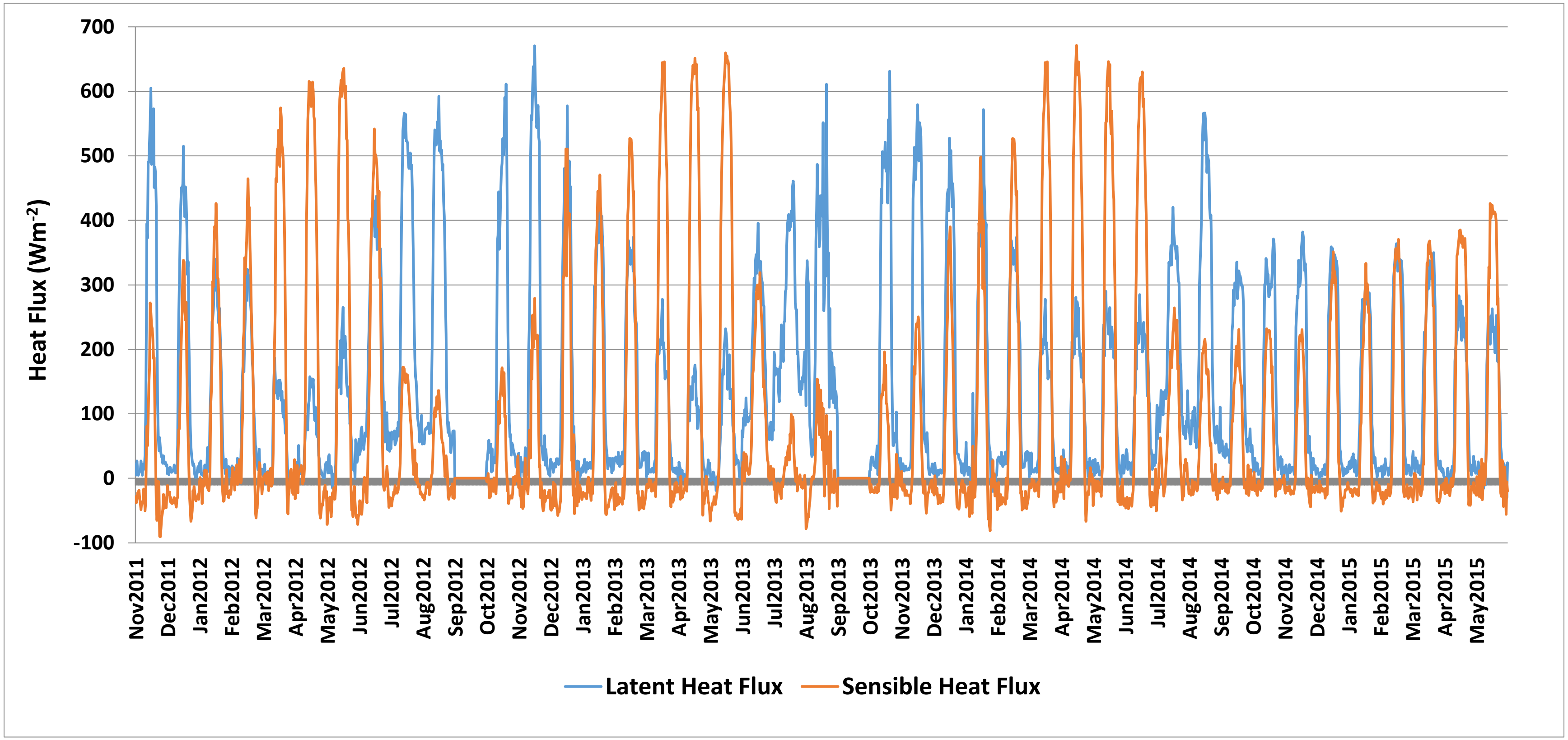
273.93 g C m^{-2}.

Latent Heat & Sensible Heat Flux- Betul



Approaches for Biomass Estimation

Approaches for biomass estimation:

- -Field measurement.
- - Remote sensing
- -Geographic information System

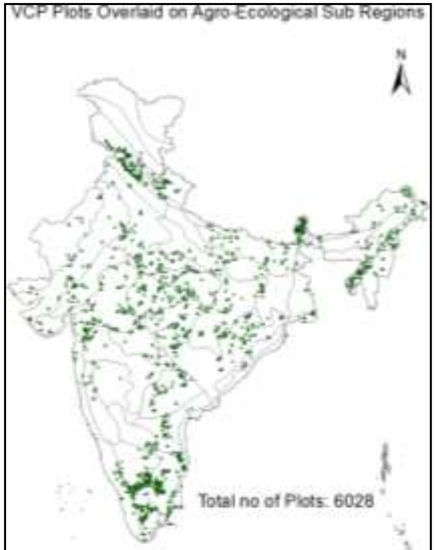
Most common used remote sensing approaches are-

- - Direct Remote Sensing (DR) Approach
- - Stratify & Multiply (SM) Approach
- - Combine & Assign (CA) Approach

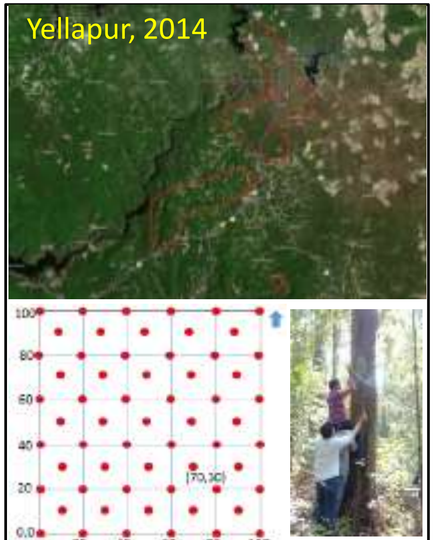
Sub Project: Vegetation Carbon Pools

Objectives

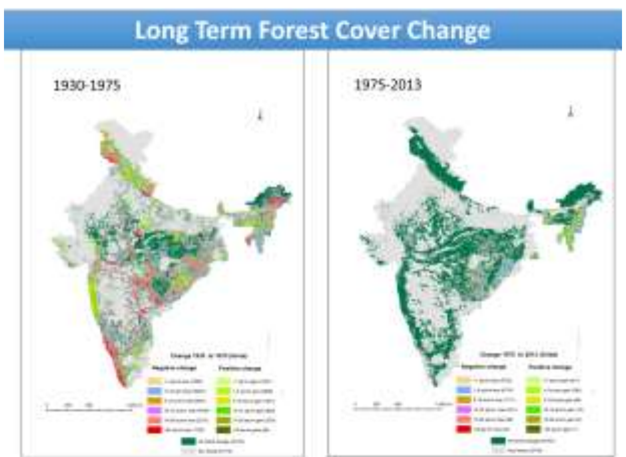
- **Spatial distribution of phytomass carbon in Indian forests**
- **Longterm forest cover change**
- **Assessment of trees outside forests**

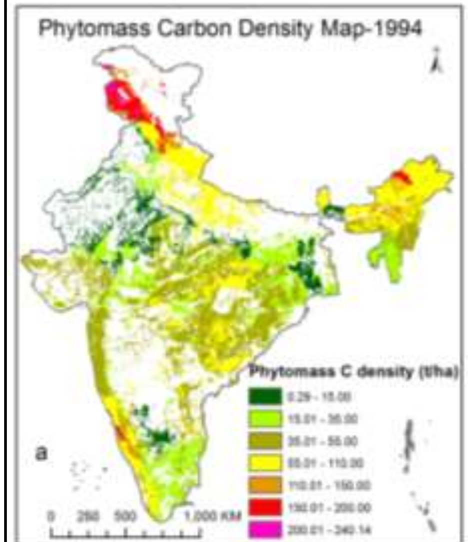


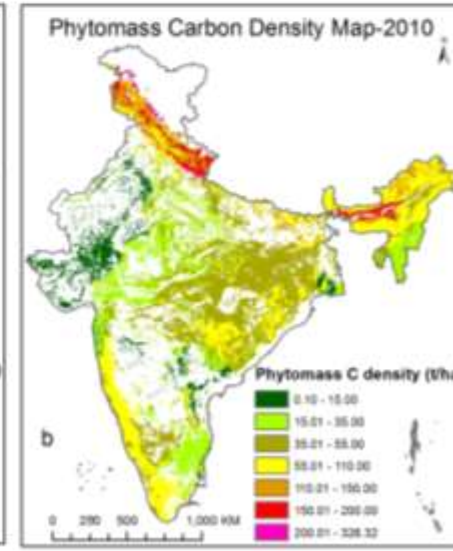
VCP-Phase-1

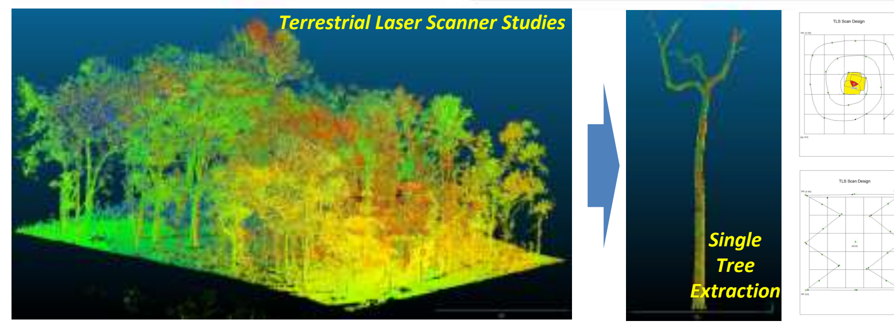


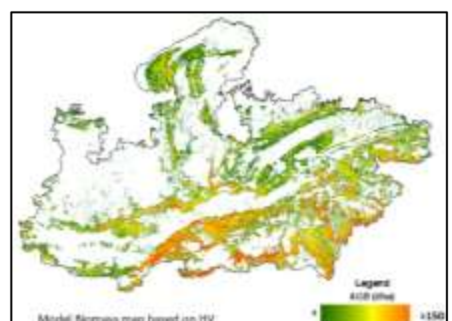
VCP-Phase-2



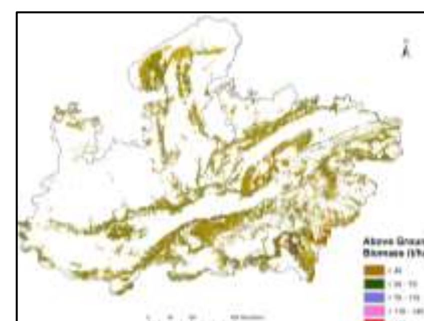








AGB Estimation using L-Band SAR



AGB Estimation using GLAS (LiDAR)

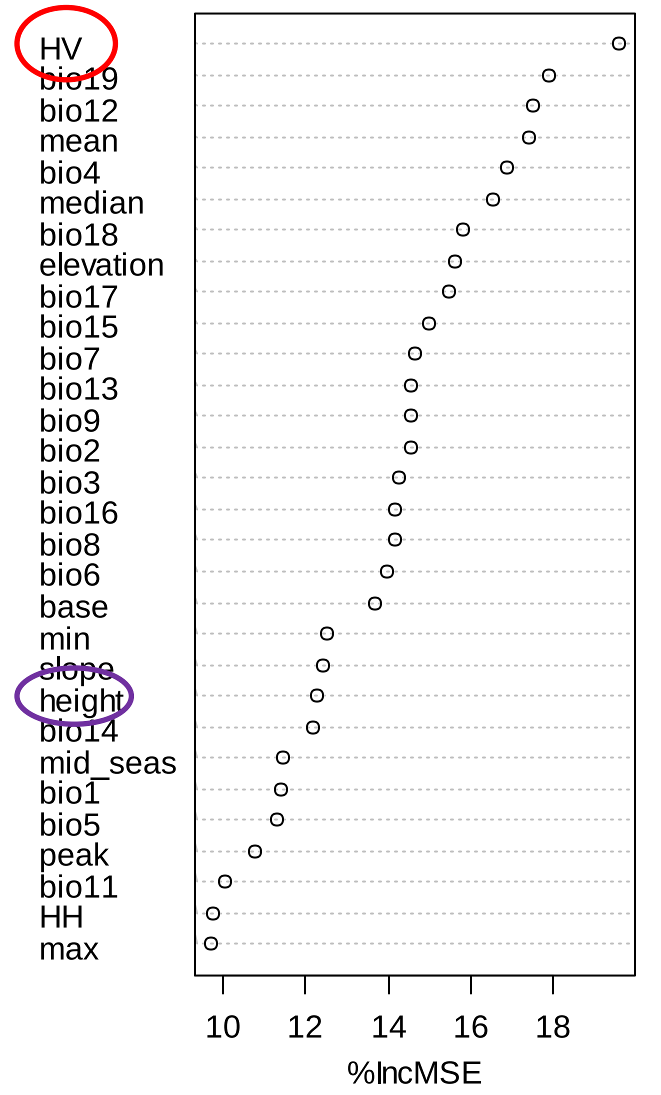
Spatial estimation of Biomass using a Random Forest

Non parametric approach, resistant to noise and outliers, very large number of variables possible, Can use categorical and continuous variables

Model based validation

Spatial Data Used:

- **Phenology MODIS**
- Bio-Climate Variables WORDCLIM
- **L-band Microwave** ALOS
  -HV, HH
- Forest Height GLAS
- Topography SRTM
  -Elevation, Slope, Aspect

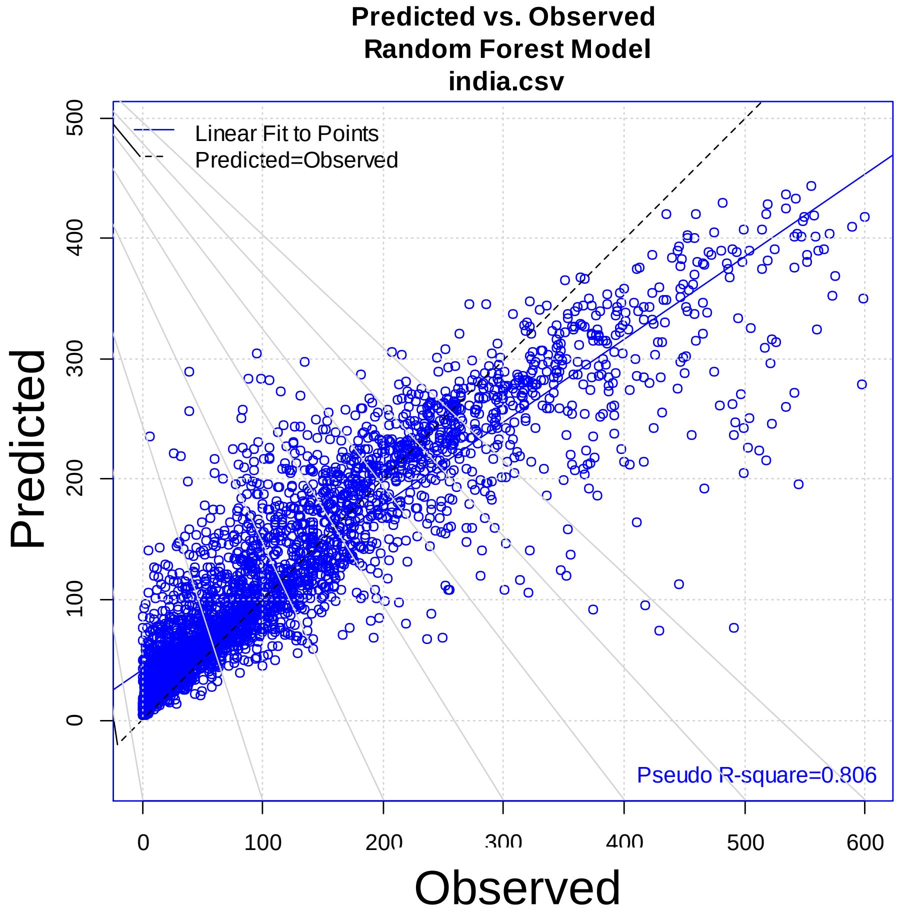


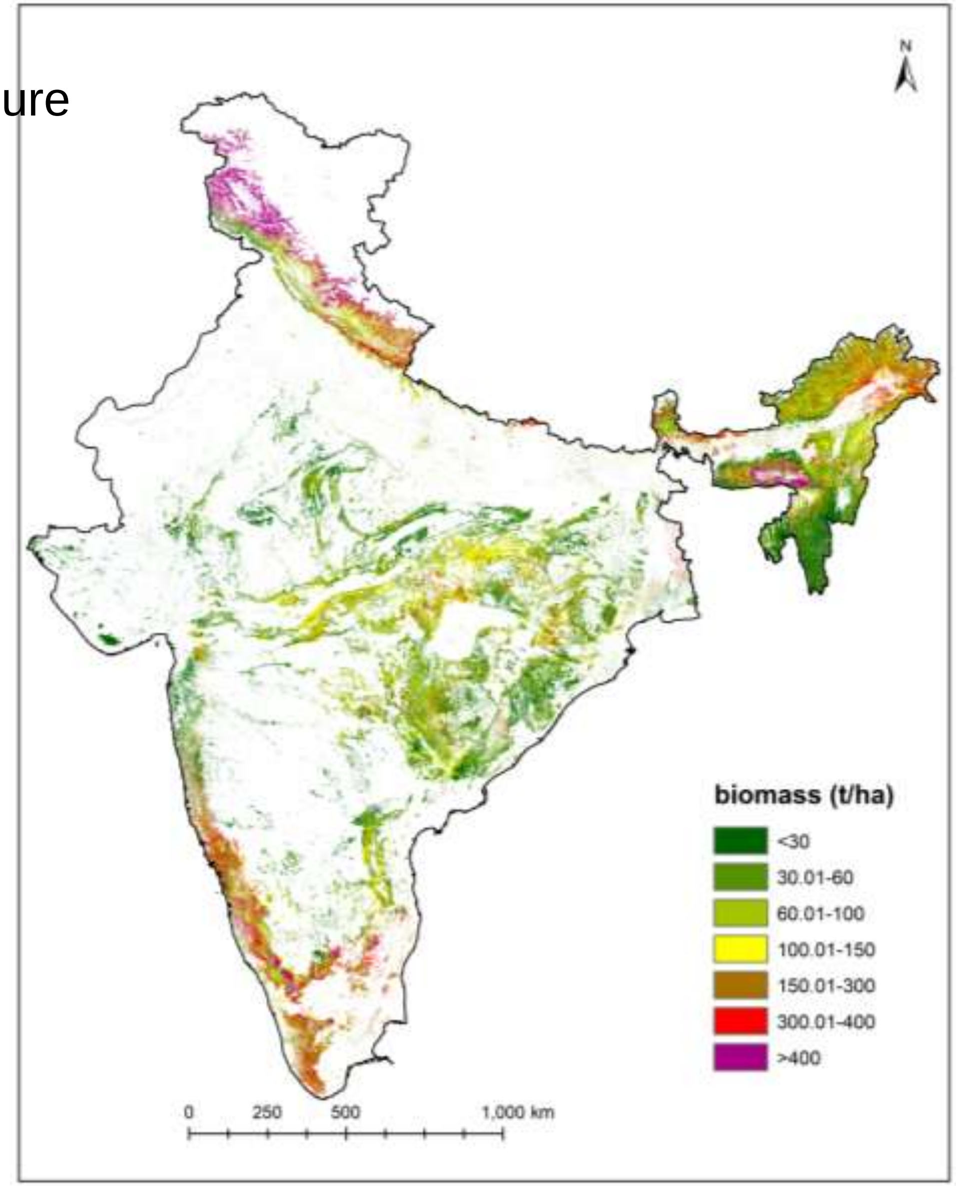
Random forest variable importance

As expected, HV is of high importance but GLOBAL forest height is insignificant

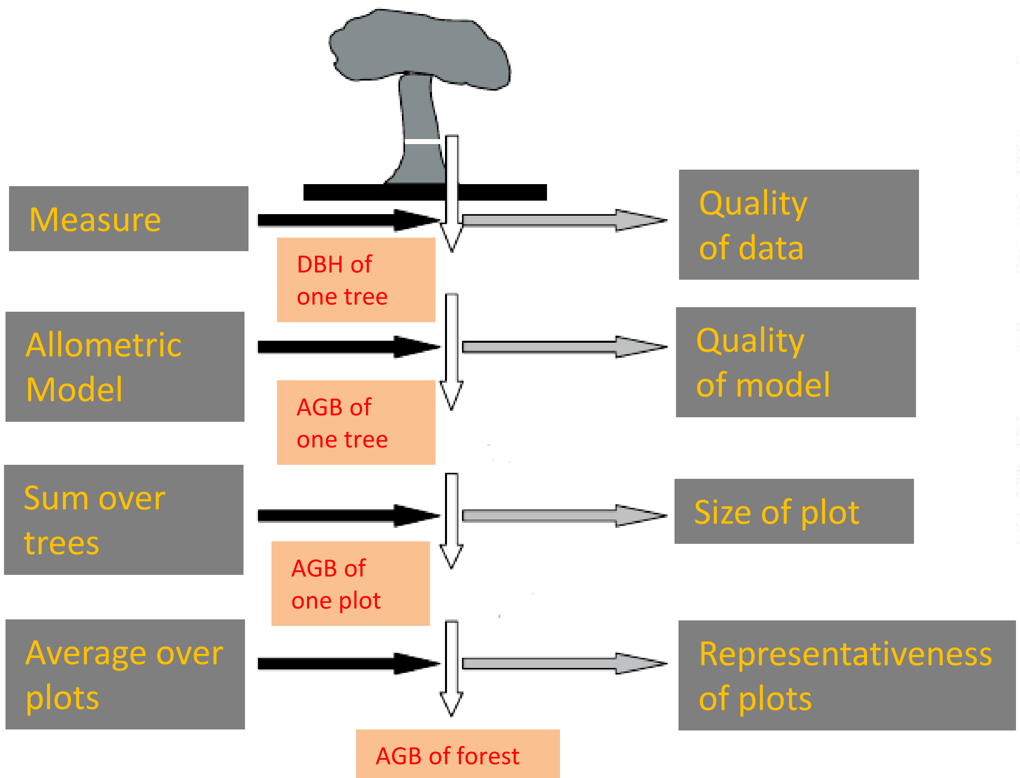
National Biomass Map – SAR, Phenology, Met & plot data

