Geospatial Assessment of Terrestrial Carbon Cycle of India: *Addressing Multi-source Data Integration, Evolution and Evaluation of Policy Options*

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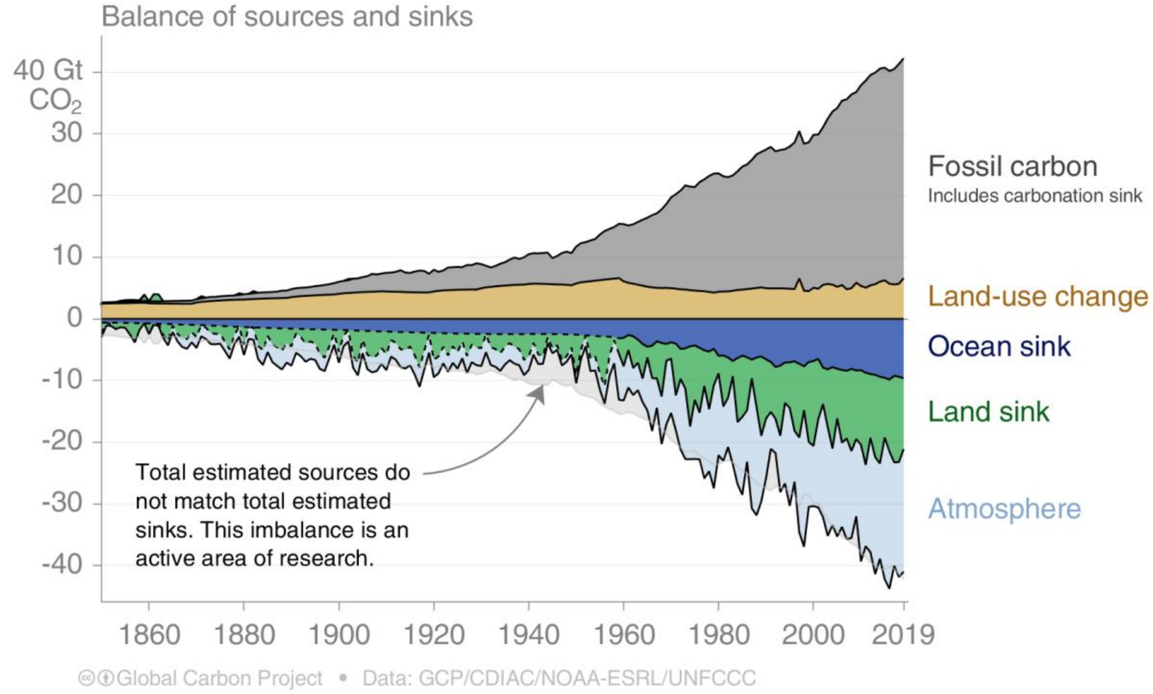
Theme: "Geo-Enabling the Global Village: No one should be left behind"
(Parallel Track 2: Data and Standards; Session TP2E : Approaches for Effective Data Integration, October 12, 2022)

Time Evolution (1860 onwards) & Fate of anthropogenic CO_2 emissions (2010–2019)

- Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean
  The "imbalance" between total emissions and total sinks is an active area of research



Sources = Sinks

34.4 $GtCO_2$/yr
86%

14%
5.7 GtCO2/yr

18.6 GtCO2/yr
46%

31%
12.5 GtCO2/yr

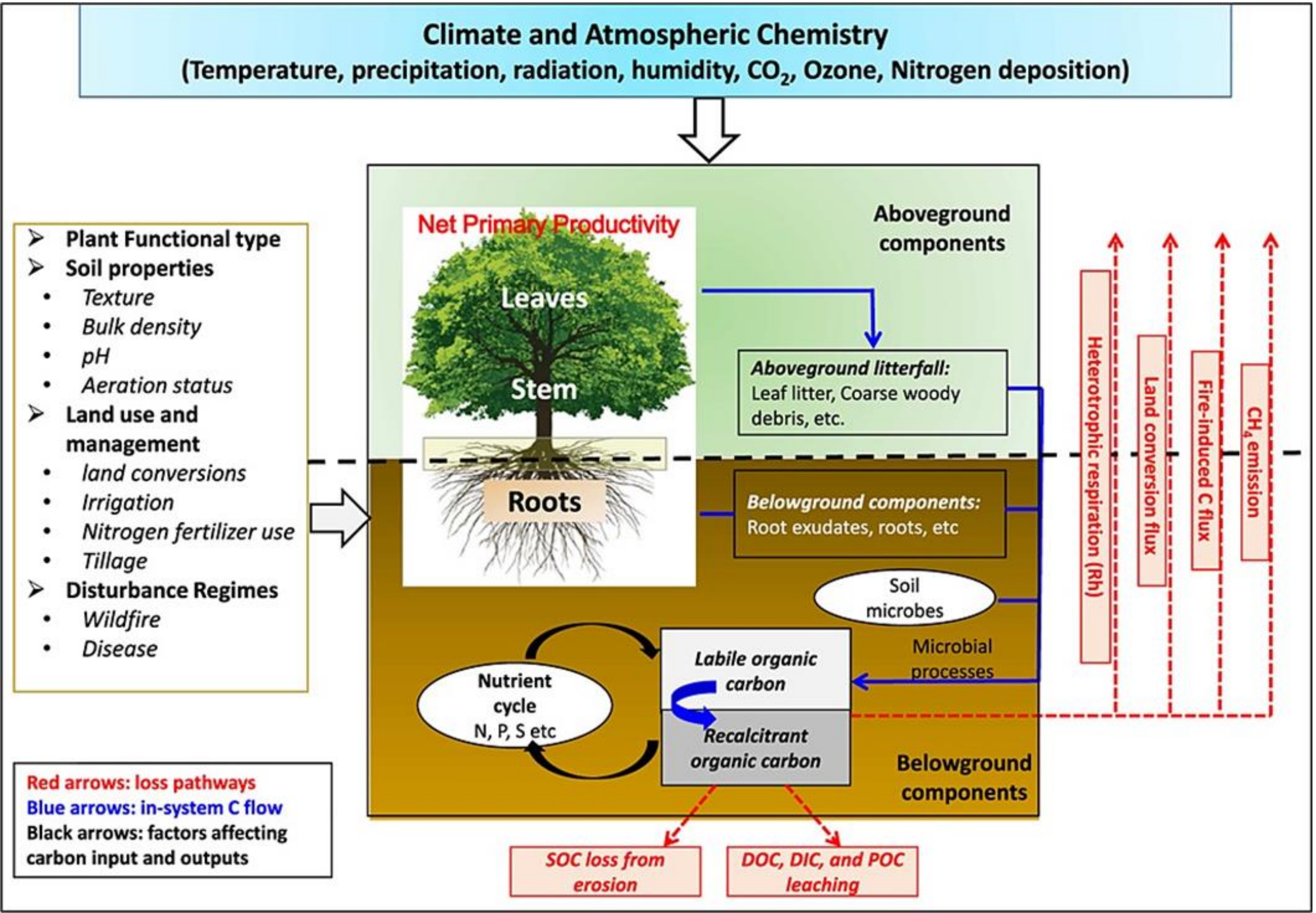
23%
9.2 GtCO2/yr

Budget Imbalance:
(the difference between estimated sources & sinks)