Knn estimate with a RF distance measure





Error budget

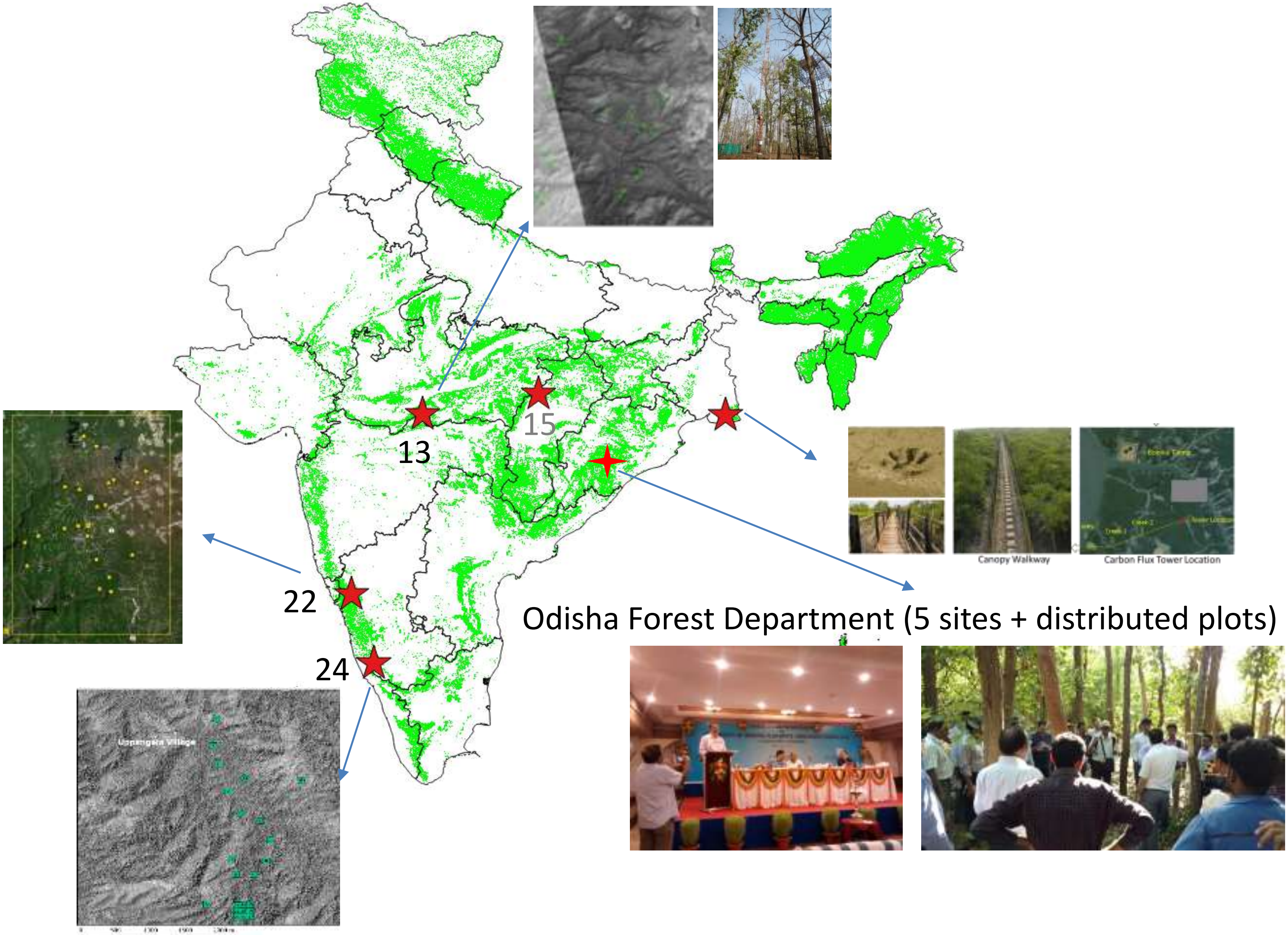


error type		s.e.m. (percentage of the mean)
1. tree level error	trees > 10 cm diameter	48
	trees < 10 cm diameter	78
2. allometric model	before ρ correction	22
	after ρ correction	13
	after large tree correction	11
3. within-plot uncertainty	0.1 ha plot	16
	0.25 ha plot	10
	1 ha plot	5
4. among-plot uncertainty		11
total	50 1 ha plots, after ρ and large tree corrections	24

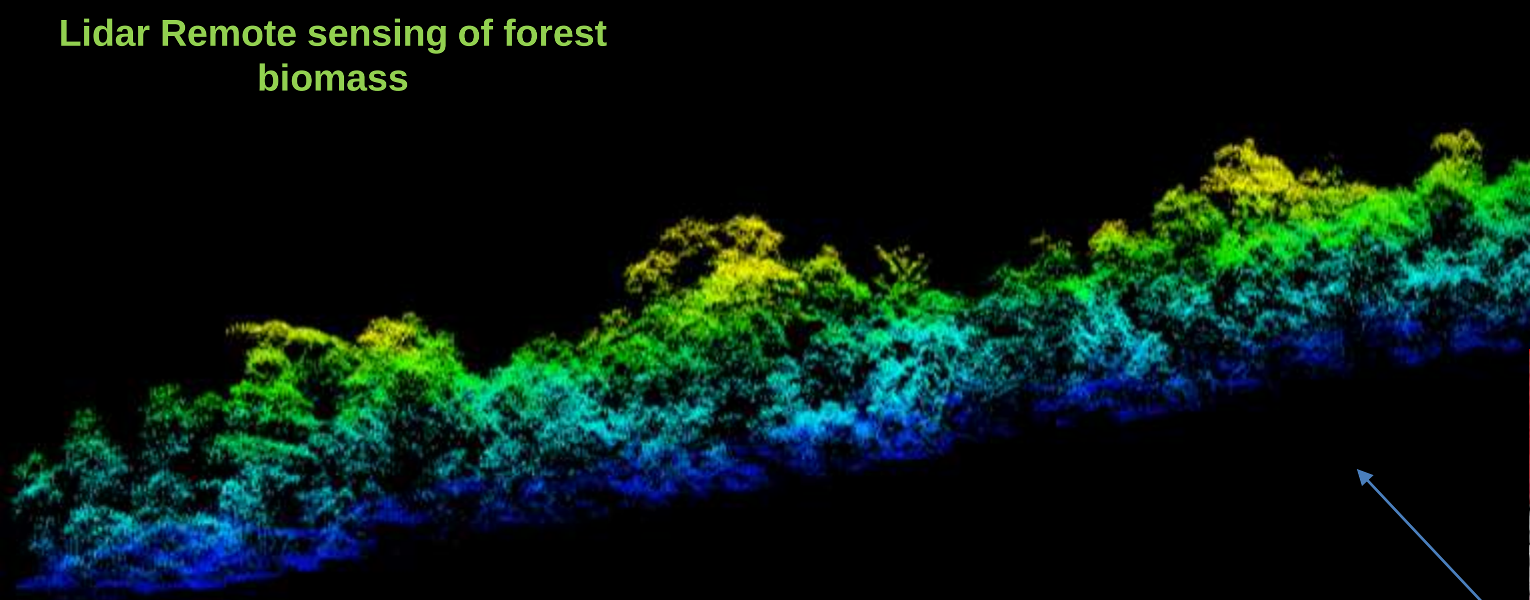
Type 1 Single tree, averages out across plots
Type 2 Choice of allometric model
Type 3
Type 4 Minimized by large sized multi plot census

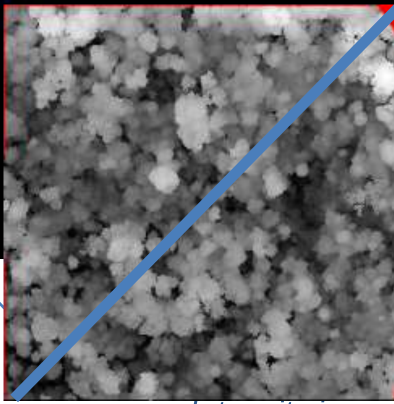
Chave, J., Condit, R., Aguilar, S., Hernandez, A., Lao, S., Perez, R., 2004. Error propagation and scaling for tropical forest biomass estimates. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences 359, 409–420.

NRSC Large Plot Network



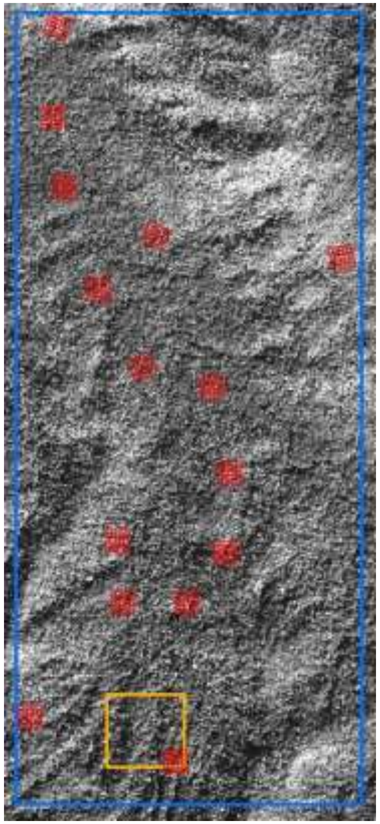
Lidar Remote sensing of forest biomass





Returns colored by height above ground

Intensity image



Target on ground

Uppangala, Karnataka

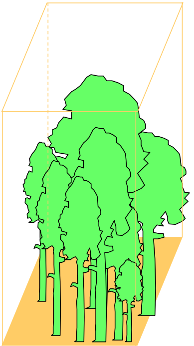
Target from air

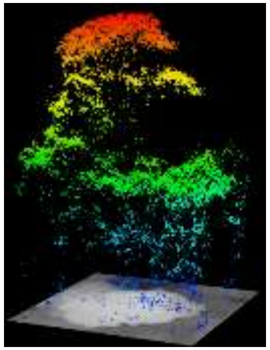
15, 1 ha plot

Biomass range (t/ha) 131 to 687 (443 ± 161)

ALTM (2005)

Growth analysis in comparision with 2005 aerial LiDAR, very high point density in 2013



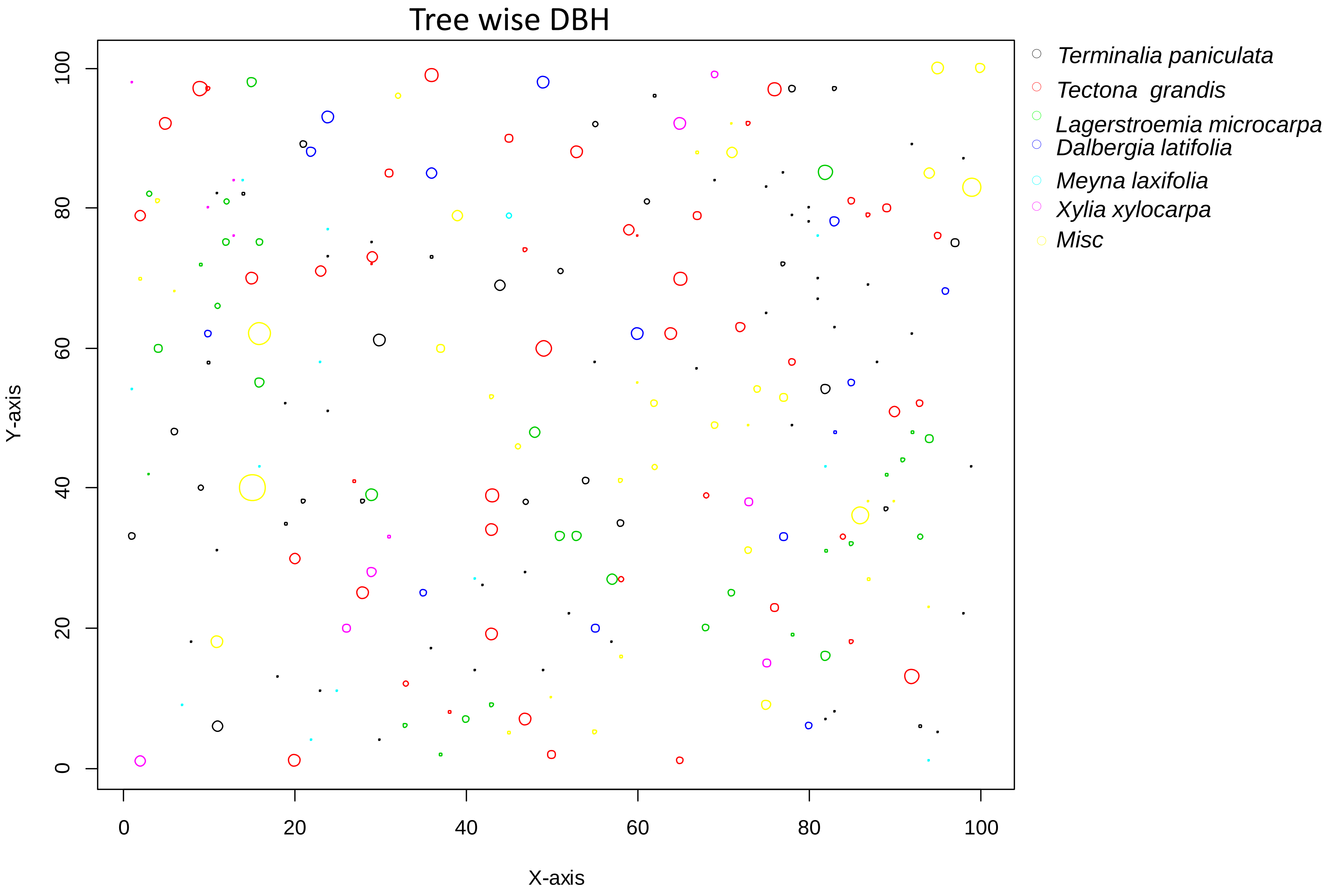


Biomass modelling using <u>Distribution metrics</u>

Large Plot Experiment Design

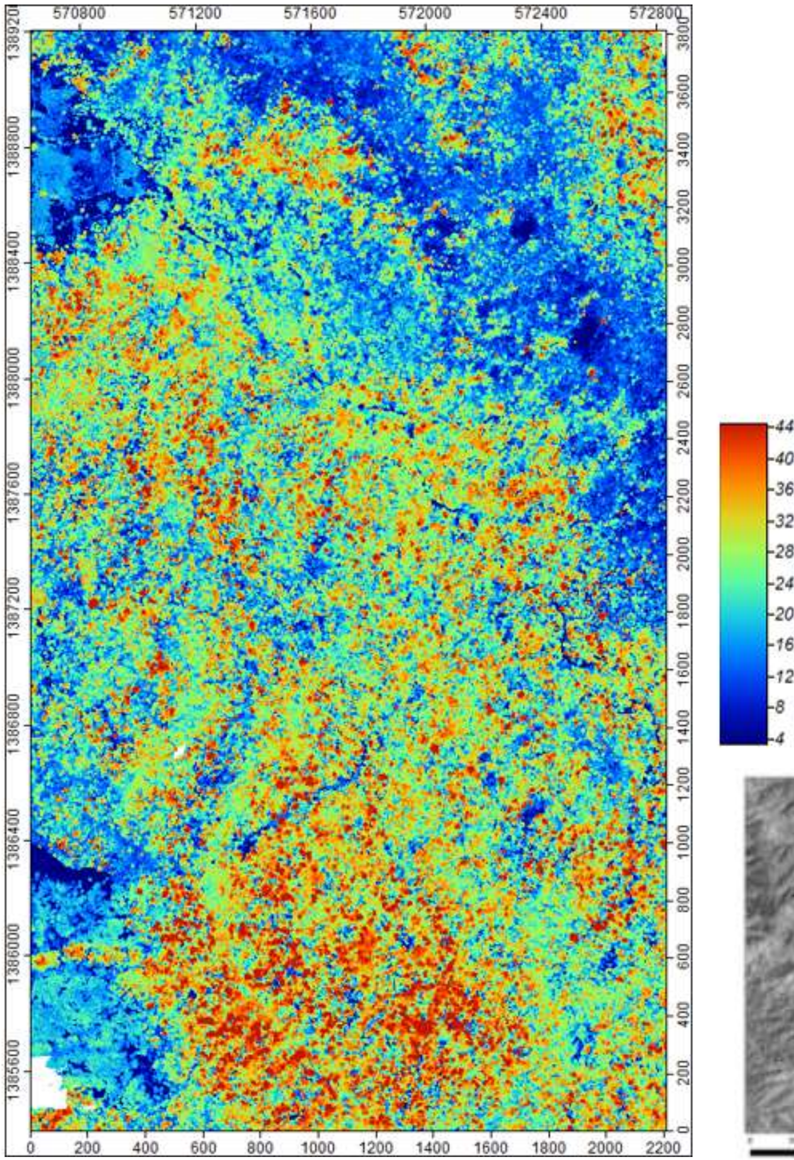
1. At least 15 1-ha permanent sampling plots per site. Plots established and monitored according the best tropical forestry standards (Rainfor or CTFS protocols) including location and height
2. Aerial LiDAR scanning (ALS) over 100 sq km, with better than 10 pts per sq. m, repeat measurement every 5 years
3. Terrestrial LiDAR scanning (TLS) at (at least) two of the permanent plots, ideally all
4. Weather/soil moisture measurements
5. Wood specific gravity and seasonal biophysical parameters

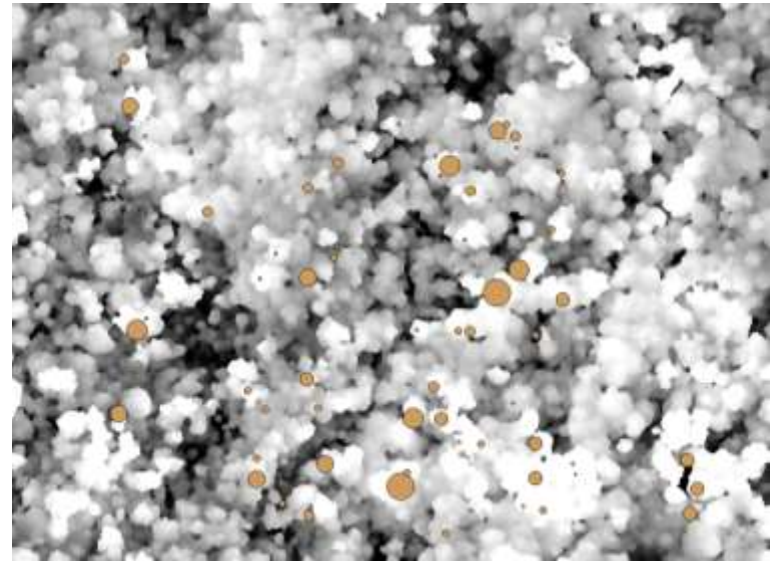
Example tree map for 1 ha permanent plot



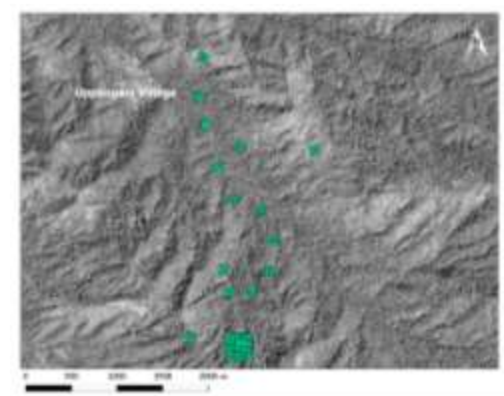
Biomass Estimation using Aerial LiDAR

Uppangala CHM, 7 sq km



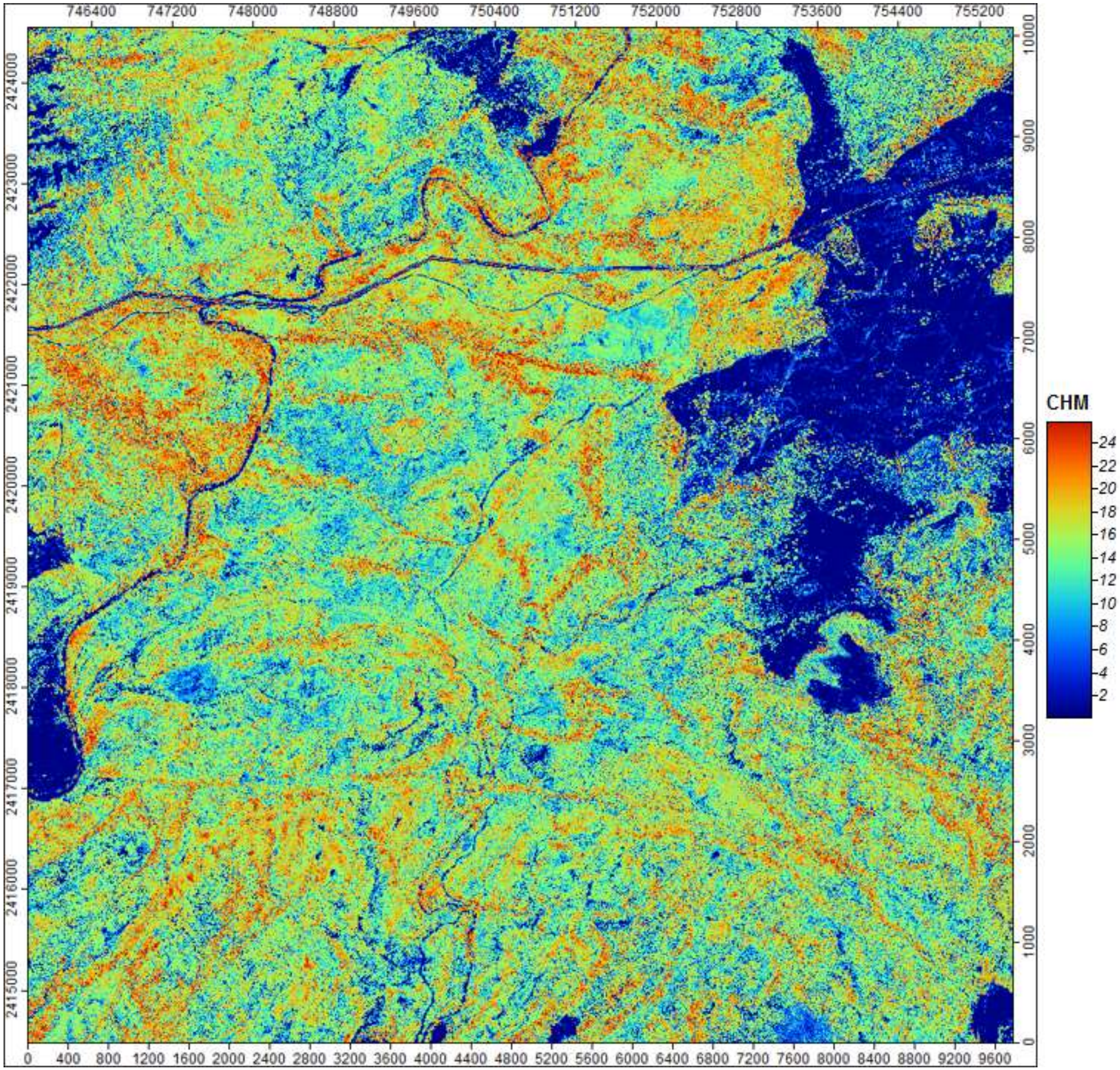


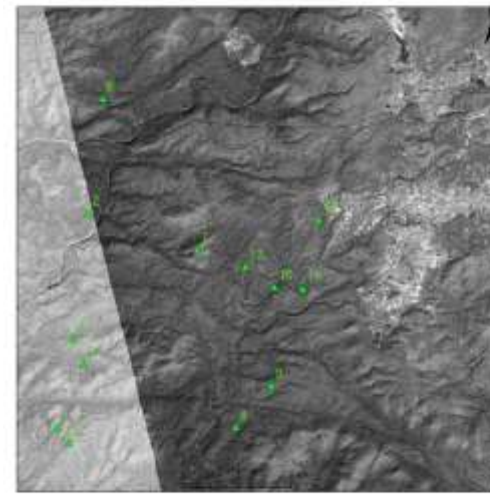
Selected tree measurements shown on CHM
(circles are proportional to field measured DBH)



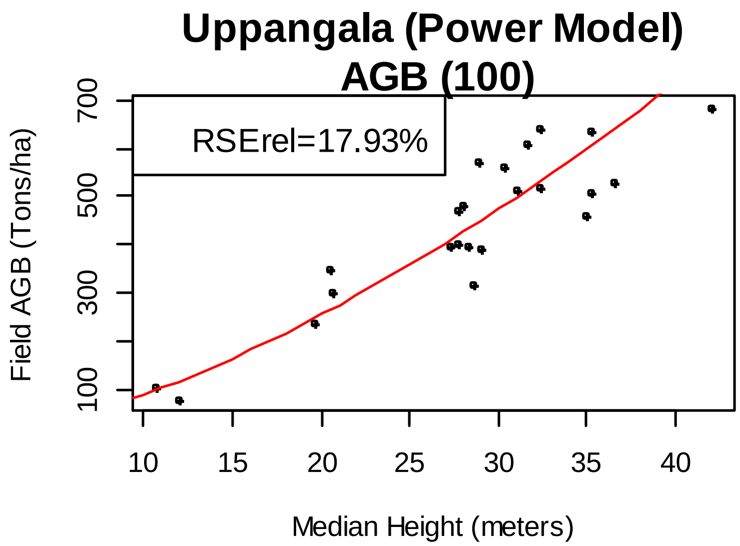
Biomass Estimation using Aerial LiDAR

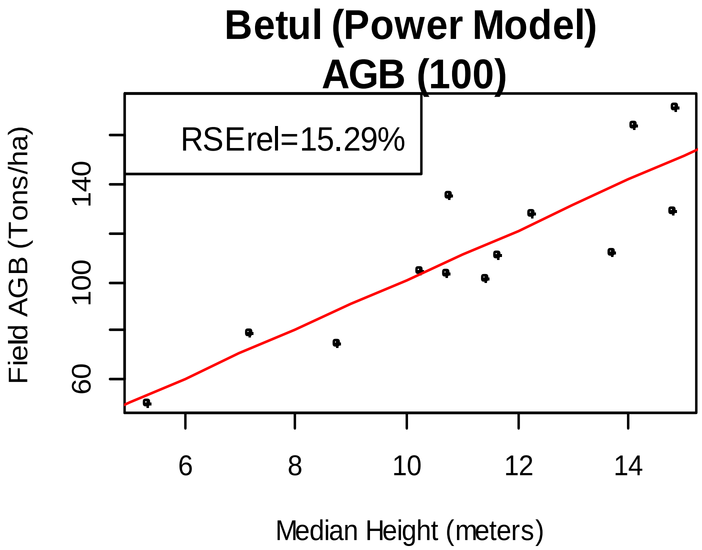
Betul CHM, 100 sq km





Biomass Model with ALS derived H_{50}





a single LiDAR derived metric, the median canopy height is useful to describe the variation in above ground biomass at the hectare scale in two very different forest systems.

A similar relationship has been described in other continents

TLS SCANNING

- Instruments Required:

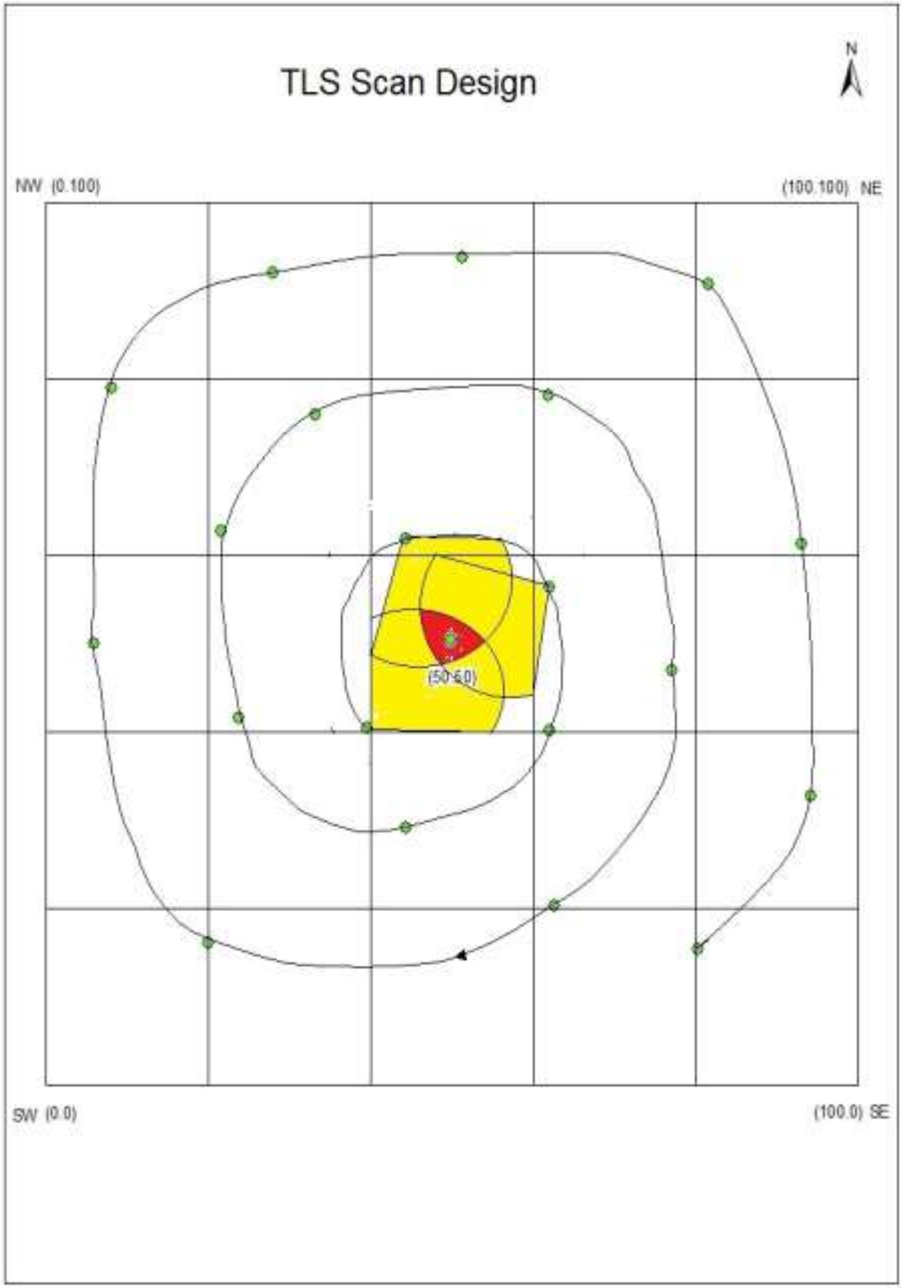
1. Terrestrial LiDAR Scanner and Camera
2. Reflectors
3. Tripods for both Scanner and Reflectors
4. Car Battery