0.4%
0.2 $GtCO_2$/yr

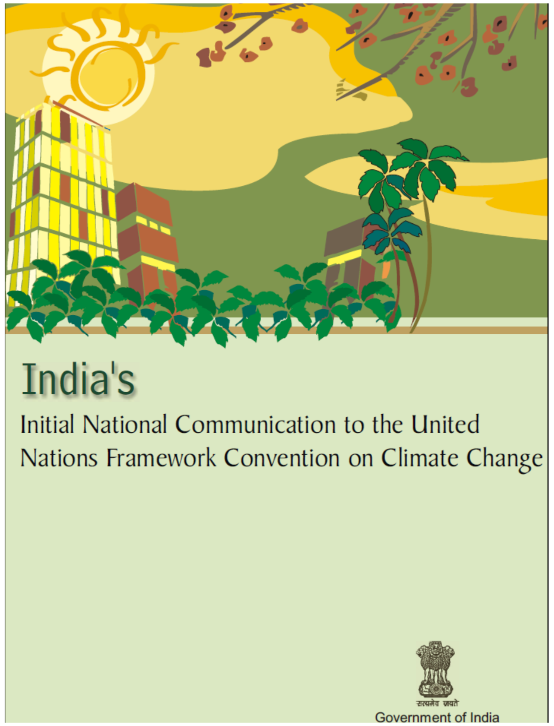
Source: Friedlingstein et al 2020; Global Carbon Budget 2020

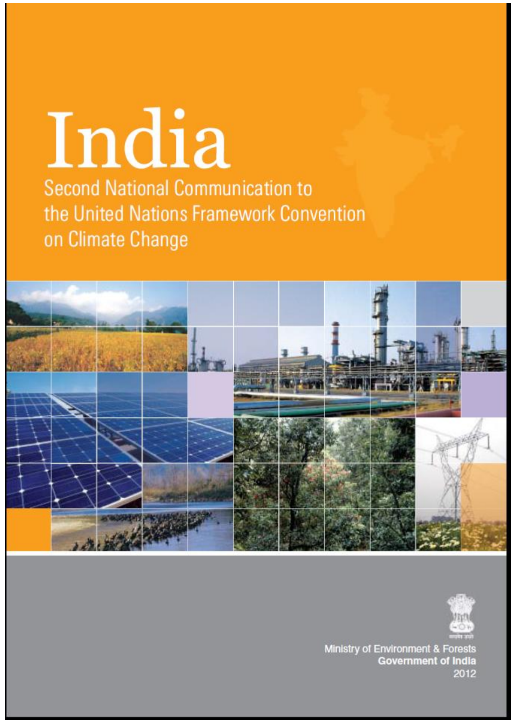
Terrestrial Carbon Cycle : Vegetation Dominated

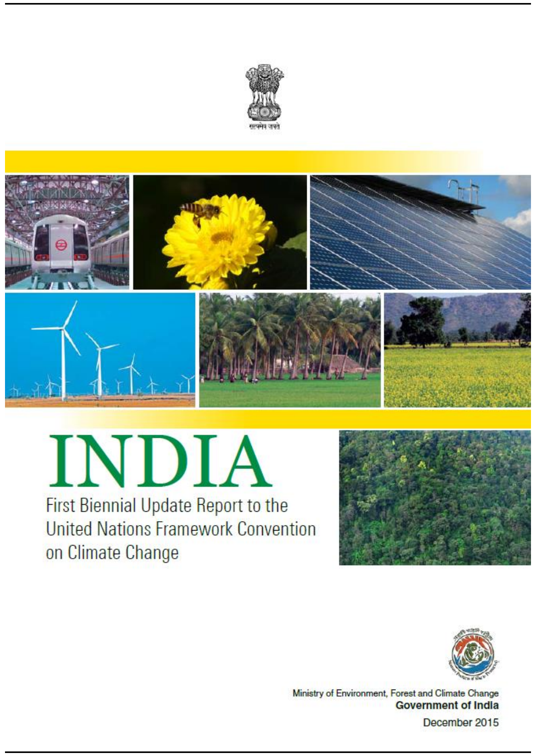


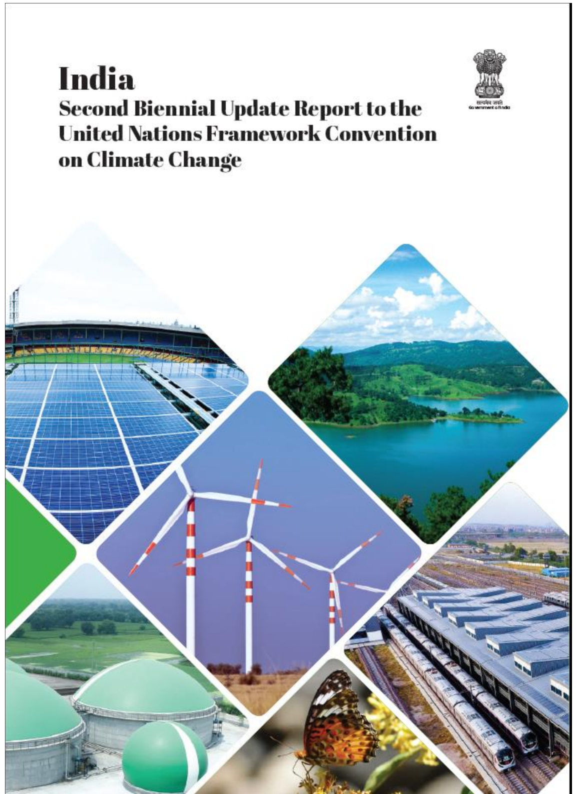
- Hydrologic C cycle
  - *DOC, POC, HCO3*
- Geochemical C Cycle
  - *Weathering*
- Human C flows
  - *Food, Wood, Fire, …*
- Human alteration of natural C Cycle
  - *Land Use / Land Cover Change*