TLS Tripod

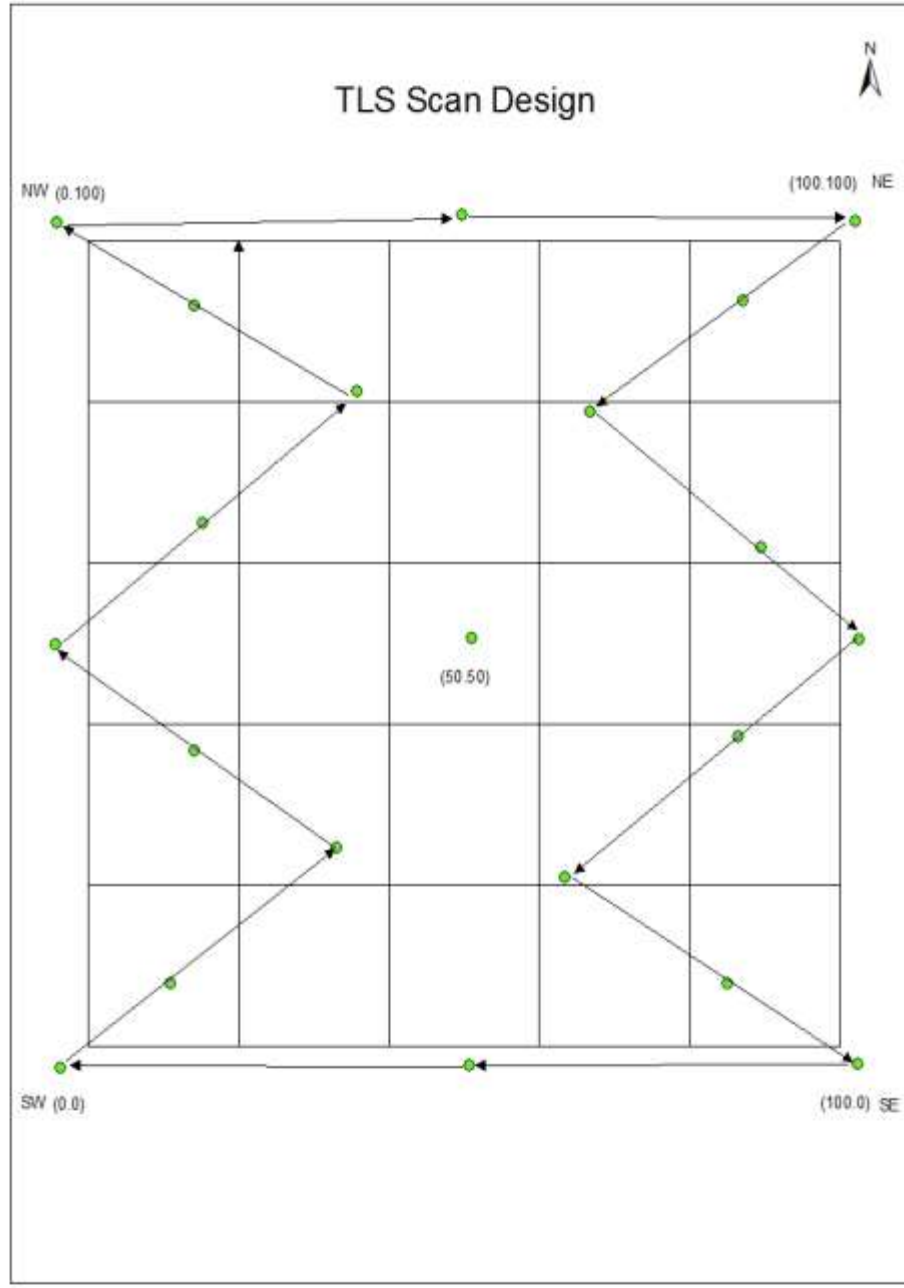
TLS

Reflector Tripod

Reflector

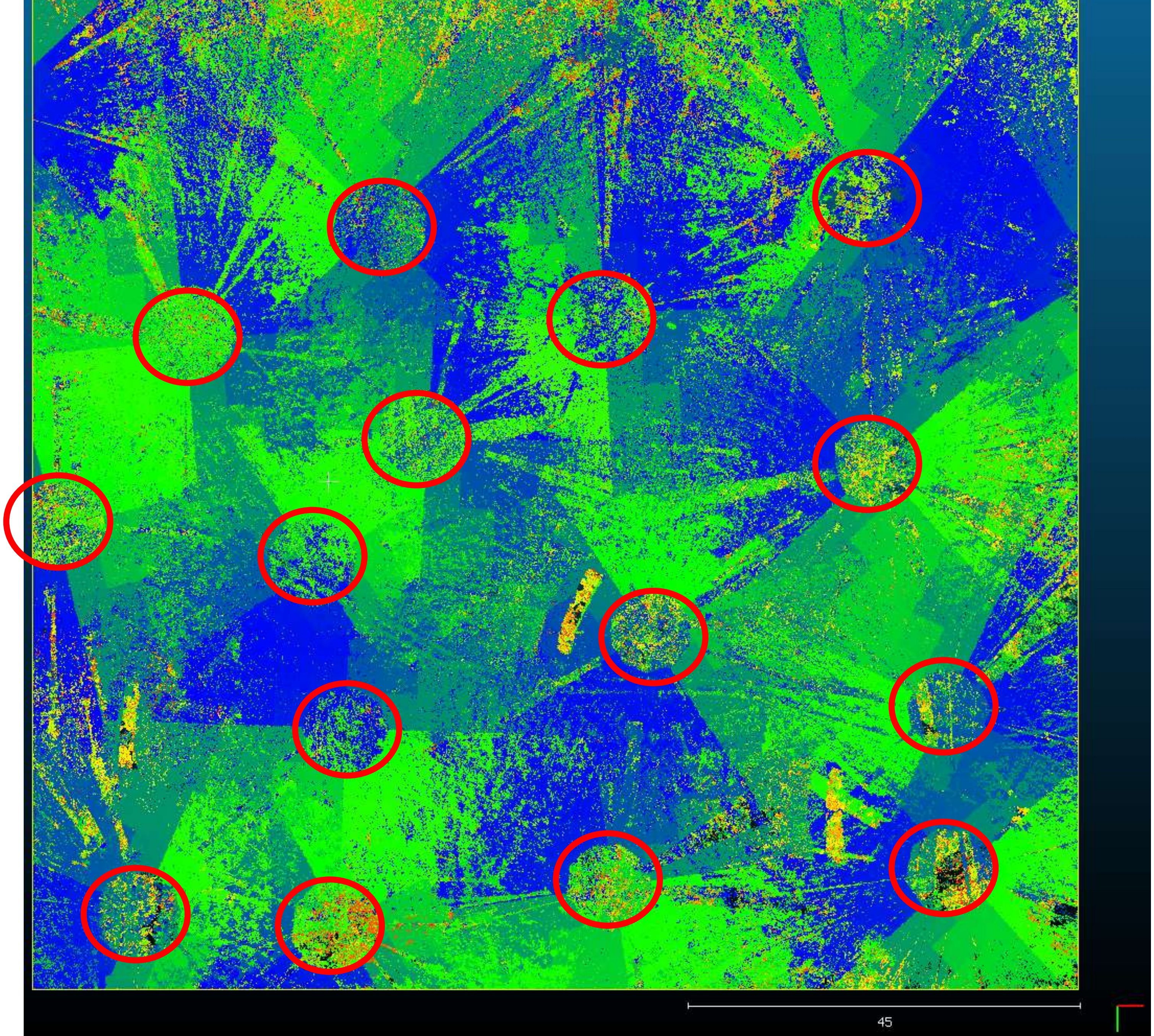


Scan design for Evergreen Forest

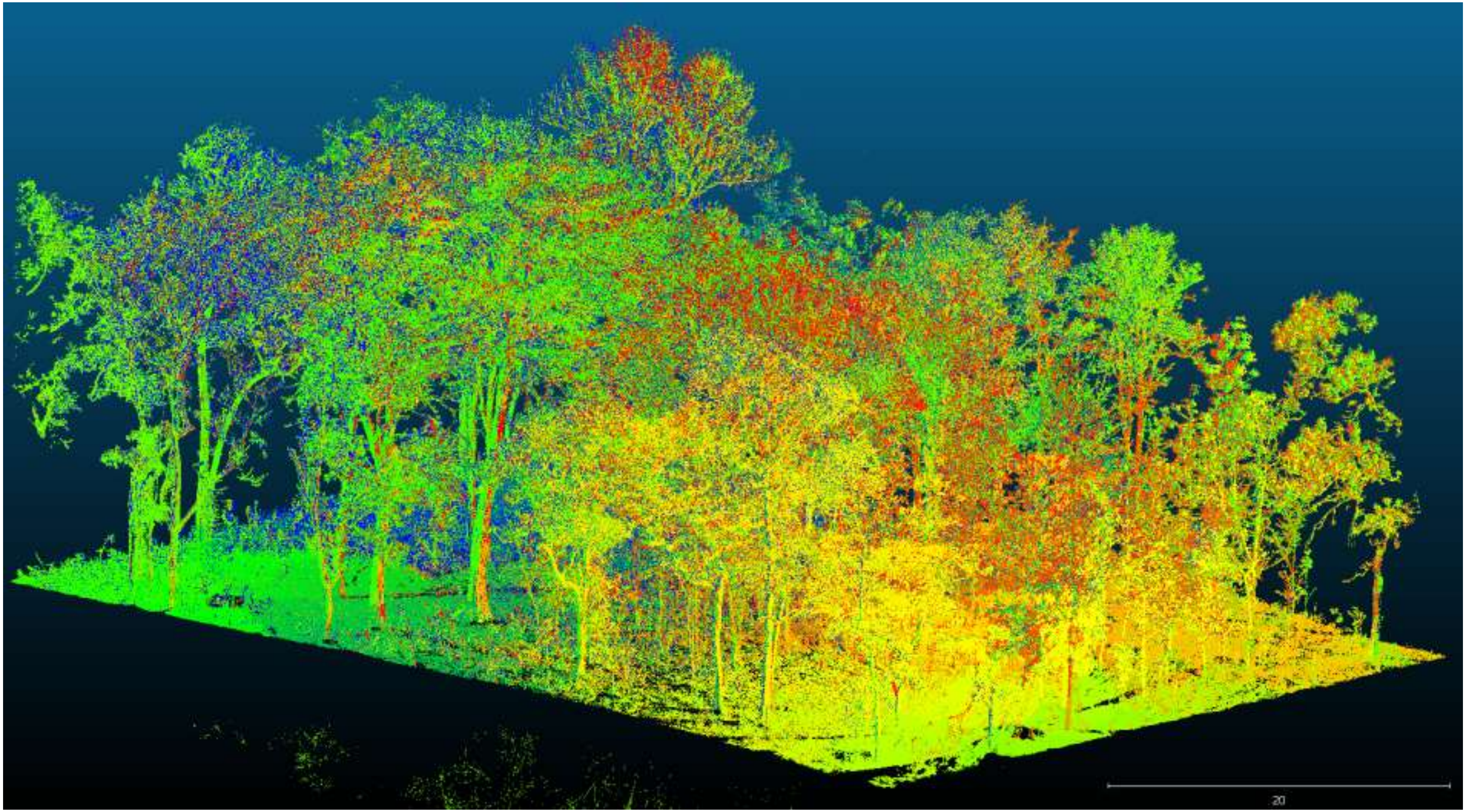


Scan Design for Dry Deciduous Forest

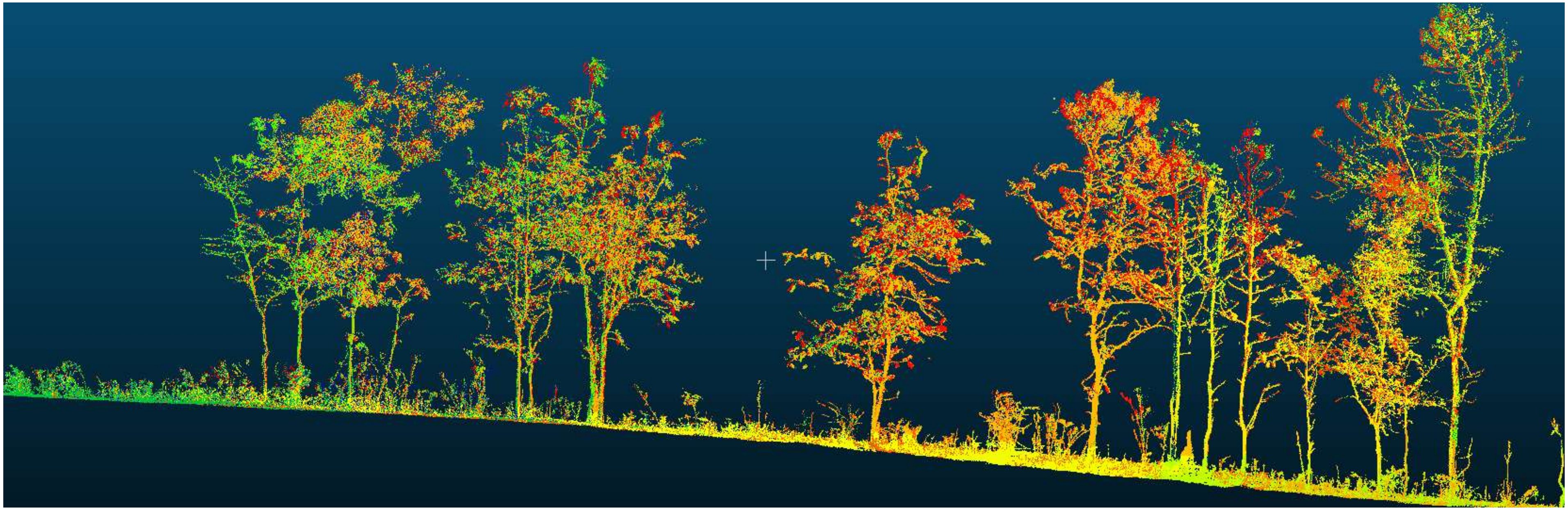
Scan Configuration

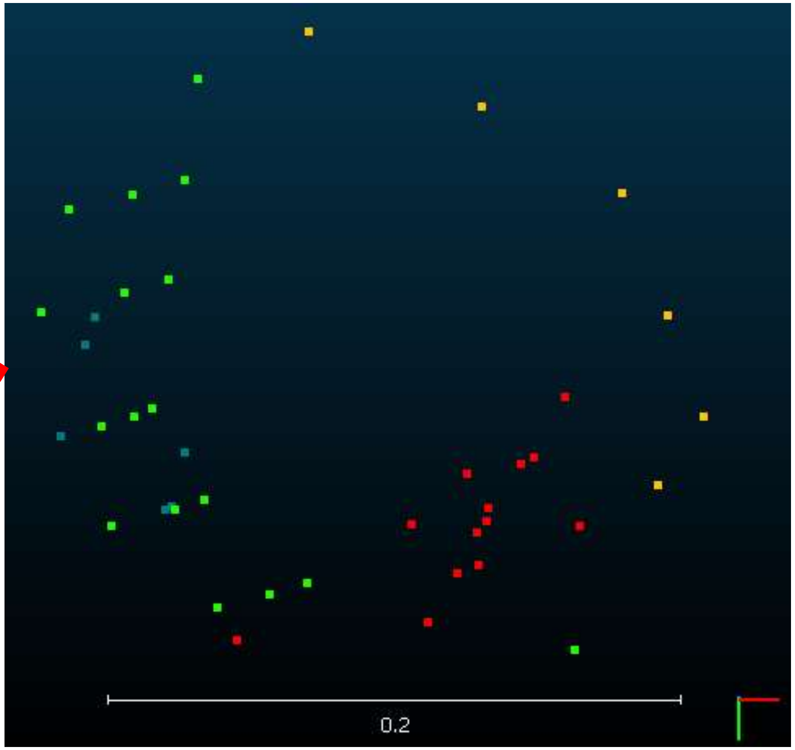


Bomanali Point Cloud



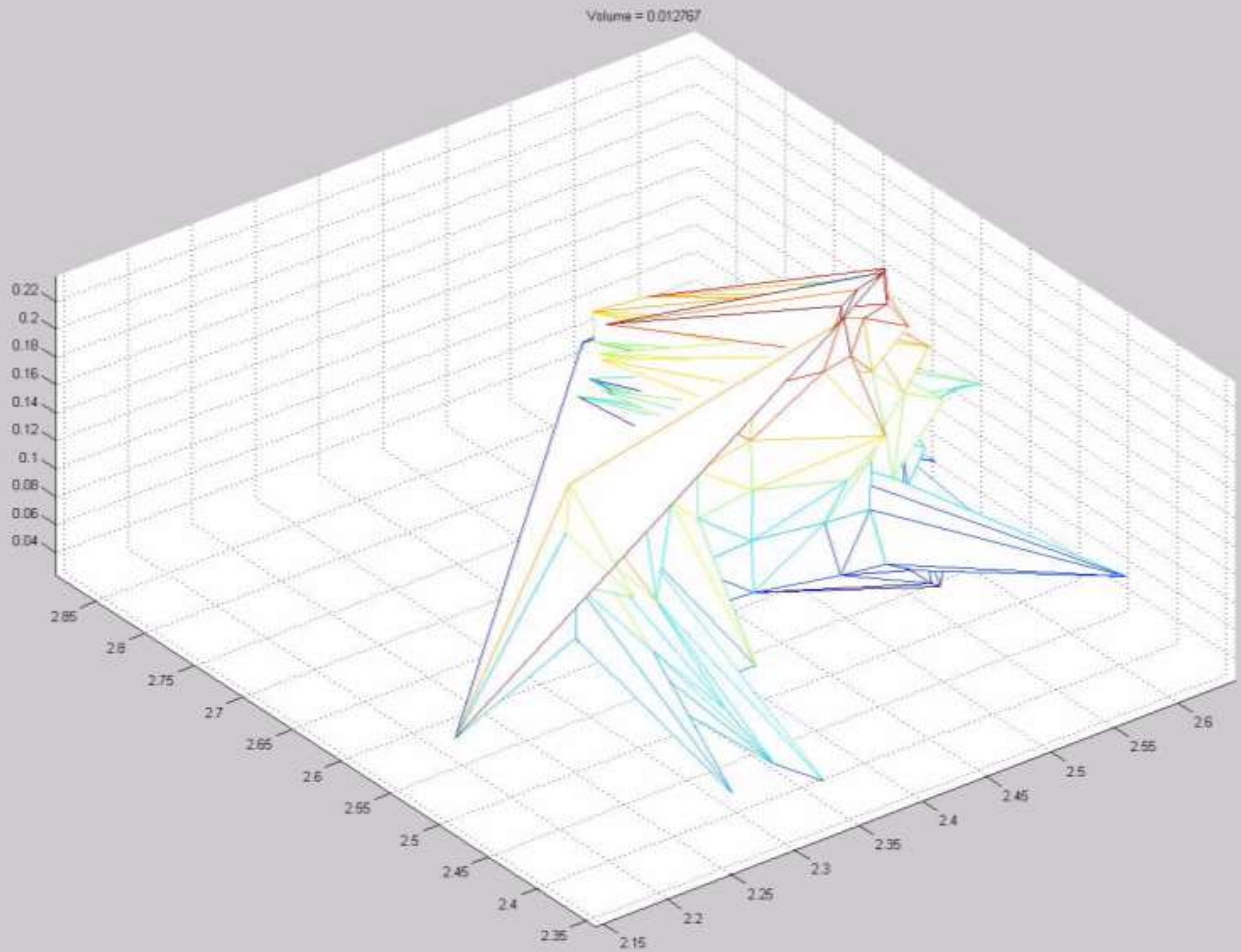
Transect





Single Tree

- Extracted manually from the full point cloud.
- Higher order branches were also removed .


Volume = 0.012767
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
2.85
2.8
2.75
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.15
2.2
2.25
2.3
2.35
2.4
2.45
2.5
2.55
2.6

Areas to work on

1. Capacity to handle extremely huge datasets.
2. Accurate Single tree detection.
3. Very precise Filtering of redundant points.
4. For further exploration:
   – Detection and filtering of points corresponding to leaves.

Future Plans

Expansion of network and new instrumentation

- Addition of network to cover major eco-regions in India with similar methodology (add ten more locations by 2020)
- Development of alternate assessment approach using drone LiDAR and high resolution satellite imagery

Development of new techniques

- TLS based improvement to Allometry
- Development of tree based approaches for estimation of AGB in place of the existing area based approach

Collaborations

- Collaborations for upscaling using RS – JAXA, GEDI, BIOMASS
- Readiness for NISAR CalVal and product

South Asia (SAARC countries):
Long Term Forest Cover Change Over Eight Decades

Contributors:
C. Sudhakar Reddy, K.V. Satish, S. V. Pasha, K.R.L. Saranya,
C.S. Jha, R.S. Reddy, P.G. Diwakar & V.K. Dadhwal

Forestry & Ecology Group, Remote Sensing Applications Area,
National Remote Sensing Centre , Hyderabad

Background

Deforestation has impacts on carbon stocks, biodiversity, ecosystem services and livelihoods.

- The scarcity of data on deforestation limits understanding of the carbon cycle, biodiversity loss and climate change (IPCC, 2005; CBD, 1992).
- A long term forest change dataset is useful to model net Carbon emissions.
- Remotely sensed data contributes for specifying the location of deforestation and the extent of the deforested area.

Objectives

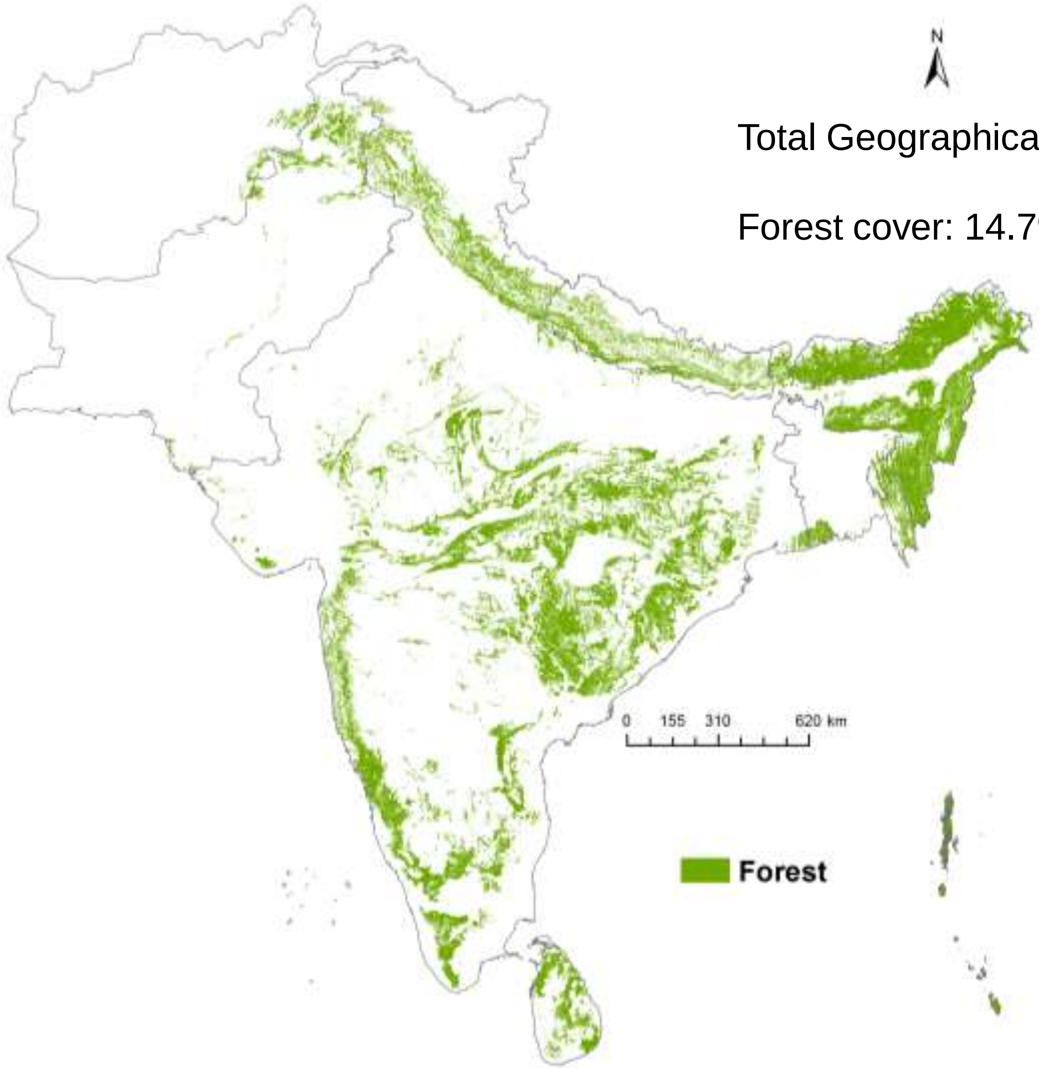
- ✓ To prepare forest cover map of South Asian countries
- ✓ Geospatial analysis of long term forest cover changes

Datasets Used

Sl.	Maps/ RS data	Period	Scale/ Resolution*	India	Nepal	Bangladesh	Bhutan	Sri Lanka	Afghanistan	Pakistan	Total
1	Topographical maps	1920-1940	1:250,000	251	17	19	6	NA	NA	10	303
2	Landsat MSS	1975	80m	356	11	14	4	8	14	16	423
3	Landsat MSS	1985	80m	452	9	16	2	5	5	8	487
4	Landsat TM	1990	30m	-	5	-	-	-	4	4	13
5	IRS 1A /1B LISS-I	1995	72.5m	470	7	17	8	5	3	5	514
6	IRS P6 AWiFS/ LISS-III	2005	56m/23.5m	64	12	9	4	5	14	15	123
7	Landsat 8 OLI	2014	30m	-	12	13	4	12	12	15	58
8	Resourcesat-2 AWiFS	2013/14	56m	64	2	-	-	-	-	-	66
				1657	**75**	**88**	**28**	**35**	**51**	**59**	**1997**

•Resolution for satellite datasets
(Topographical maps: http://www.lib.utexas.edu/maps/ams/; Landsat data: NASA; IRS data : NRSC,ISRO)

South Asia : Forest Cover (2013/2014)

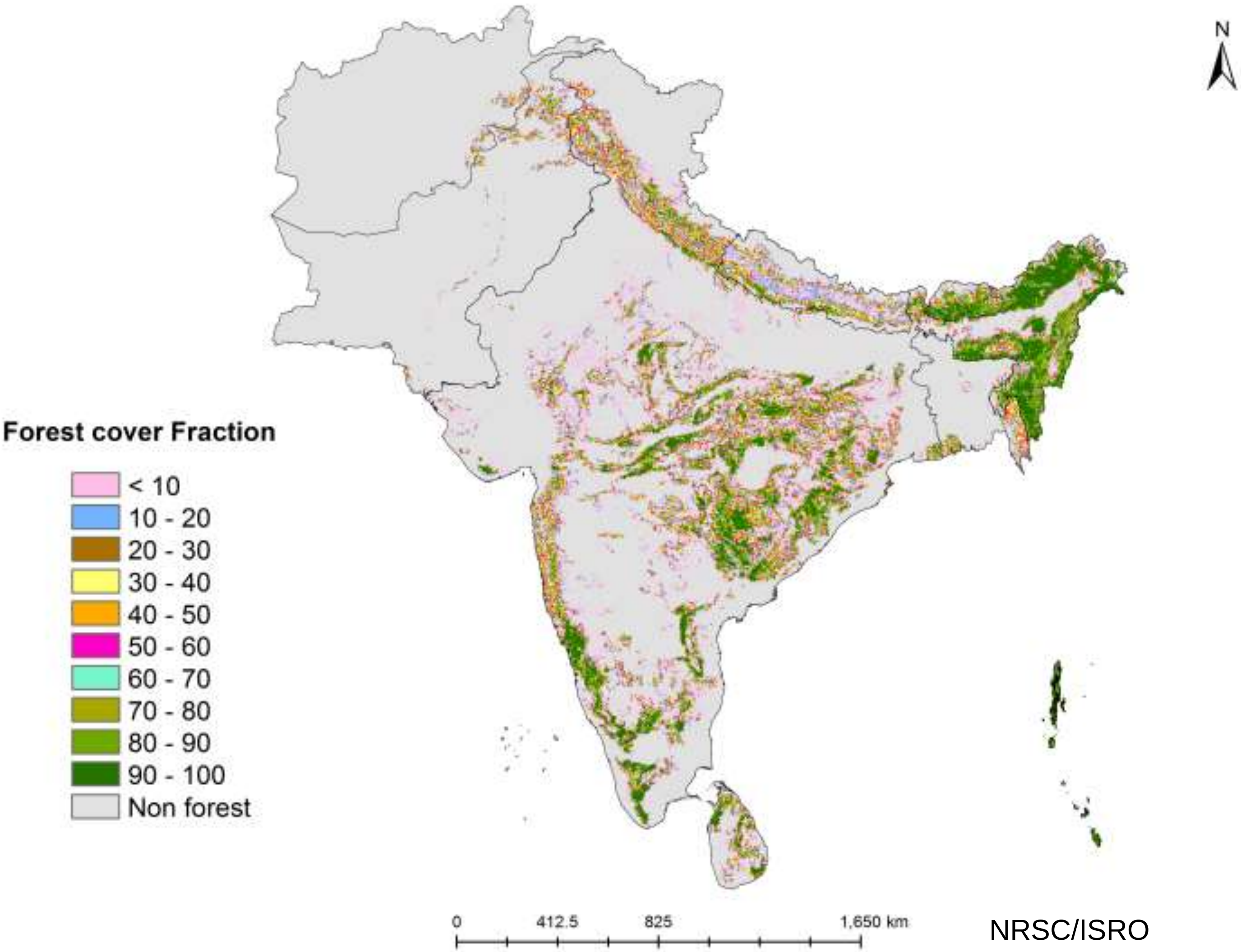


Total Geographical Area: 51,35,263 km^2

Forest cover: 14.7% of geographical area

NRSC/ISRO

South Asia : 5 km gridded Fractional Forest Cover map (2013/2014)



NRSC/ISRO

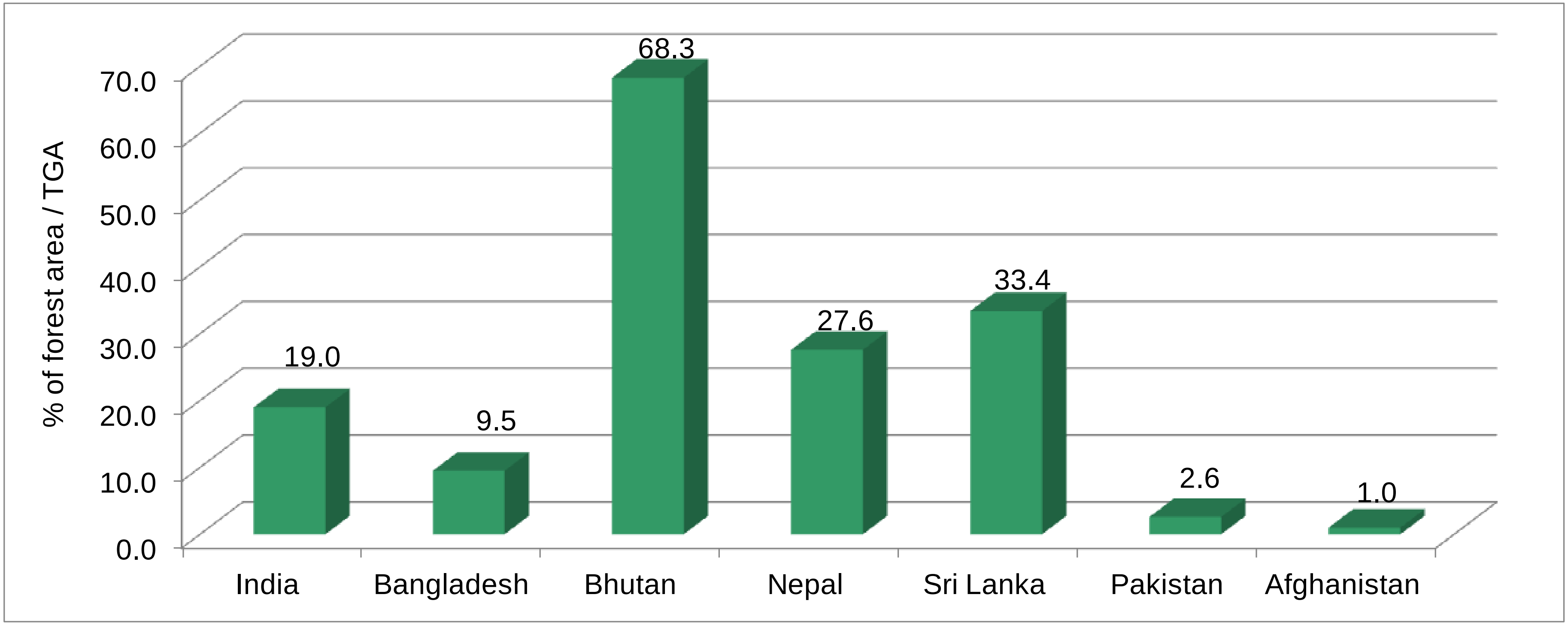
South Asia : Forest Cover (Area in km^2)

Country	Total Geographical Area	Forest 1930	Forest 1975	Forest 2013/14
India	3287253	8,69,012	6,53,220	6,25,565
Bangladesh	147570	23,140	16,568	14,086
Bhutan	38394	26,896	26,269	26,207
Pakistan	796095	36,379	20,479	20,306
Sub total	42,69,312	9,55,427	7,16,536	6,86,164
Sri Lanka	65610	No Data	23217	21936
Afghanistan	652860	No Data	6739	6646
Sub total	7,18,470	NA	29,956	28,582
Total	**49,87,782**	**9,55,427**	**7,46,492**	**7,14,746**

The percentage of **forest loss** in last 8 decades: **44.2%** in Pakistan, **39.1%** in Bangladesh,

28% in India, **5.5%** in Sri Lanka, **2.6%** in Bhutan and **1.4%** in Afghanistan.

Country wise forest cover 2013/14 (Area in %)

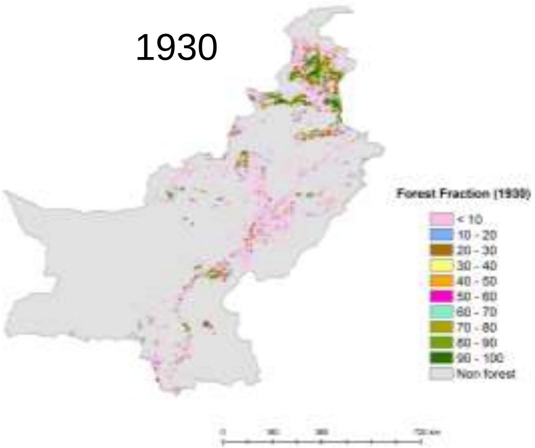


- South Asia represents 14.7% of geographical area under forest cover in 2013/14.
- The highest percentage of forest cover found in **Bhutan**, followed by **Sri Lanka.**

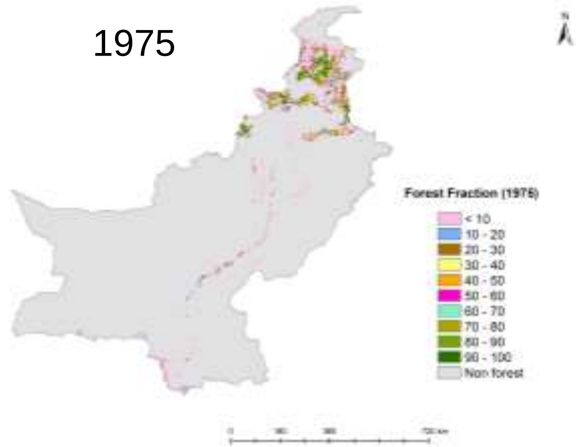
South Asia:
5 km gridded Fractional Forest Cover (1930, 1975 & 2014)

Pakistan

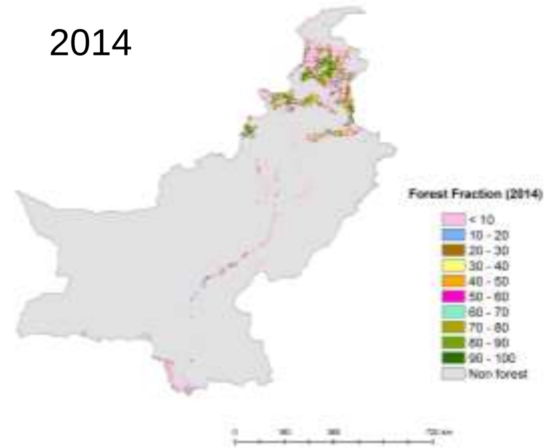
1930



1975

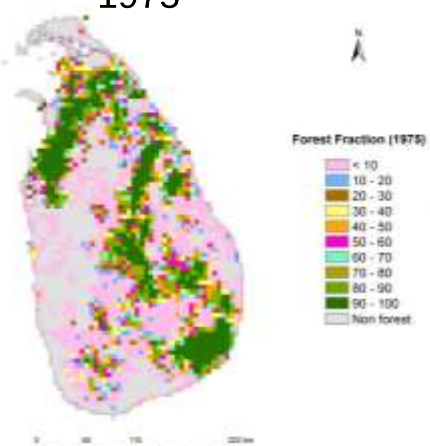


2014

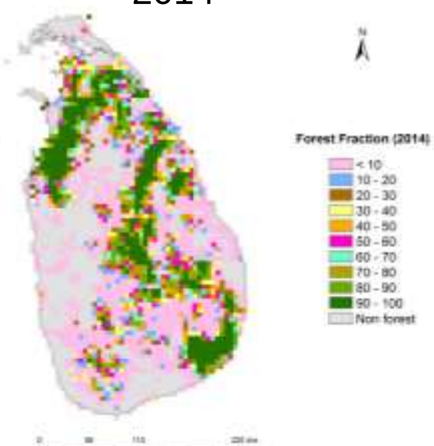


Sri Lanka

1975

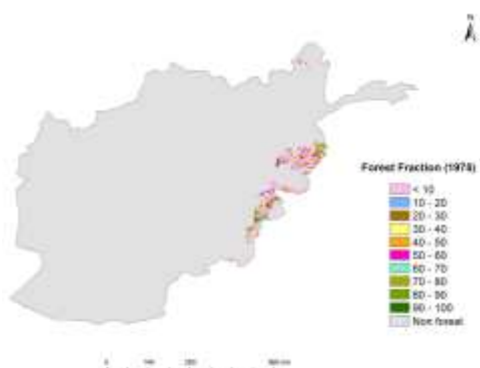


2014

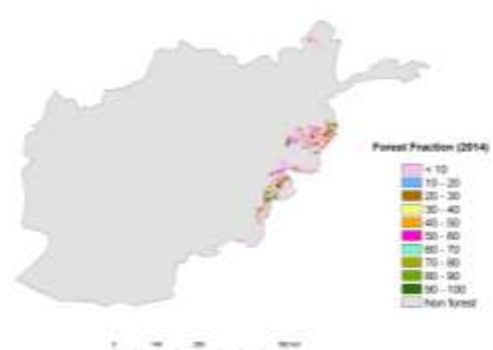


Afghanistan

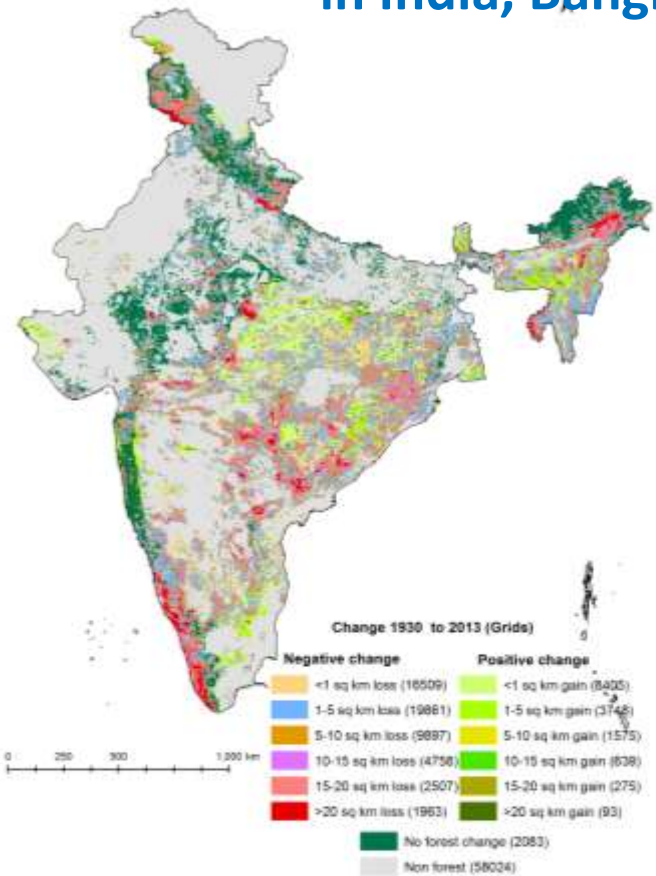
1975

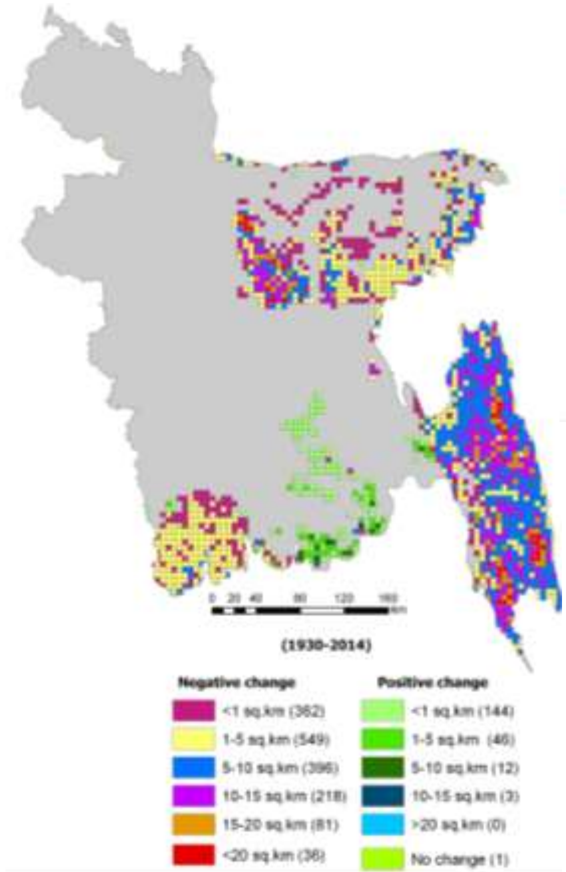


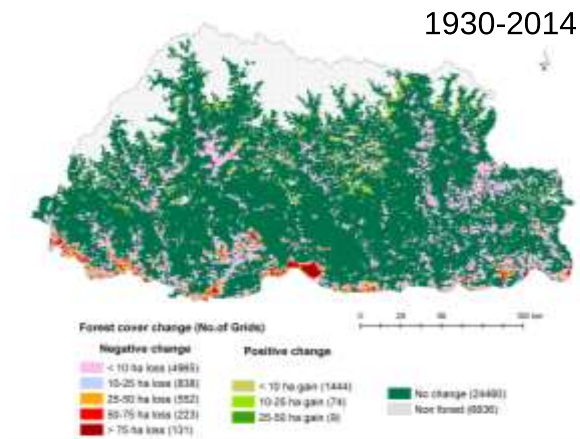
2014

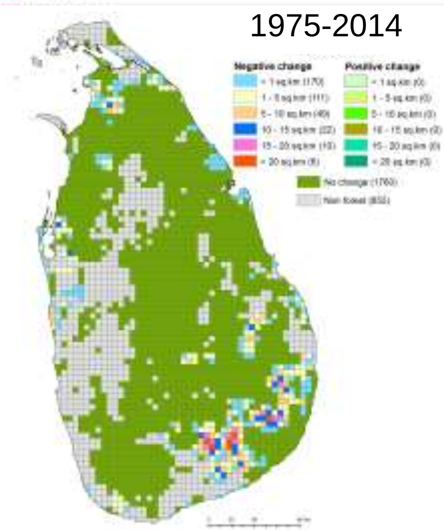


Long term forest cover change
in India, Bangladesh, Bhutan and Sri Lanka







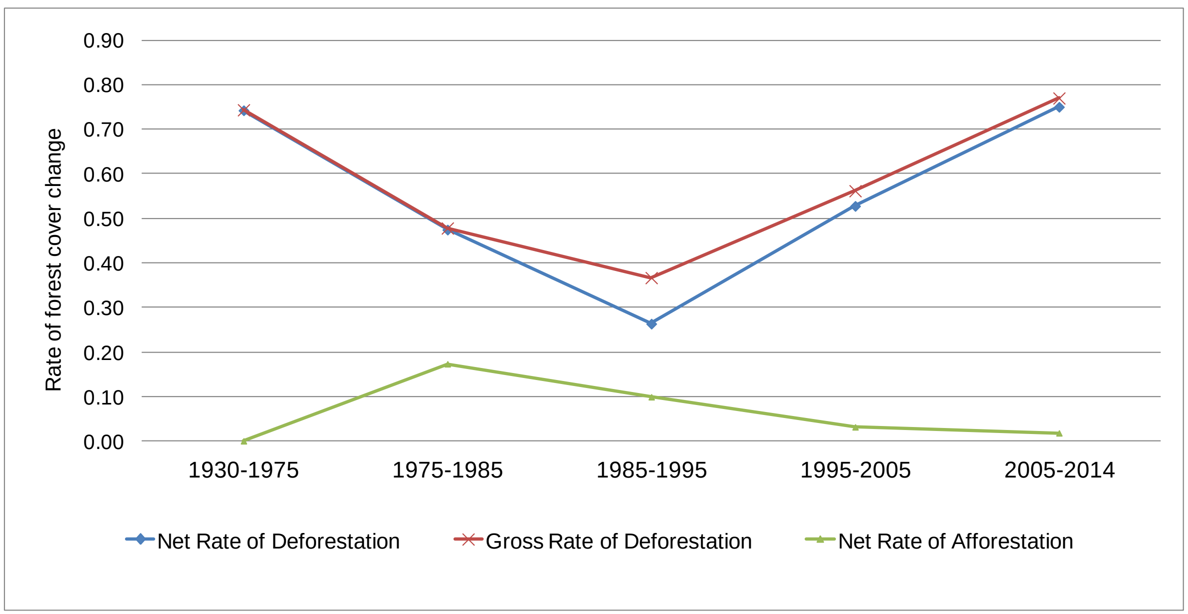


Reddy, C.S., Jha, C.S., Dadhwal, V.K., Harikrishna, P., Pasha, S.V., Satish, K.V. et al. 2016. **Biodiversity and Conservation** 25: 93–116.
Reddy, C.S., Jha, C.S., Diwakar, P.G. & Dadhwal, V.K. 2015. **Environmental Monitoring and Assessment** 187:1-30.
Reddy, C.S., Pasha, S.V., Jha, C.S., Diwakar, P.G. & Dadhwal, V.K. 2016. **Global and Planetary Change** 139: 173–182.
Reddy, C.S., Rakesh, F., Jha, C.S., Athira, K., Diwakar, P.G. Dadhwal, V.K. et al. 2016. **Global and Planetary Change** 143: 50-65.

Forest cover change in Bangladesh

Period	Area (km^2)	% of Total Geographical Area
1930	23140	15.7
1975	16568	11.2
1985	16275	11.0
1995	15852	10.7
2005	14957	10.1
2014	14086	9.5

Period	Net rate of Deforestation	Gross rate of Deforestation	Rate of Afforestation
1930-1975	0.74	0.74	0.00
1975-1985	0.47	0.48	0.17
1985-1995	0.26	0.37	0.10
1995-2005	0.53	0.56	0.03
2005-2014	0.75	0.77	0.02



Formula to calculate rate of forest cover change

$$P = \frac{100}{t_2 - t_1} \ln \frac{A_2}{A_1}$$

where A_1 and A_2 are the forest cover at time t_1 and t_2, respectively. P is percentage per year.

Highlights of the study

- The highest annual rate of deforestation found in Pakistan, Bangladesh and India between 1930-1975.

- The highest annual rate of deforestation found in Bangladesh (0.43), followed by Sri Lanka (0.15) from 1975-2014.

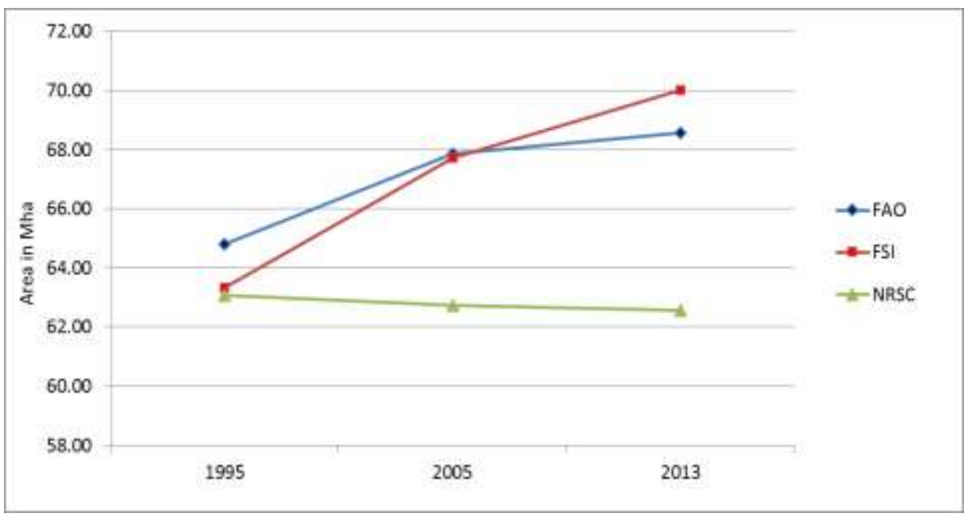
- Bhutan and Afghanistan shows low annual rate of deforestation among South Asian countries.

- Overall annual rate of deforestation for South Asia was estimated as 0.60 during 1930-1975 and 0.12 in 1975-2013/14.