Indian National Communication to UNFCCC





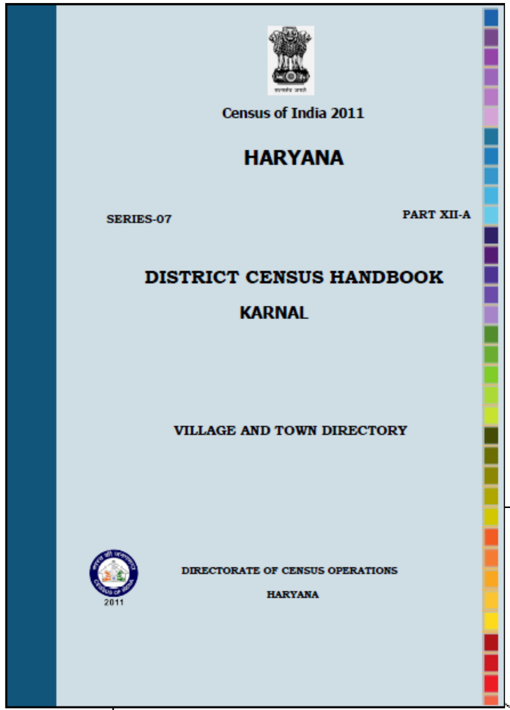


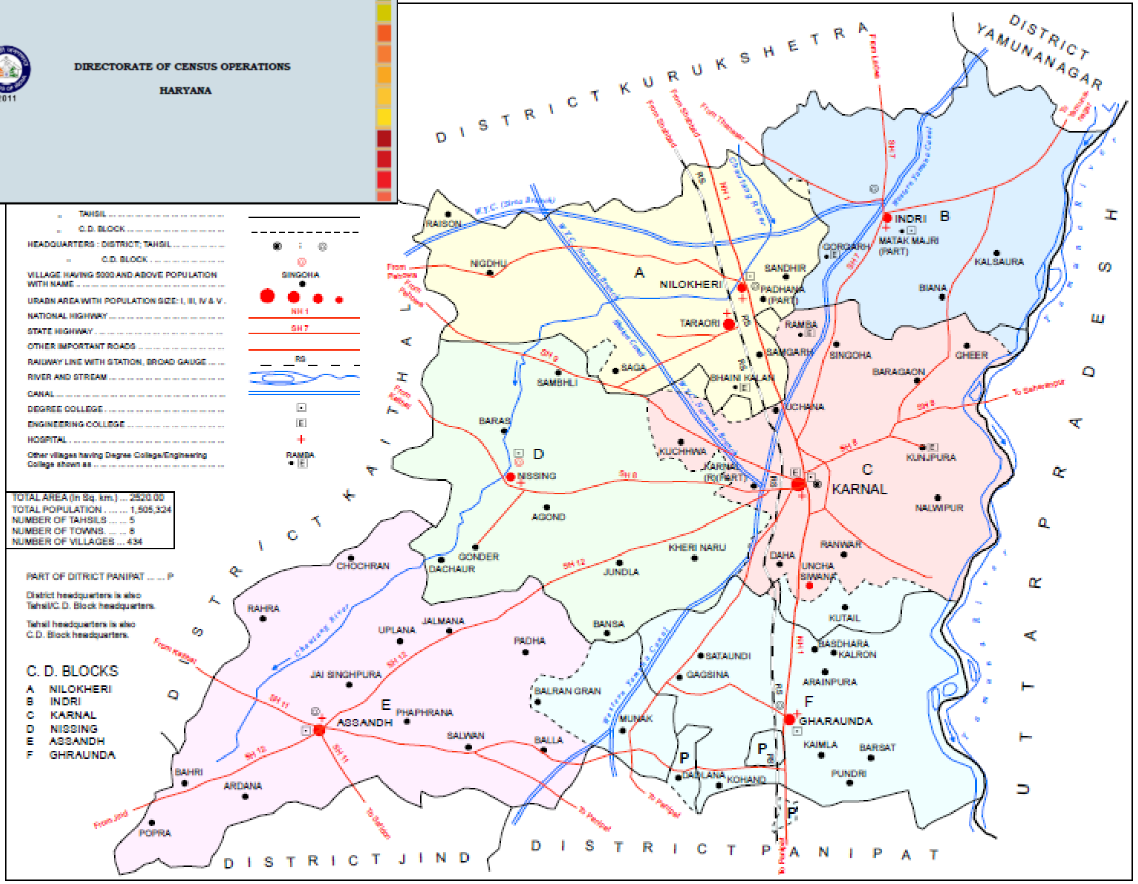


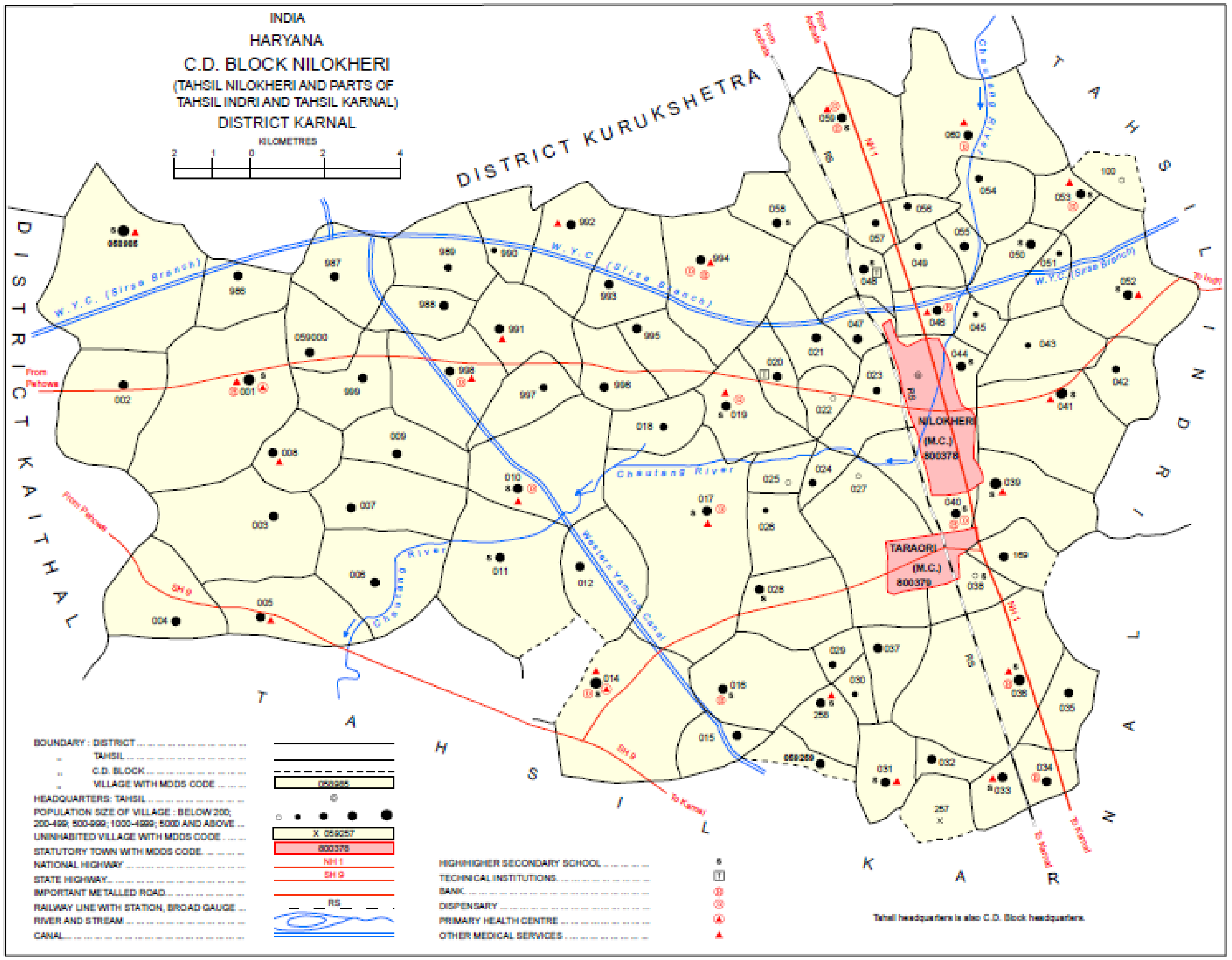
Challenge of Spatial Correspondence

- Official Administrative Regions have a hierarchy
  - State – Districts – Tahsils/Talukas – Community Development Blocks/Mandals – Gram Panchayats – Villages
  - Union Territories
- Forest Administration uses independent demarcation in a state