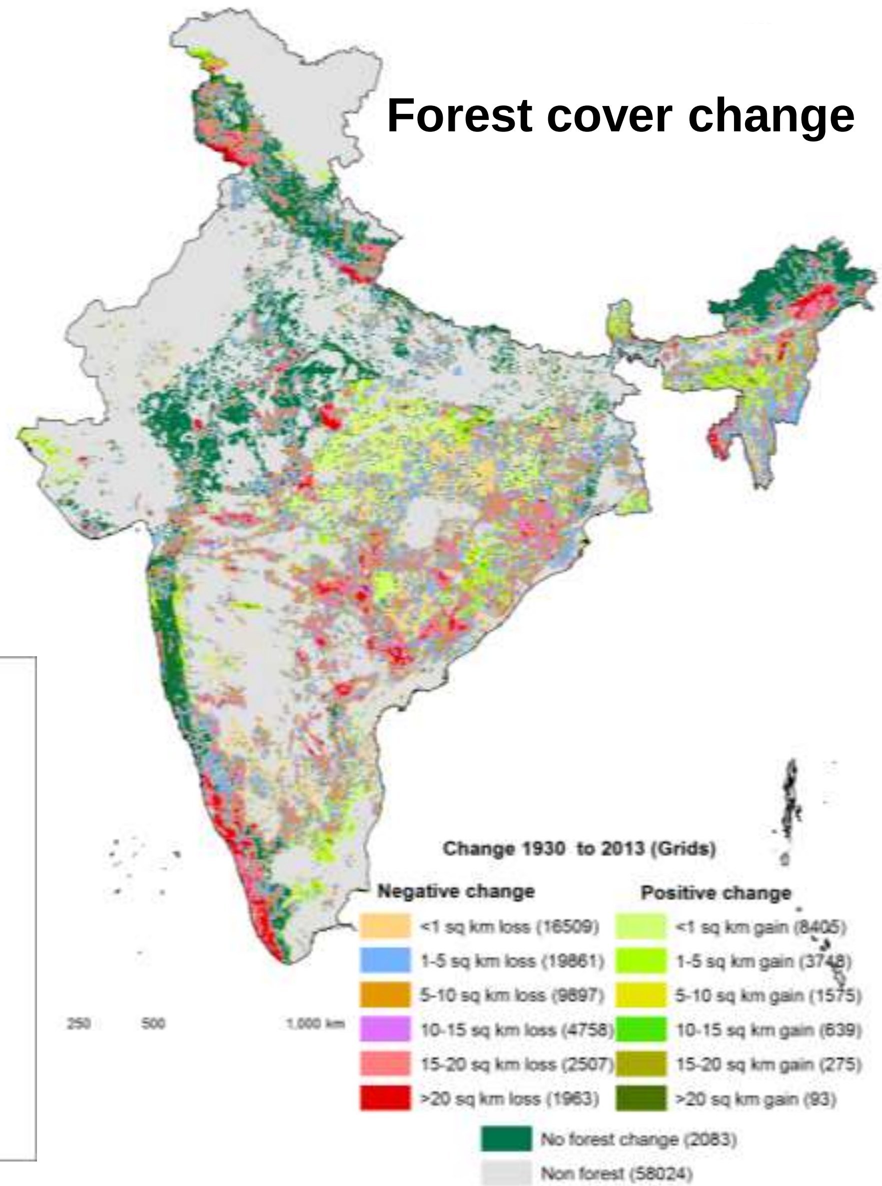
India: Forest cover

Period	Area (km²)	% of TGA
1930	869,012	26.4
1975	653,220	19.9
1985	638,460	19.4
1995	630,795	19.2
2005	627,233	19.1
2013	625,565	19.0

Comparison of forest cover as per FAO, FSI & NRSC

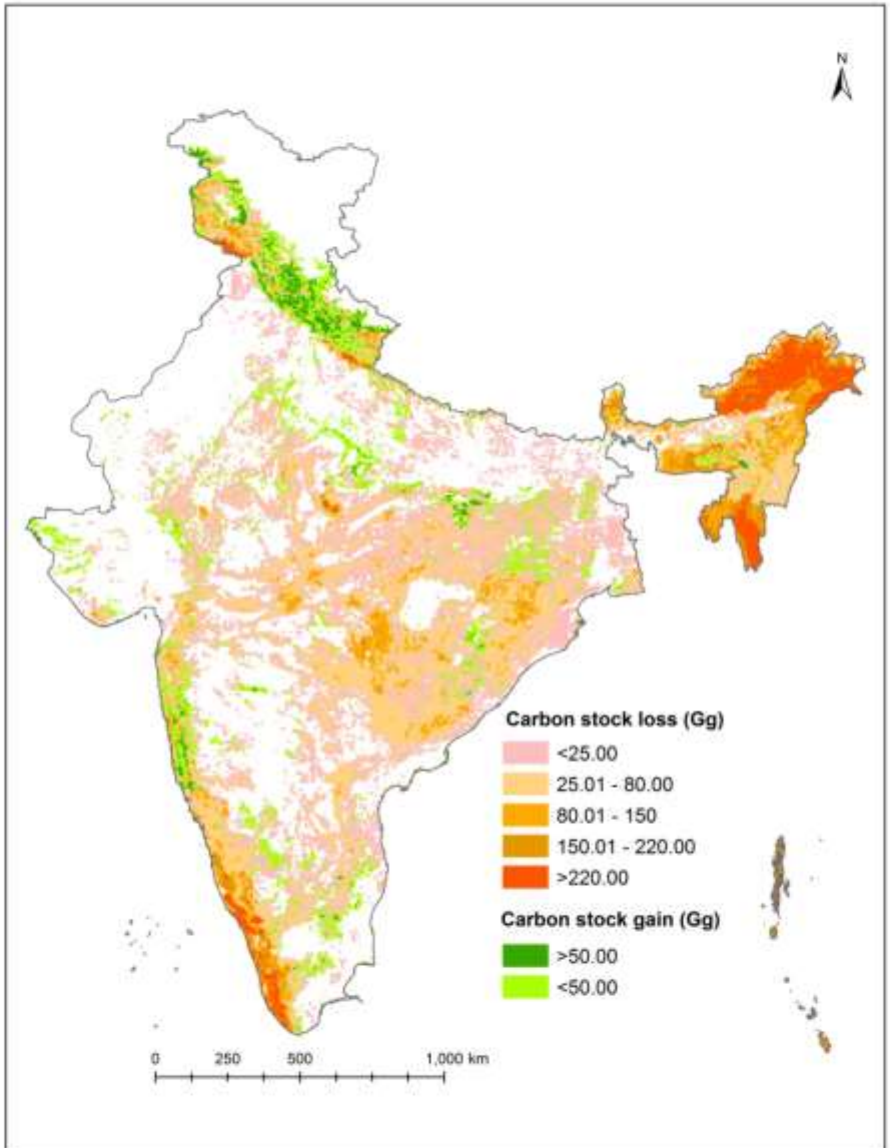


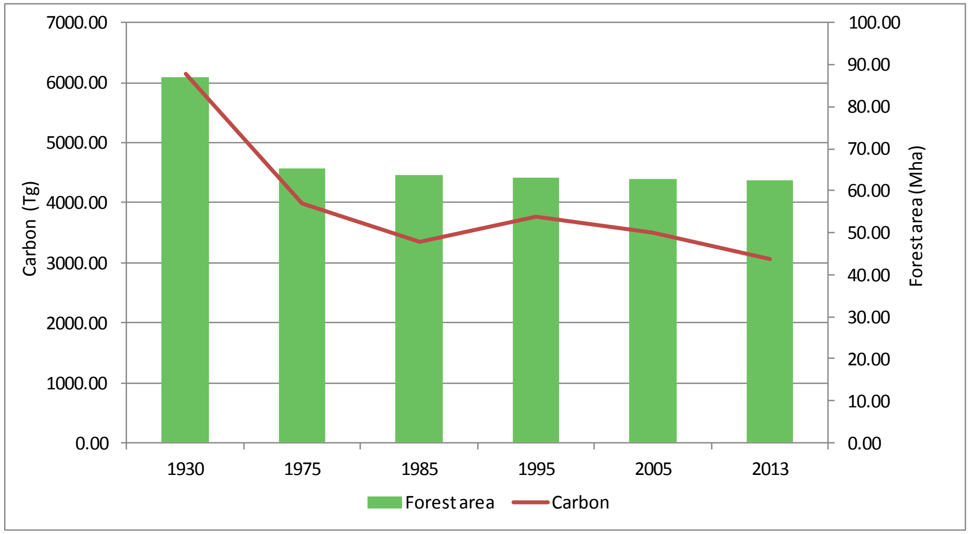
Forest cover change



Reddy, C.S., Jha, C.S., Dadhwal, V.K., Hari Krishna, P., Pasha, S.V, Satish, K.V., Dutta, K., Saranya, K.R.L., Rakesh, F., Rajashekar, G. & Diwakar, P.G. 2015. Quantification and monitoring of deforestation in India over eight decades (1930-2013) (*Biodiversity and Conservation*).

Historical trend in phytomass carbon



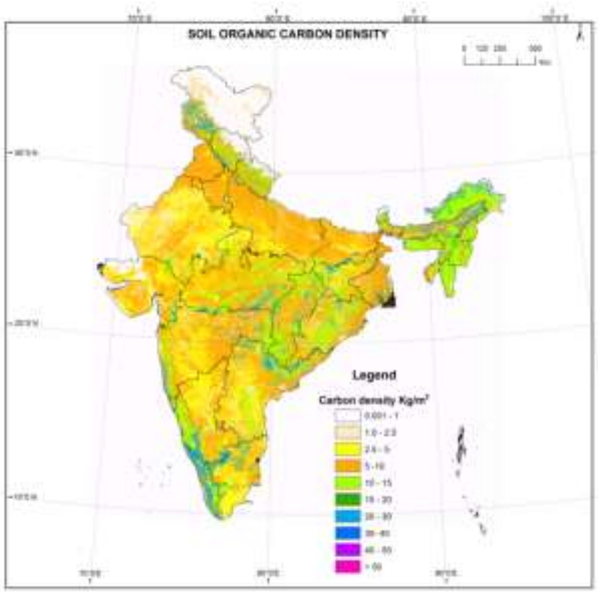


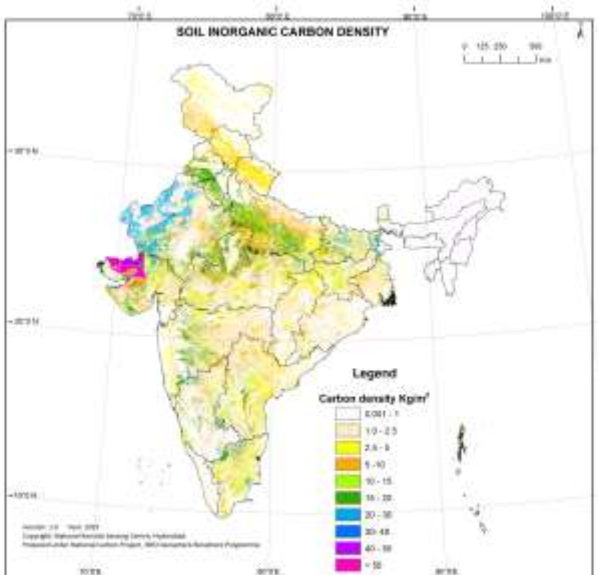
C. Sudhakar Reddy, F. Rakesh, C.S. Jha, K. Athira, Sonali Singh, V.V.L. Padma Alekhya, G. Rajashekar, P.G. Diwakar & V.K. Dadhwal Indian forest phytomass carbon stocks and fluxes during 1930-2013 – Geospatial assessment. Accepted in Global and Planetary change.

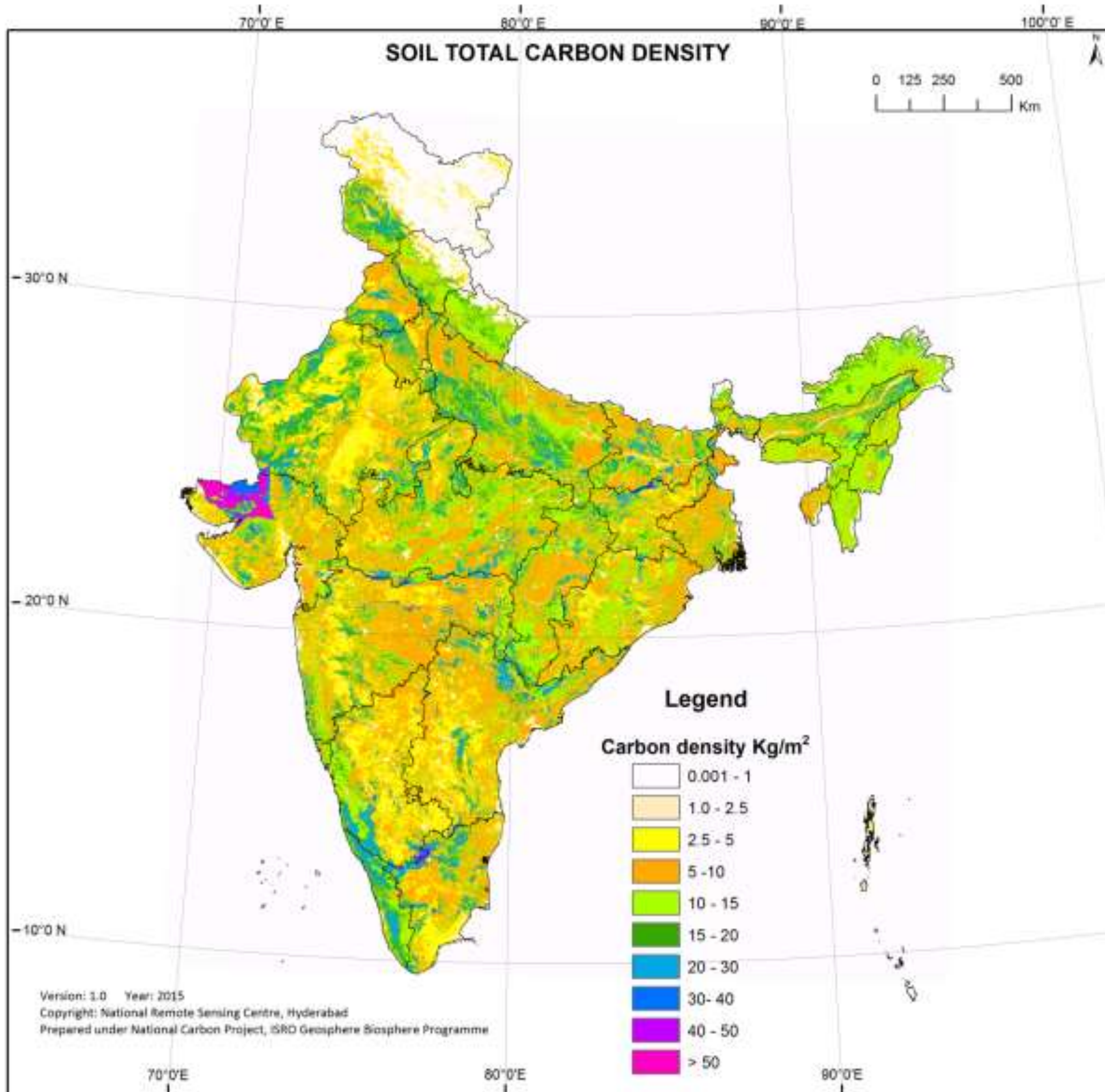
Sub Project: Soil Carbon Pools

Objectives

- **Spatial assessment of organic and inorganic soil carbon stocks**







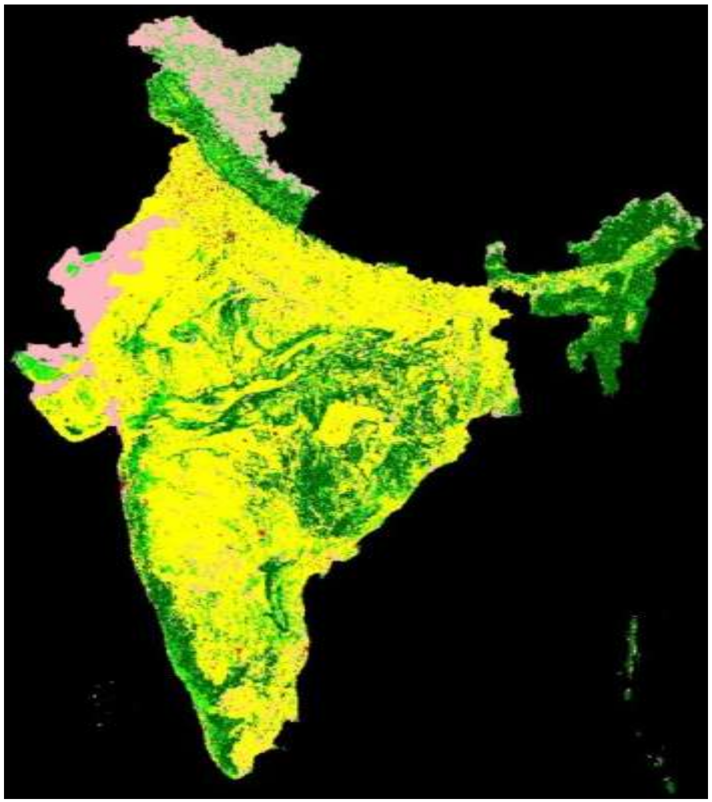
Indian National Communication to UNFCCC

SNC, BU-Report – 2014 & TNC

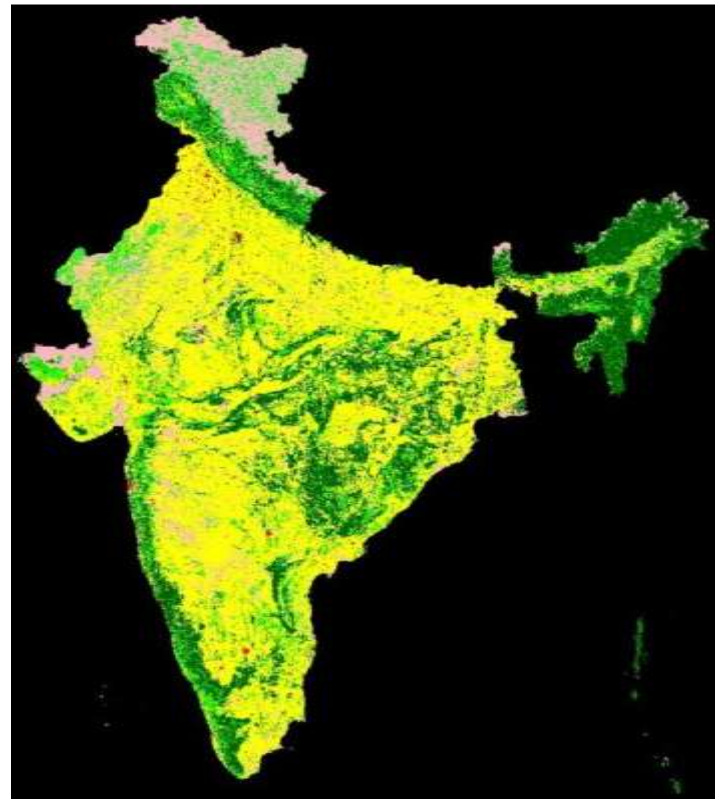
Remote Sensing based Inputs to Land use, land-use Change and Forestry (LULUCF)

Results

2005



2010



177 TC sequestered


FOREST FIRES
SATELLITE REMOTE SENSING IN
FOREST FIRE MONITORING AND MANAGEMENT

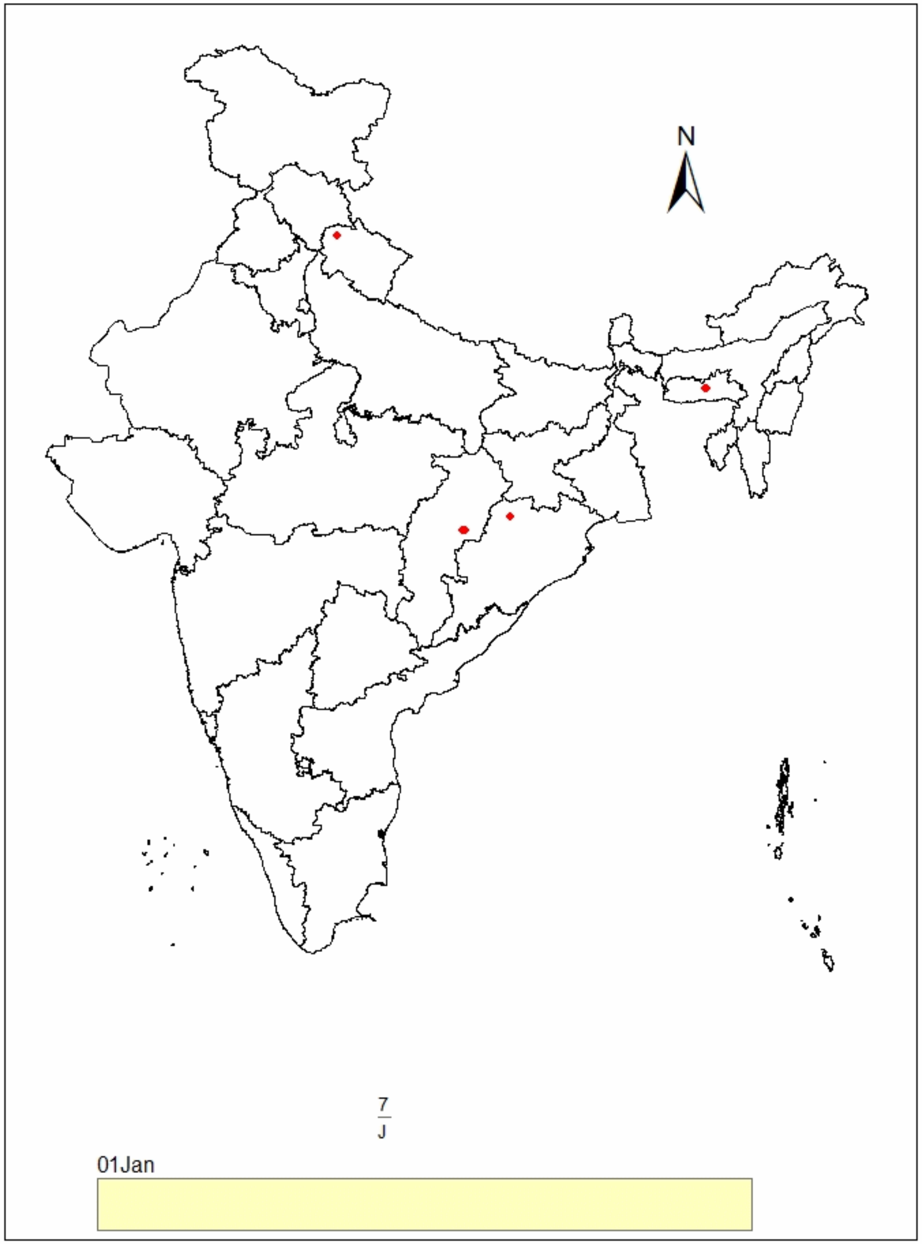
Importance

- Forest fires effect ecology, biodiversity, climate, environment, human health and economy.
- Significant source of carbon to the atmosphere.
- Emission of trace gases and aerosol particles.
- Direct contributors to climate change.

Relevance

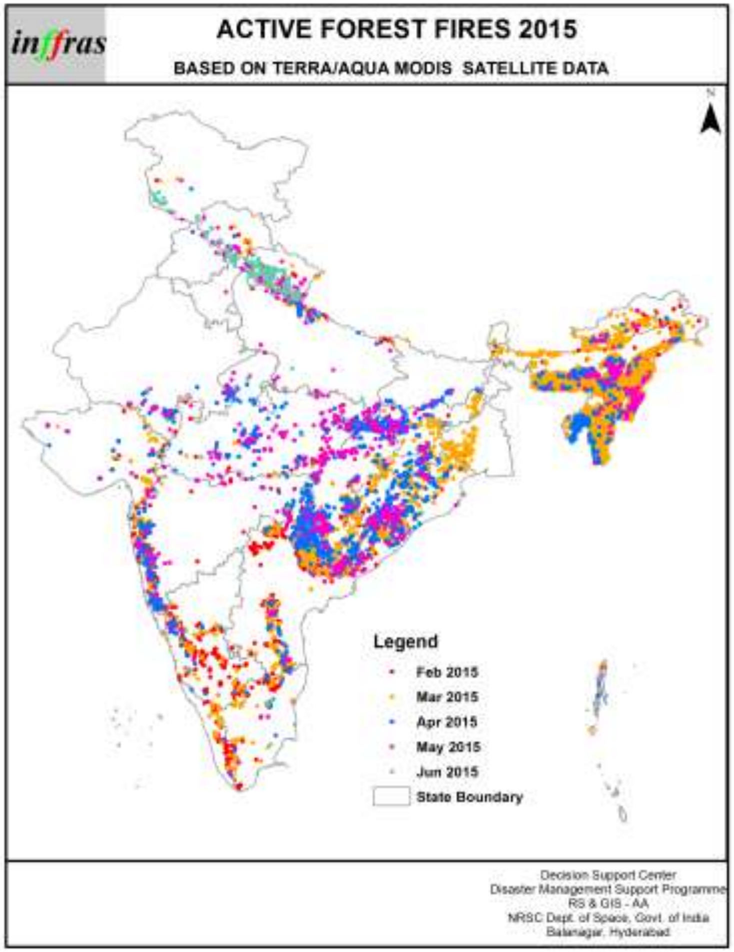
- > 50% of Indian forests are prone to fire, ~6-9% experience intense fire episodes
- ~ Rs 500 crores is spent annually in India on fire fighting
- Information on location, extent, intensity and rate of spread – critical
- Near real time information necessary for effective fire management
- RS sensors have the potential to identify active fires and burn scars
- <u>Identified as a continued effort as part of National Meet, Sep 2015</u>

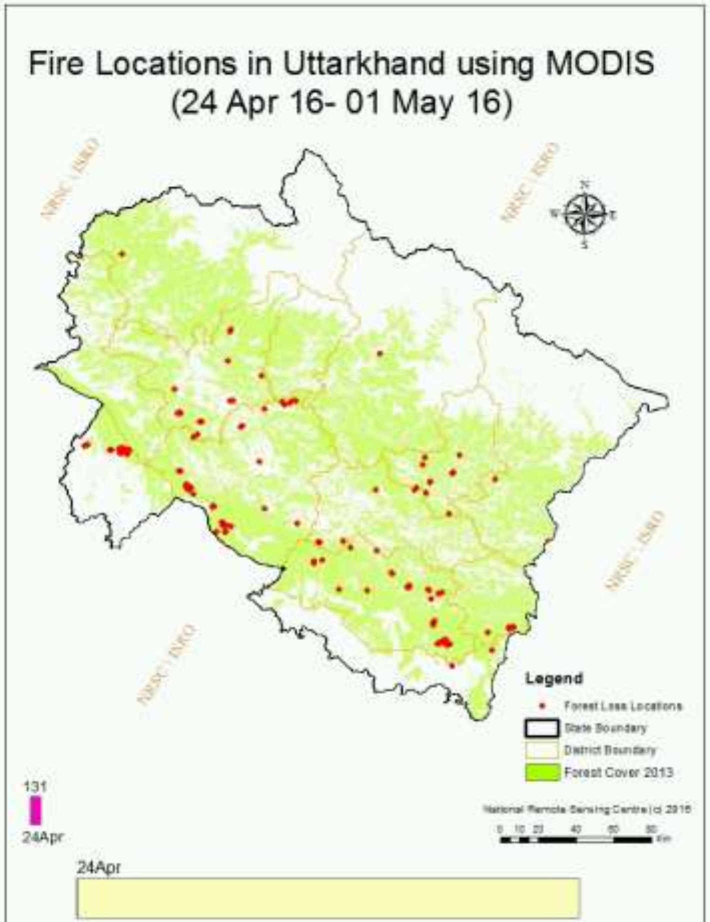
Daily monitoring of Forest Fires in India



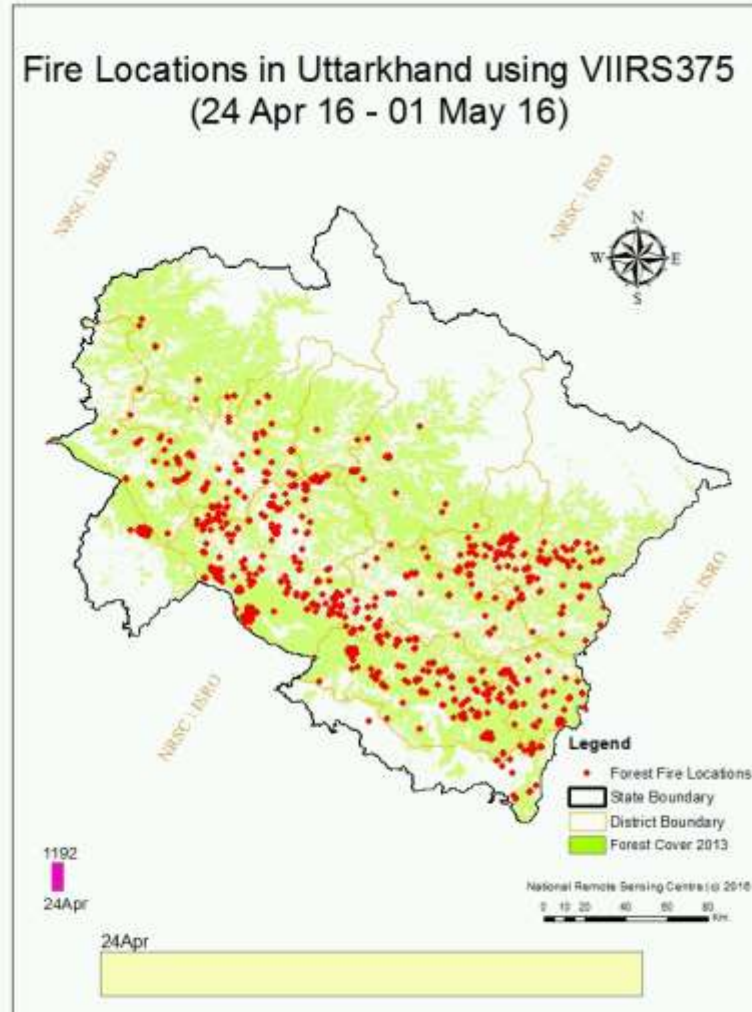
NRSC, ISRO, 2014

Active Fire Monitoring - 2015





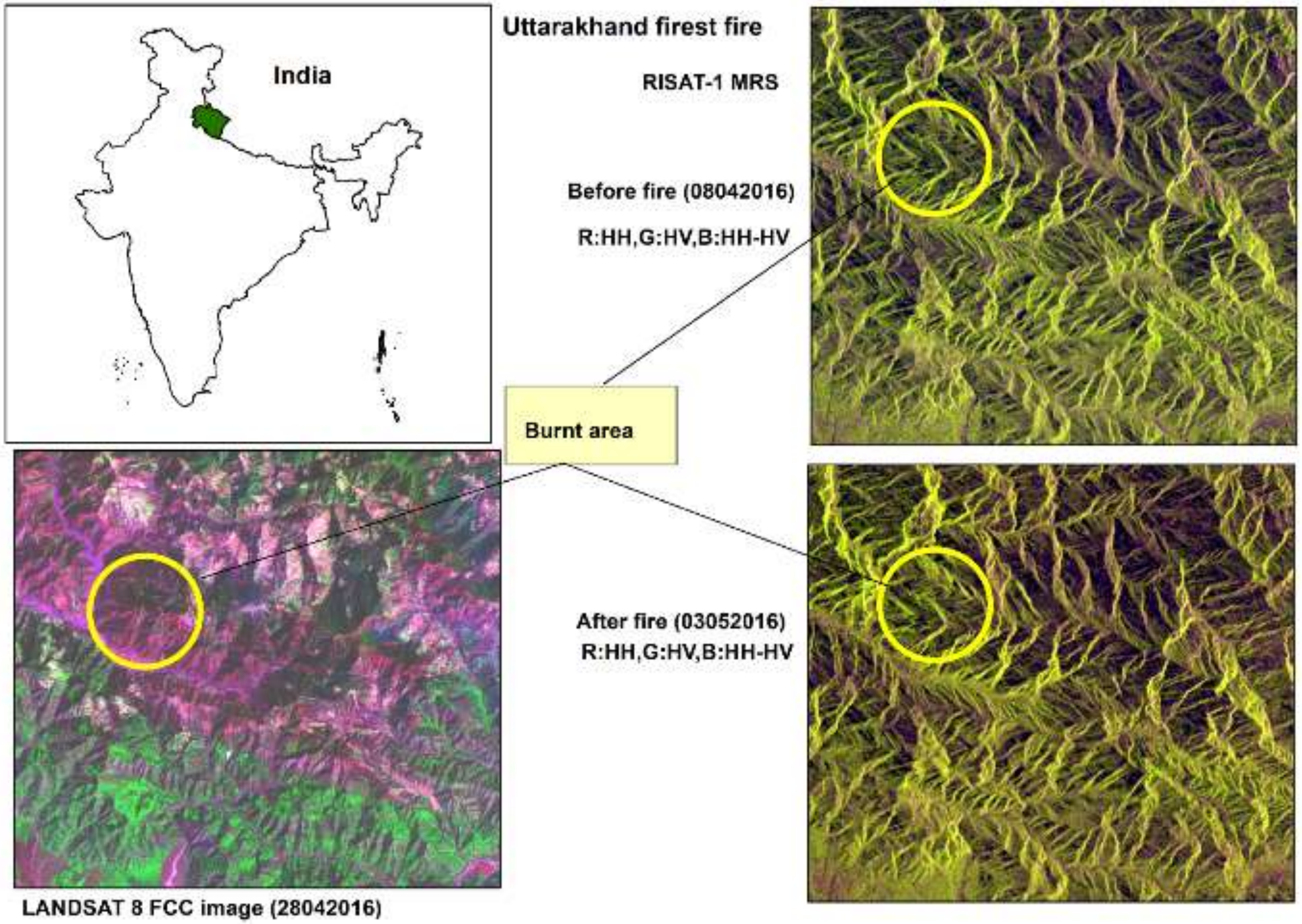
Fire Locations in Uttarkhand using MODIS
(24 Apr 16- 01 May 16)
NRSC / ISRO
N
W
E
S
Legend
Forest Loss Locations
State Boundary
District Boundary
Forest Cover 2013
National Remote Sensing Centre (c) 2016
0 10 20 40 60 80
Km
131
24Apr
24Apr



Fire Locations in Uttarkhand using VIIRS375
(24 Apr 16 - 01 May 16)
NRSC / ISRO
N
W
E
S
Legend
Forest Fire Locations
State Boundary
District Boundary
Forest Cover 2013
National Remote Sensing Centre (c) 2016
0 10 20 40 60 80
Km
1192
24Apr
24Apr

Khurpa Tal, Naini Tal

Uttarakhand burned area analysis using RISAT-1 MRS SAR data

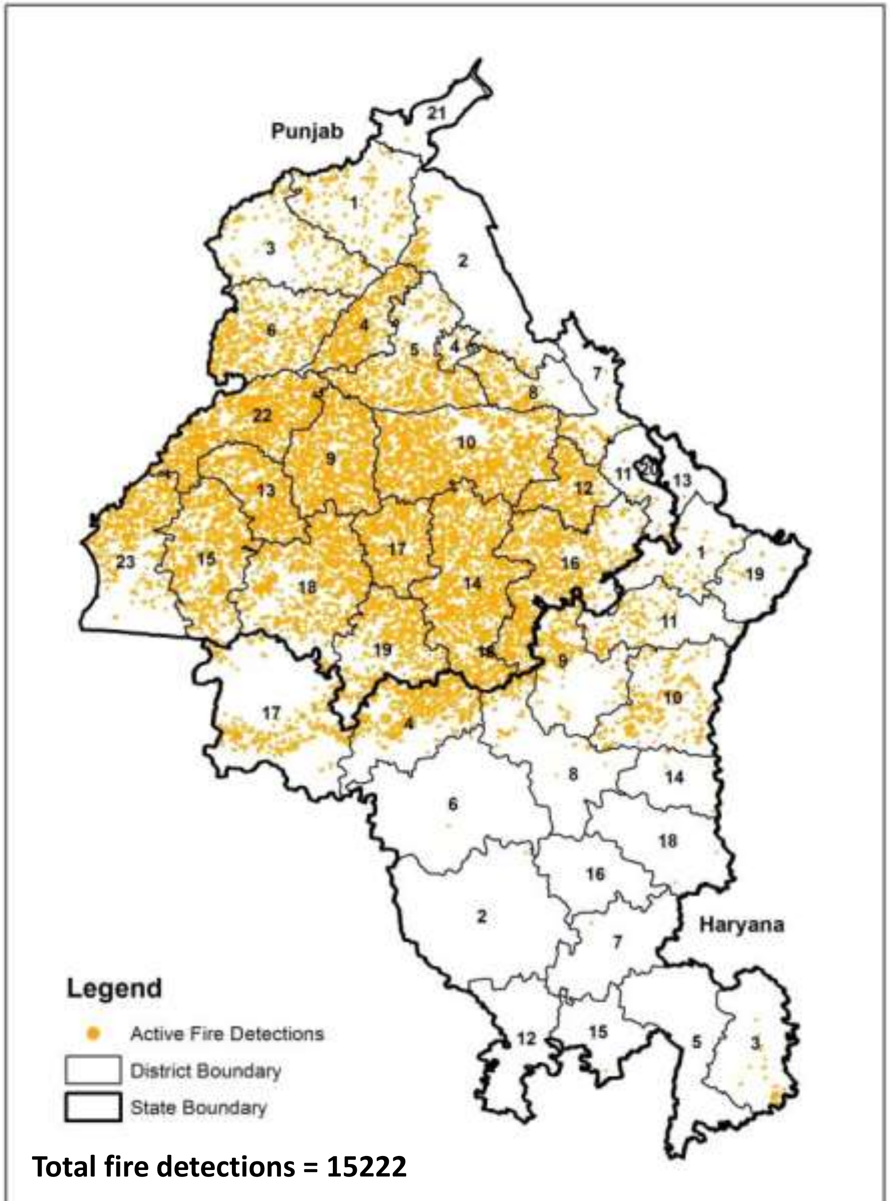


Agriculture Residue (Stubble) Burning

Background

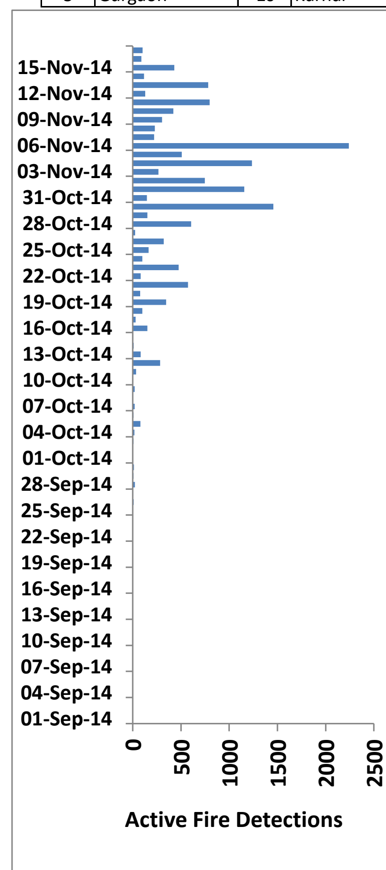
- The Rice-wheat cropping system (RWS) is widely practiced in the Indus (Punjab and Haryana) and Gangetic Plains (UP, Bihar & WB), which accounts for nearly 12 million hectares.
- Common practice to clear remaining straw and stubble after harvest to prepare the field for next cropping cycle
- Very few localized studies exist
- Uncertainty in estimates of total area and amount of residue (biomass) burnt.

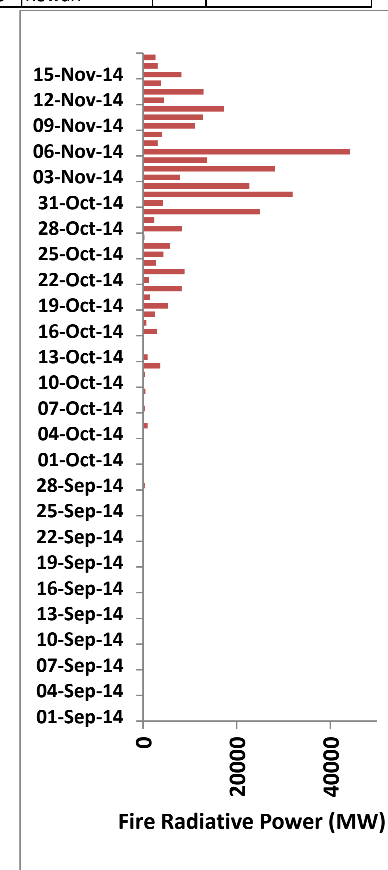
MODIS based active fire detections during Sep-Nov 2014
Based on Overpasses at ~1030 and ~1430 daily