  - Forest Circle – Forest Division – Range – Beat – Compartment
- State Reorganization have increased
- Common thread is a large number of administrative reorganizations
  - Common time series generation requires data at lower hierarchies
  - **No. Districts in 1961 : 339**
  - **No. Districts in 2021 : 757**
- Authentic Administrative Regions data at national scale is presented in Census of India, published at decadal frequency

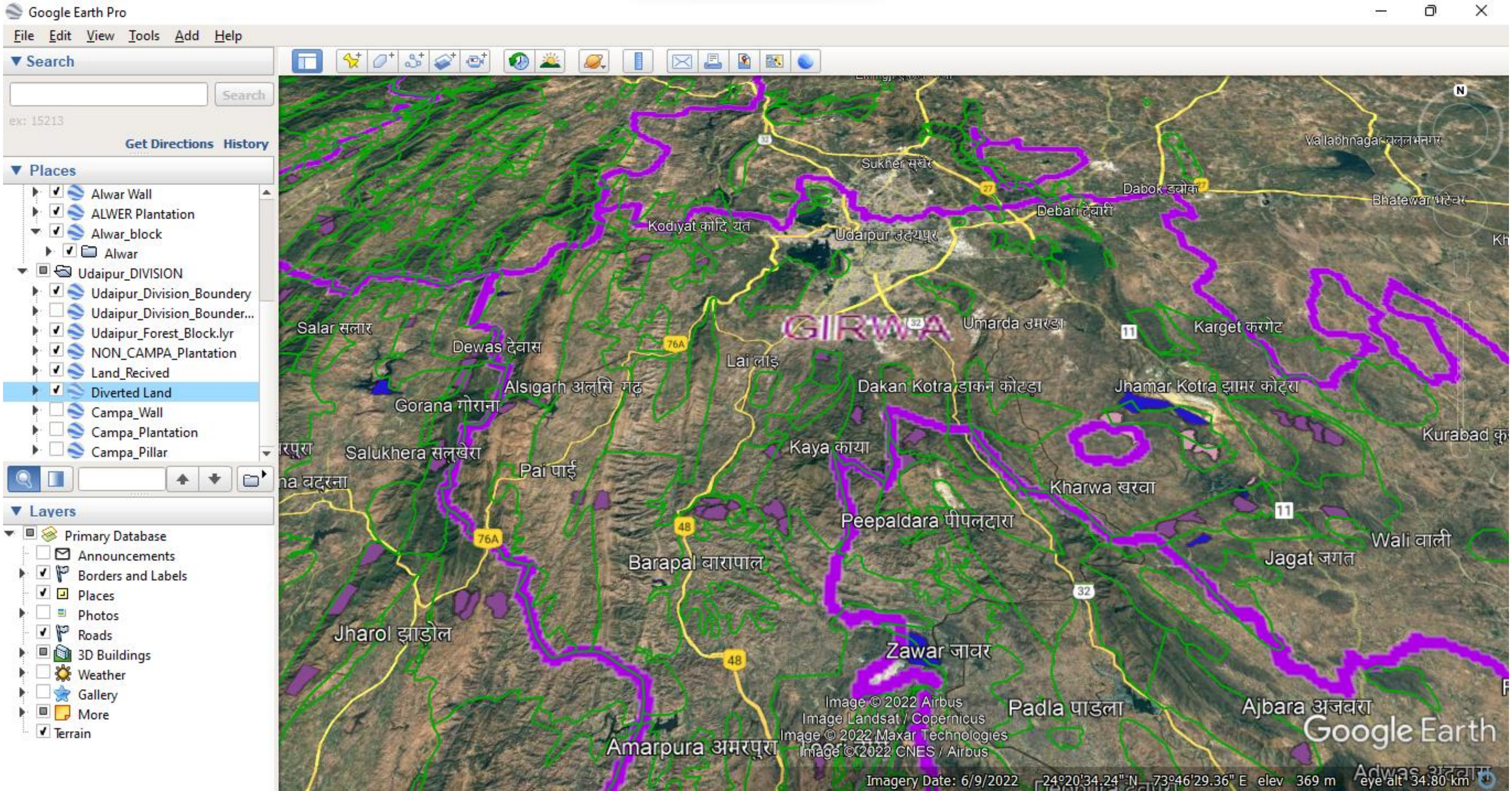
Karnal District (Haryana)







Udaipur District (Complexity of Forest Boundaries)



RS Forest Area input in Carbon studies –
Additional Parameters

- Linking forest cover change with forest type
- Study forest fragmentation
  - Linkage with forest biodiversity and degradation
- Link forest cover with forest fire including temporal dimension
  - Fire number, burnt area, (intensity – RFI)
  - Trends & Recovery
  - Fire and linkage with shifting cultivation

FOREST COVER, DENSITY & CHANGE

EARTH OBSERVATION DATA FOR SPATIAL-TEMPORAL DYNAMICS OF FOREST/TREE COVER IN INDIA

i. MAPPING TWO DECADES OF FOREST/TREE REMOVAL & ITS IMPLICATIONS FOR CARBON POOL IN STANDING FORESTS & TREES

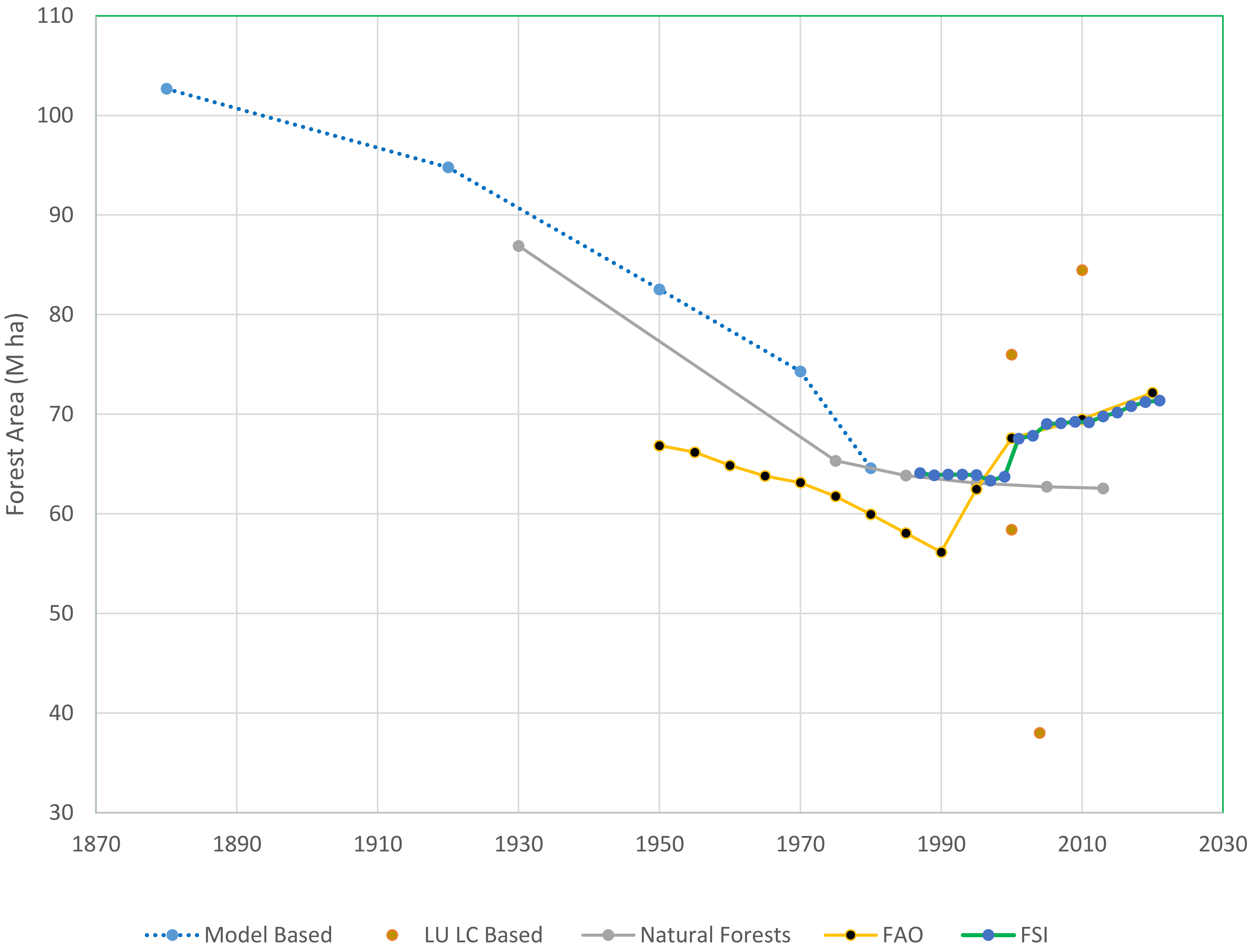
ii. MAPPING EXPANSION OF RUBBER PLANTATIONS IN TRIPURA AND GENERATING AGE-CLASS MAPS OF RUBBER FROM EO DATA

Forest Area Assessment

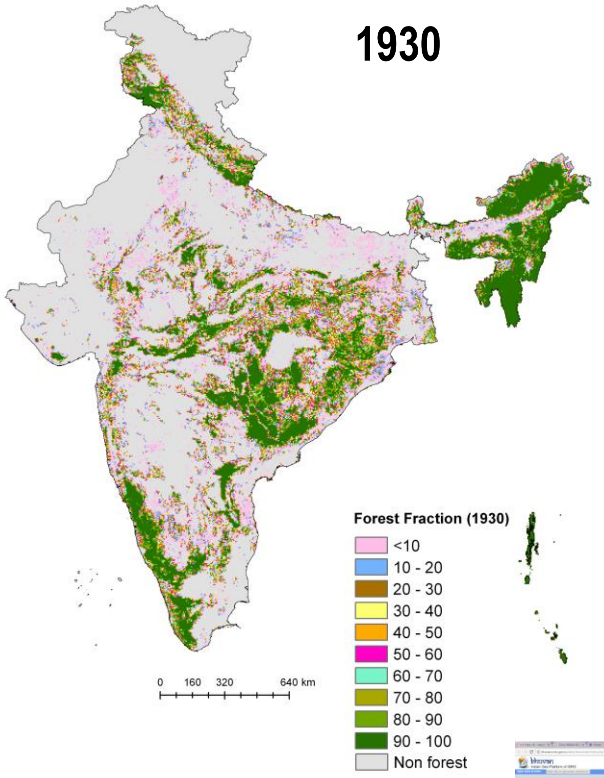
- Reliable estimates of forest area are starting point for all assesments
  - Challenges
  - Current estimates based on RS can be accurate, spatial disaggregated
  - Past estimates based on maps and reconstruction from historical statistical summaries
  - Area alone is not sufficient (Forest Type, Density, ...)
  - OFFICIAL ESTIMATES (FSI, GFRA)
  - Flint & Richards (1990) [1880-1980]
  - .....
  - Tian et al., (2014) [1880-2010]
  - NCP (Reddy et al., 2016-2018)