District Reference

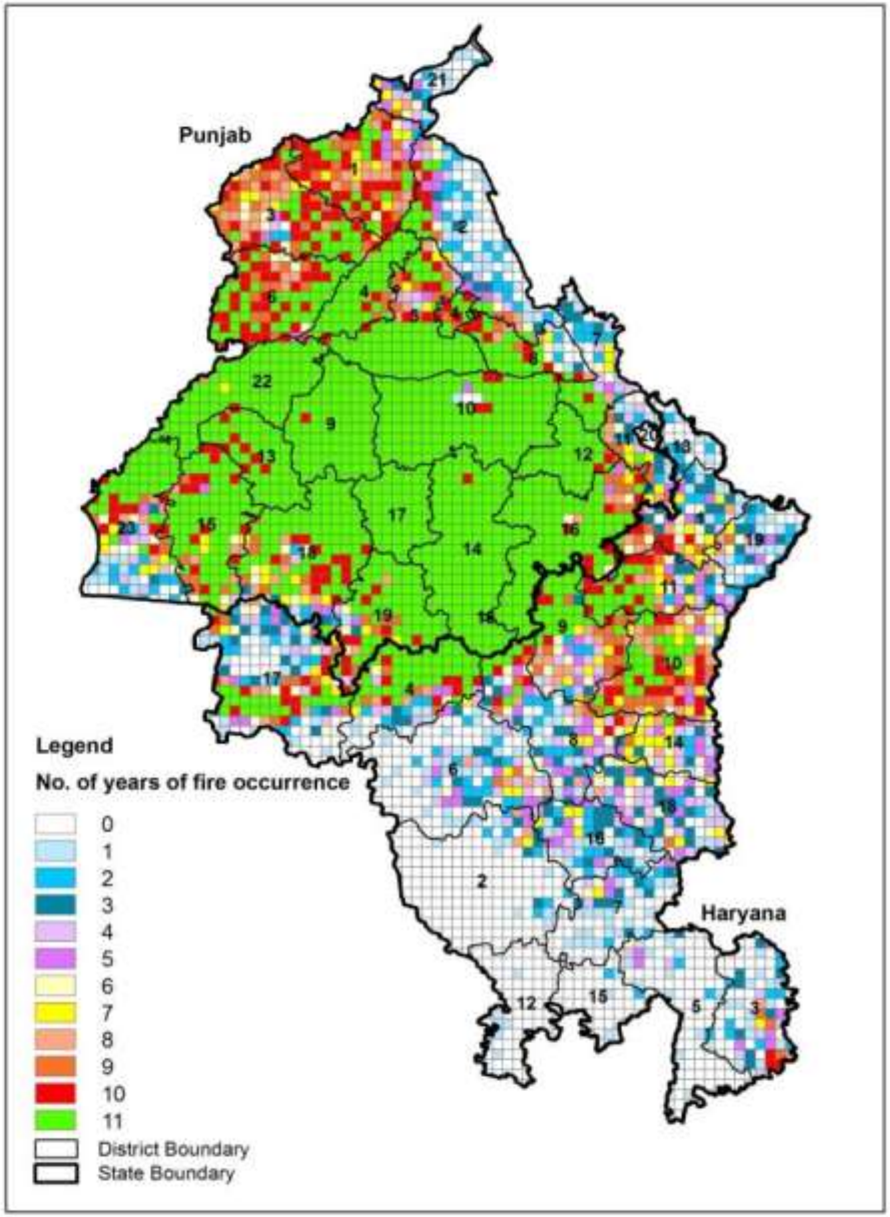
Punjab							
Sl.No	District	Sl.No	District	Sl.No	District	Sl.No	District
1	Amritsar	7	Fazika	13	Ludhiana	19	Patiala
2	Barnala	8	Firozpur	14	Mansa	20	Rupnagar
3	Bathinda	9	Gurdaspur	15	Moga	21	Sangrur
4	Chandigarh	10	Hoshiarpur	16	Muktsar	22	Sas Nagar (Mohali)
5	Faridkot	11	Jalandhar	17	Nawan Shehar	23	Tarn Taran
6	Fatehgarh Sahib	12	Kapurthala	18	Pathankot		
Haryana							
Sl.No	District	Sl.No	District	Sl.No	District	Sl.No	District
1	Ambala	6	Hisar	11	Kurukshetra	16	Rohtak
2	Bhiwani	7	Jhajjar	12	Mahendragarh	17	Sirsa
3	Faridabad	8	Jind	13	Panchkula	18	Sonepat
4	Fatehabad	9	Kaithal	14	Panipat	19	Yamuna Nagar
5	Gurgaon	10	Karnal	15	Rewari		





Kiran Chand et al., Current Science, 2015

MODIS based number of fire occurrence years during 2004-2014 (Sep-Nov)



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Haryana							
Sl.No	**District**	**Sl.No**	**District**	**Sl.No**	**District**	**Sl.No**	**District**
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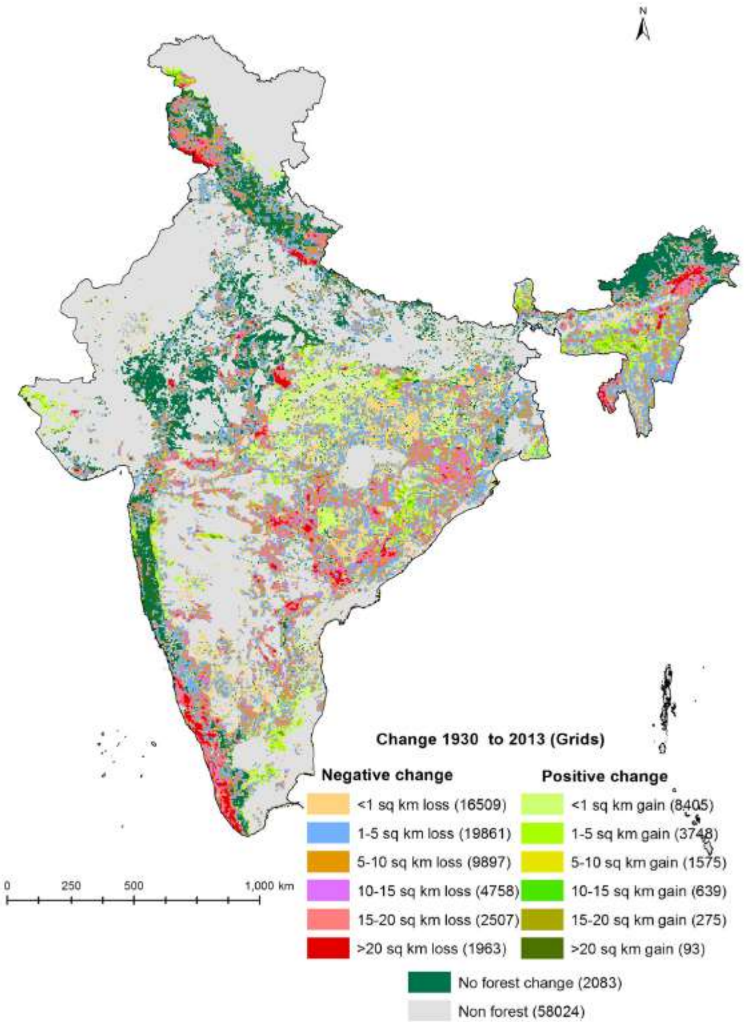
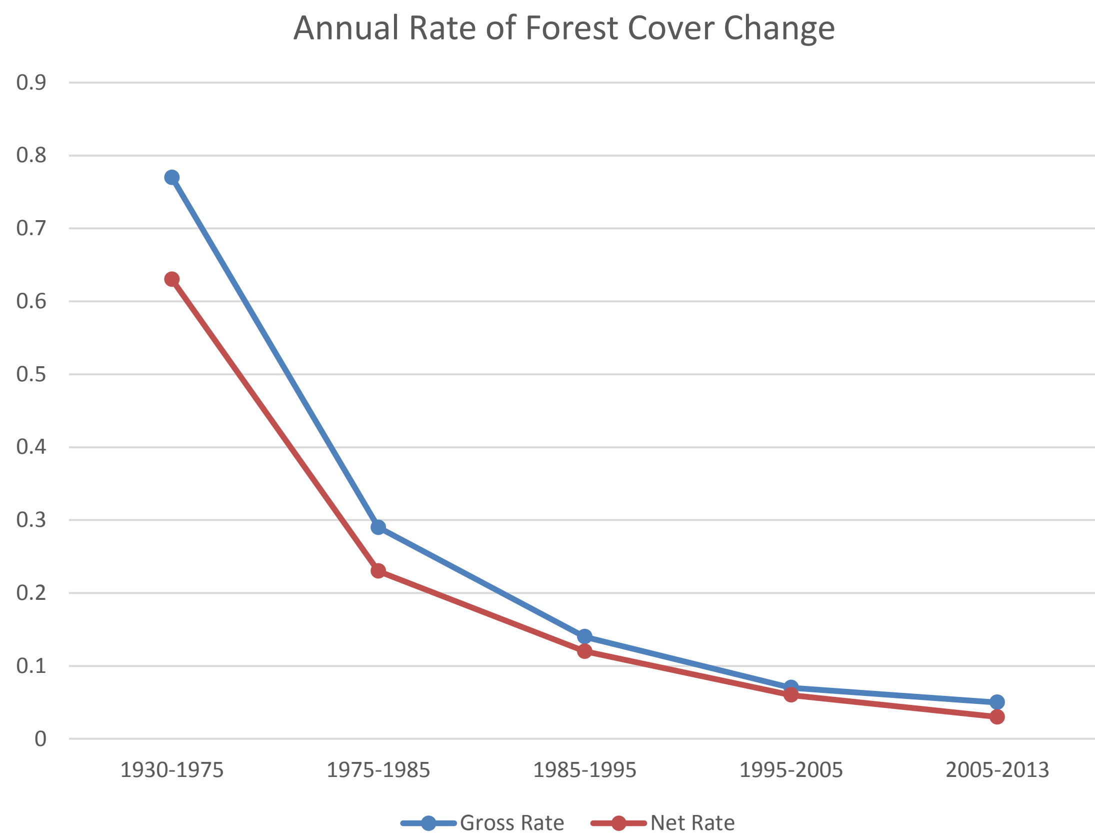
2	Bhiwani	7	Jhajjar	12	Mahendragarh	17	Sirsa
3	Faridabad	8	Jind	13	Panchkula	18	Sonepat
4	Fatehabad	9	Kaithal	14	Panipat	19	Yamuna Nagar
5	Gurgaon	10	Karnal	15	Rewari		

Automated Forest Loss Alerts

Historical trend in India’s forest area





Reddy, C.S., Jha, C., Dadhwal, V., Krishna, P.H., Pasha, S.V., Satish, K., Dutta, K., Saranya, K., Rakesh, F., Rajashekar, G., others, 2016. Quantification and monitoring of deforestation in India over eight decades (1930-2013). Biodiversity and Conservation 25, 93–116.

- Intended Nationally Determined Contribution (INDC): additional carbon sink of 2.5 to 3.0 billion tonnes of CO_2 by 2030

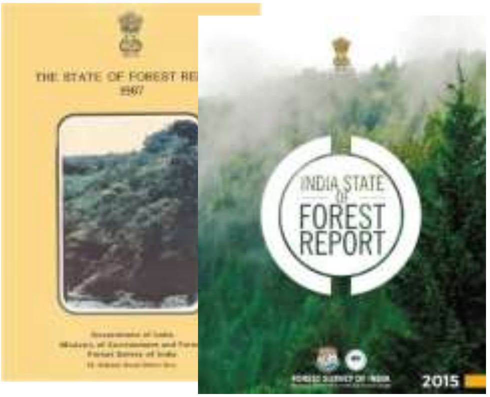
Automated Forest Cover Change Alert System

Forestry and Ecology Group

National Forest Cover Monitoring

Current Scenario

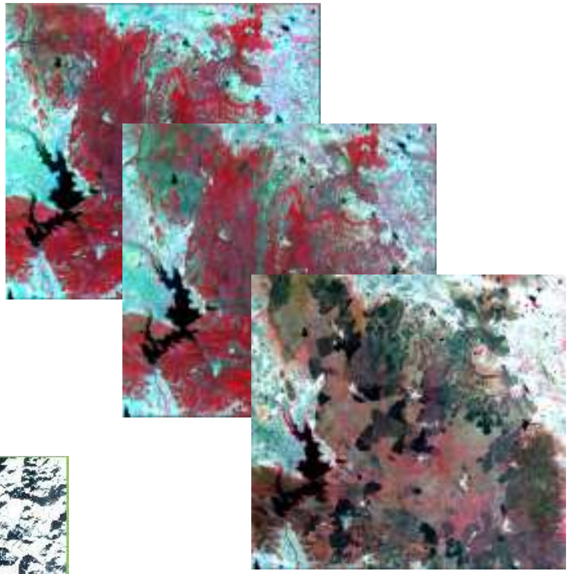
- National Forest Cover Mapping – Forest Survey of India (FSI)
  - ✓ Biennial (2 years)
  - ✓ LISS-3 (24m data)
  - ✓ Large scale Mapping (1:50000)
  - ✓ Four Density Classes with Area Estimates
- × No spatial Map of Forest Cover Change.



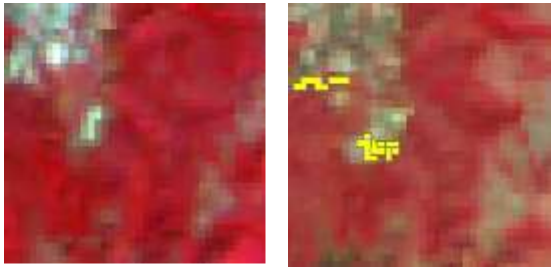
Requirement

- Monitoring at annual to sub-annual scales for detection of forest cover change.
- Automated Method.
- Detect Fine changes.
- Not sensitive to Phenological changes.
- Not Sensitive to transient events (cloud, snow etc.,).
- Low Commission error (False alerts).

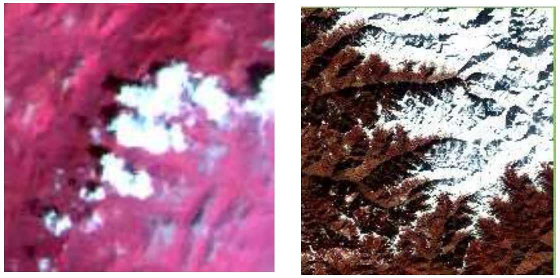
Phenological changes



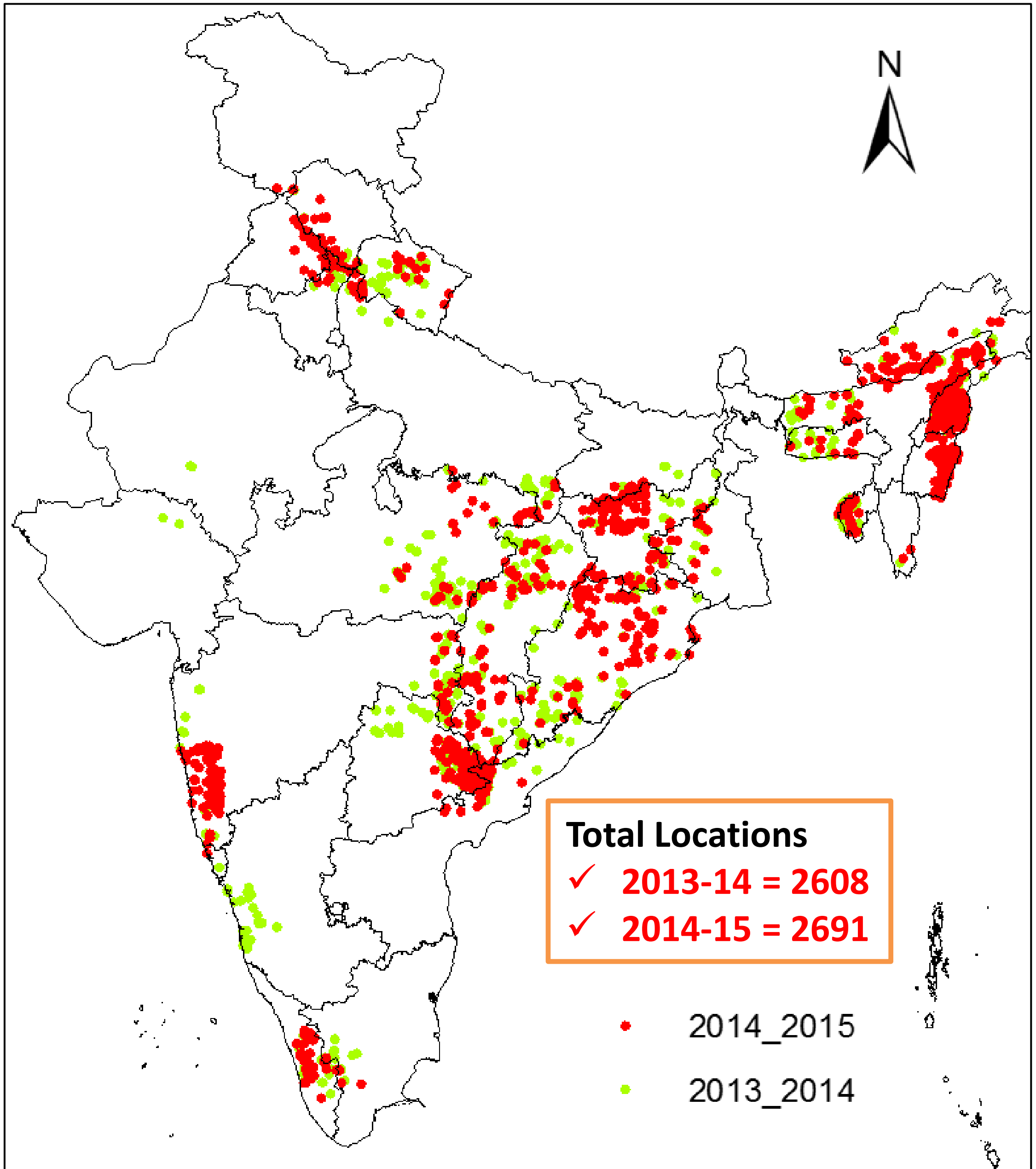
Fine change

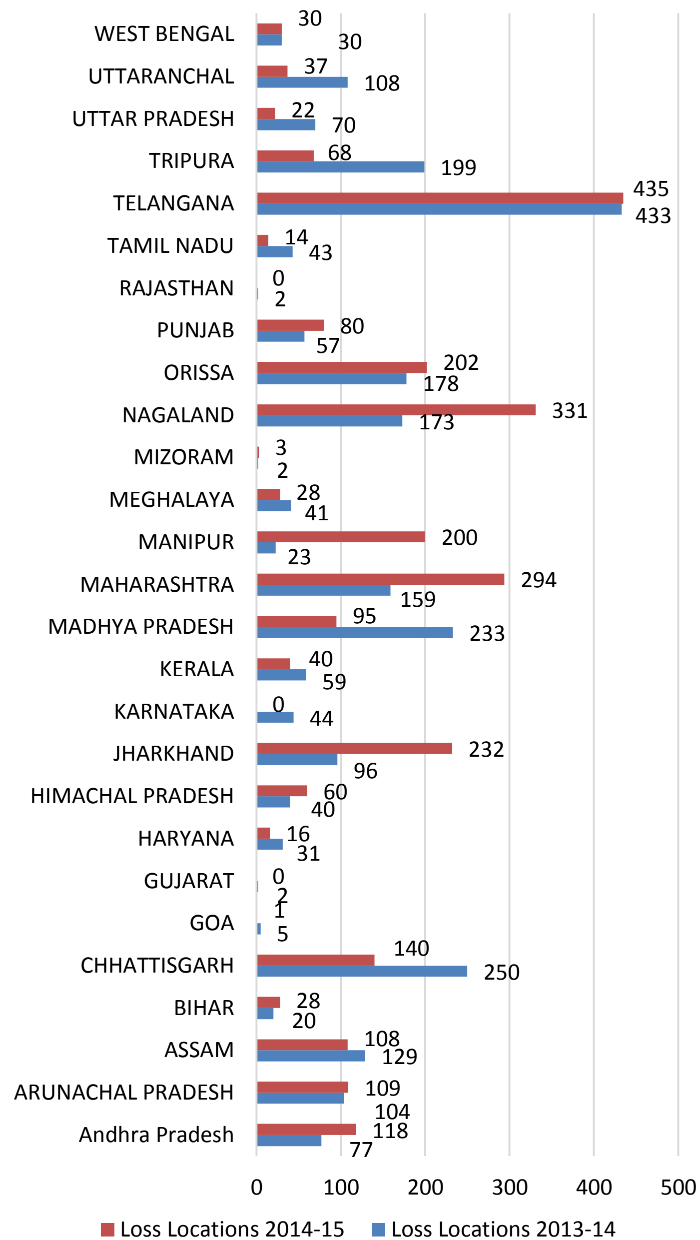


Cloud and Snow



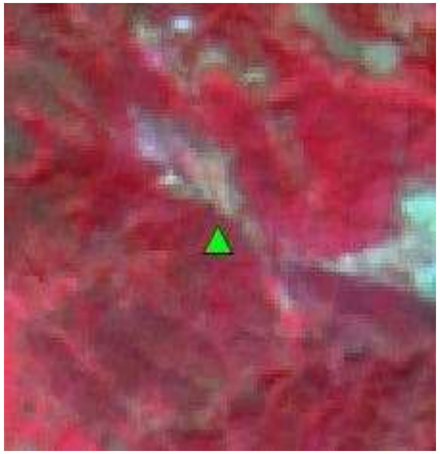
Automated forest cover loss locations using IRS AWiFS





Comparision of AWiFS loss locations with Very High resolution satellite imagery

2010



30 October 2014

2014

22 November 2014

Forest cover change due to mining activity in Telangana

2011

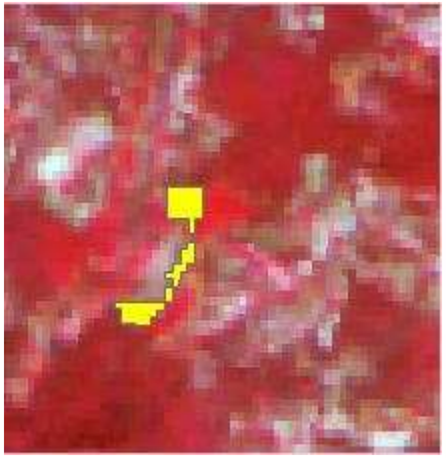
2014

Location: Devadurgam
Lat: 19.279336°
Long:80.955359°

2011

22 November 2014

2014



06 December 2014

Forest plantation change in Karnataka

2010

2014

Location: Kalkoppa
Lat: 13.927254°
Long: 75.206108°

Way forward

- Monitoring of Indian vegetation
- Efforts towards reducing uncertainty in AGB
- Advances in SAR, LiDAR for tree height, volume, LAI etc.
- National fire burnt area assessment
- Fire Danger Rating and emission scenarios
- Developing methods for tier-3 based inputs to NATCOM

Thank you

Acknowledgements :
ISRO Projects Teams
and
Collaborators