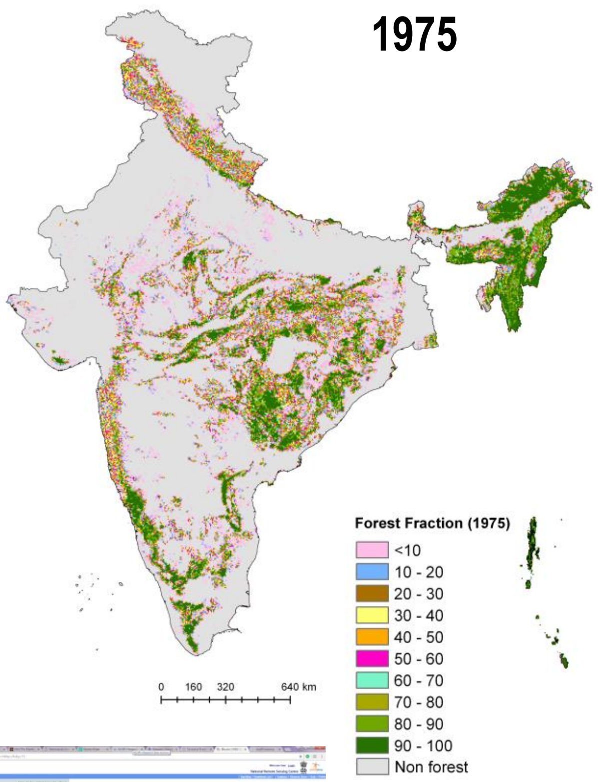
Indian Forest Area over Time

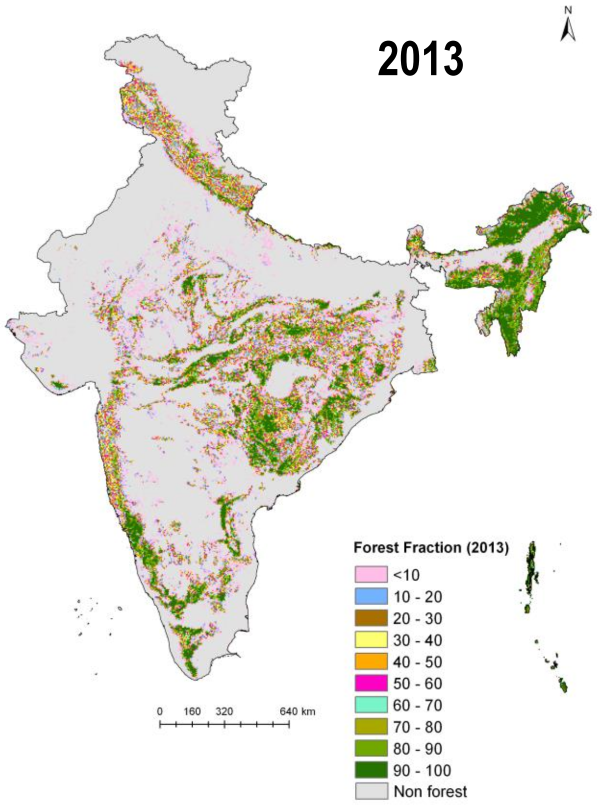
- **Model Based (1880-1980)**
  (Richards and Flint 1994)
- **Natural Forests (1930 – 2013)**
  (Sudhakar Reddy et al., 2016)
- **FAO (1950 – 2020)**
  (FAO Reports)
- **Forest Survey of India (1987-2021)**
  (Source: State of Forest Reports)



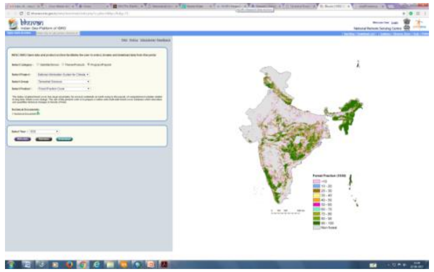
Forest cover Maps of India







http://bhuvan.nrsc.gov.in

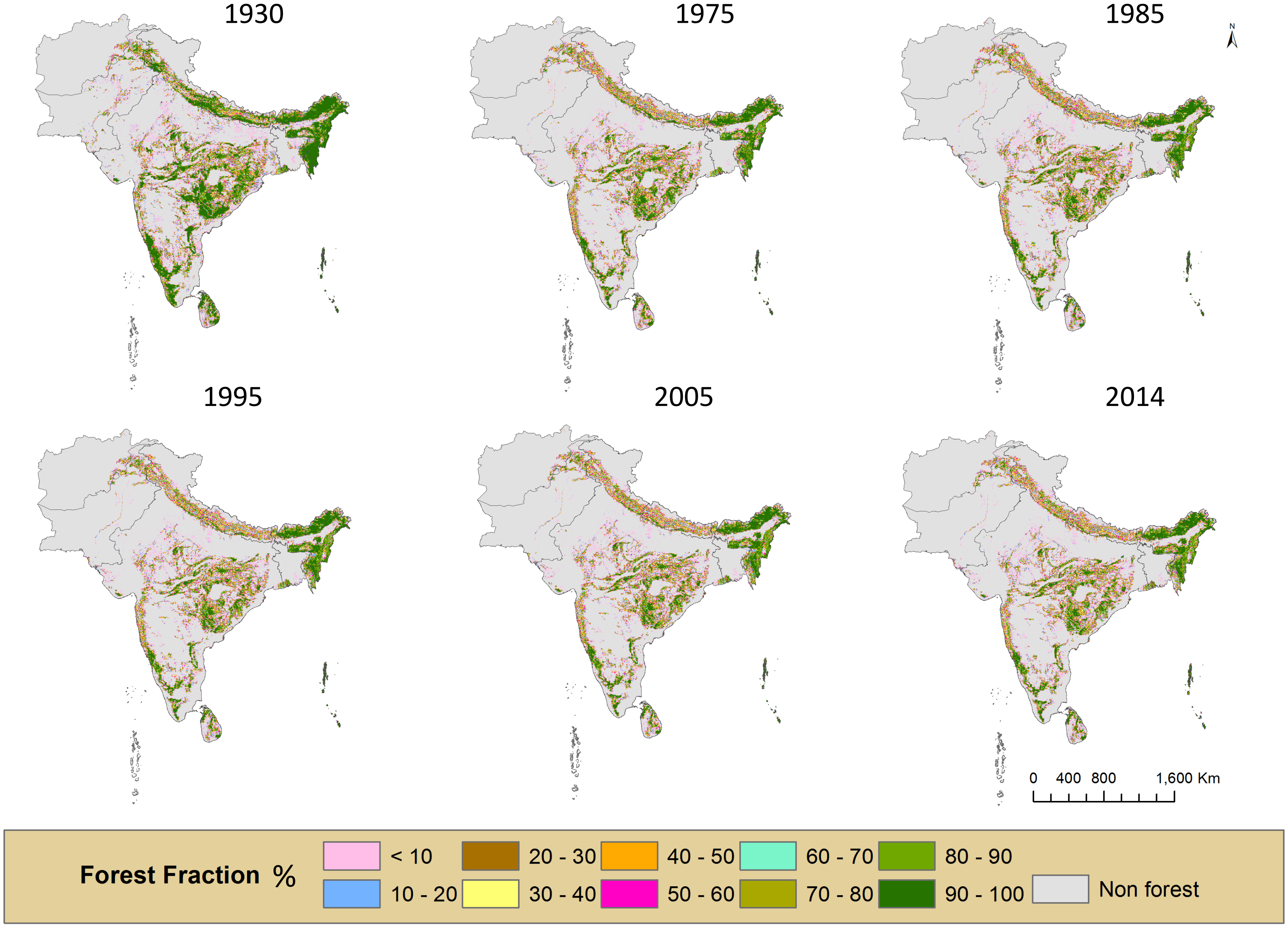


Fractional Forest cover Maps (5 km grid)

http://www.nrsc.gov.in/nices

Reddy, C.S., Jha, C.S., Dadhwal, V.K., Harikrishna, P., Pasha, S.V., Satish, K.V., Dutta, K., Saranya, K.R.L. et al. 2016. Quantification and monitoring of deforestation in India over eight decades (1930-2013). ***Biodiversity and Conservation*** **25: 93–116.**

Distribution of Forest cover in South Asia



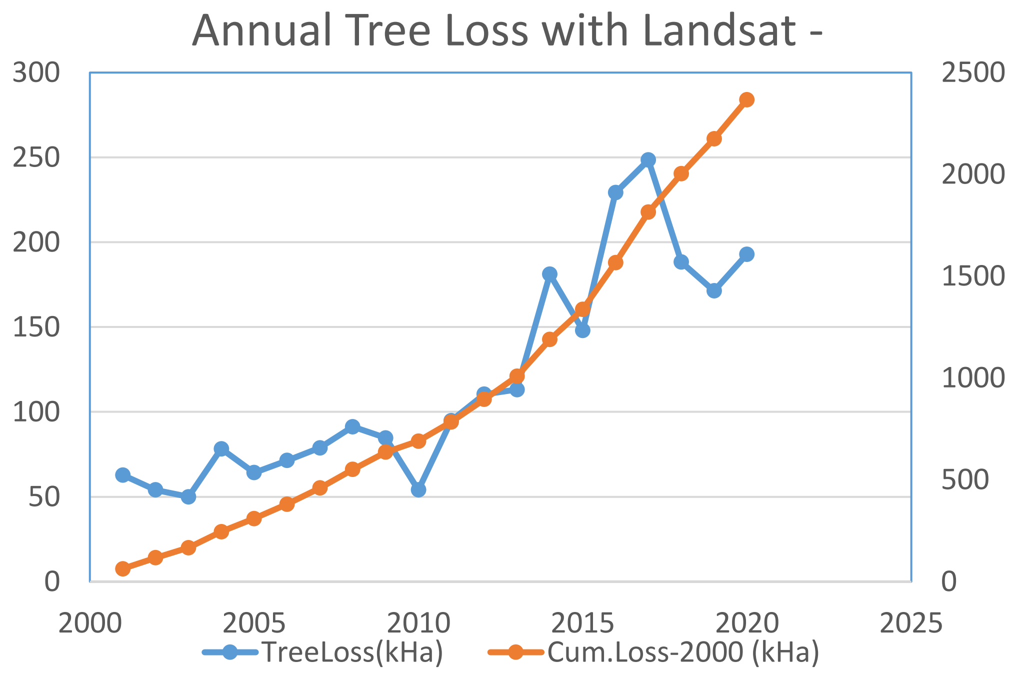
Deforestation : Estimation and Mapping

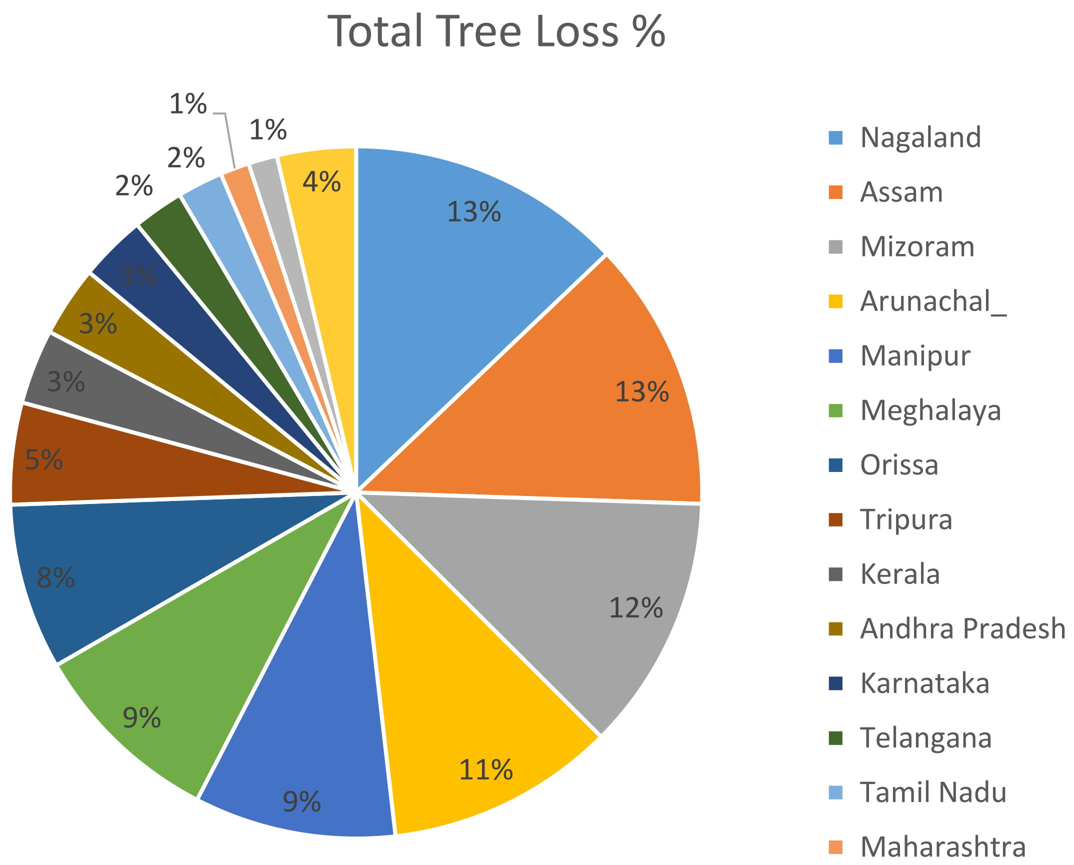
- Estimates are ‘available’ but vary due to ‘definition’, ‘methodology’ and ‘data source’

  - FSI publishes ‘Forest Cover Change’ at state and district level from previous report.
  - Change in area aggregated at state would be much lower than at district level
  - EO data could detect tree cover loss at pixel / minimum mapping unit level
  - FSI presents ‘Change Matrix’ between succesive reports which is rarely interpreted
  - EO technology permits type and biophysical characterization for improved understanding

Annual Tree Cover Loss (2001-20) with Landsat (30m)

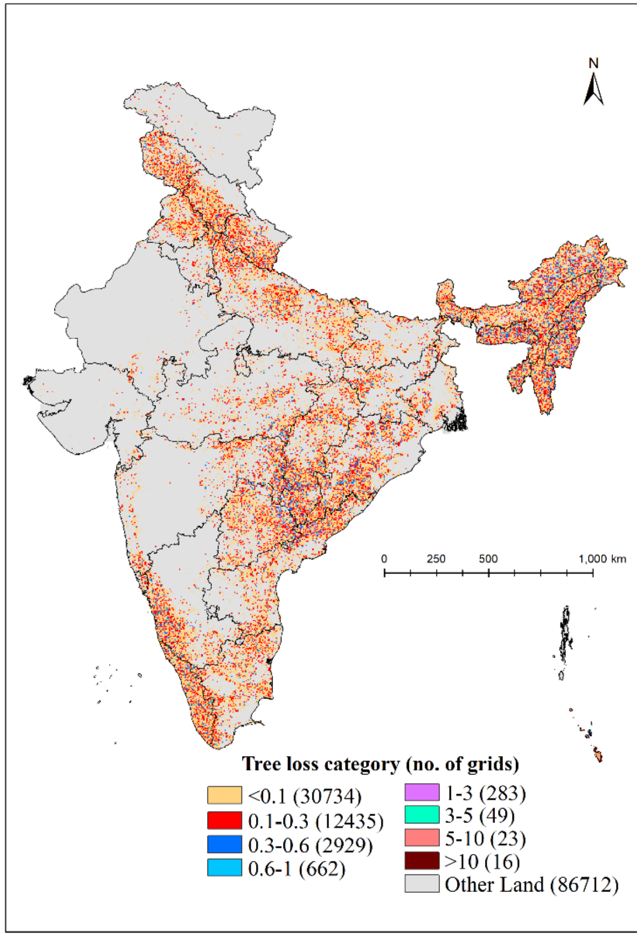
- Cumulative Tree Loss detected from annual automated algorithm for 201-2020 period was 2.366 Mha
- State-wise distribution of tree loss indicated that 15 top ranked state contributed 96.32 percent of tree loss. North-east states contributed 71.4 percent and top 5 states outside NE were Odisha, Kerala, Andhra Pradesh, Karnataka and Telengana
- Tree Loss is critical to estimate decrease in standing carbon but could be part of working plan or clearing for plantations or outside ‘FOREST’

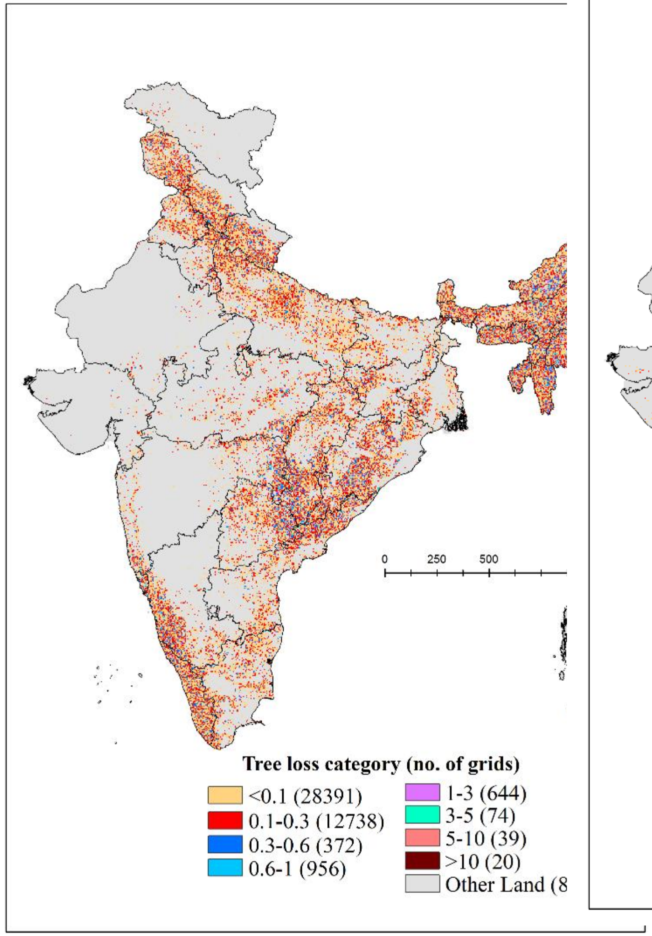


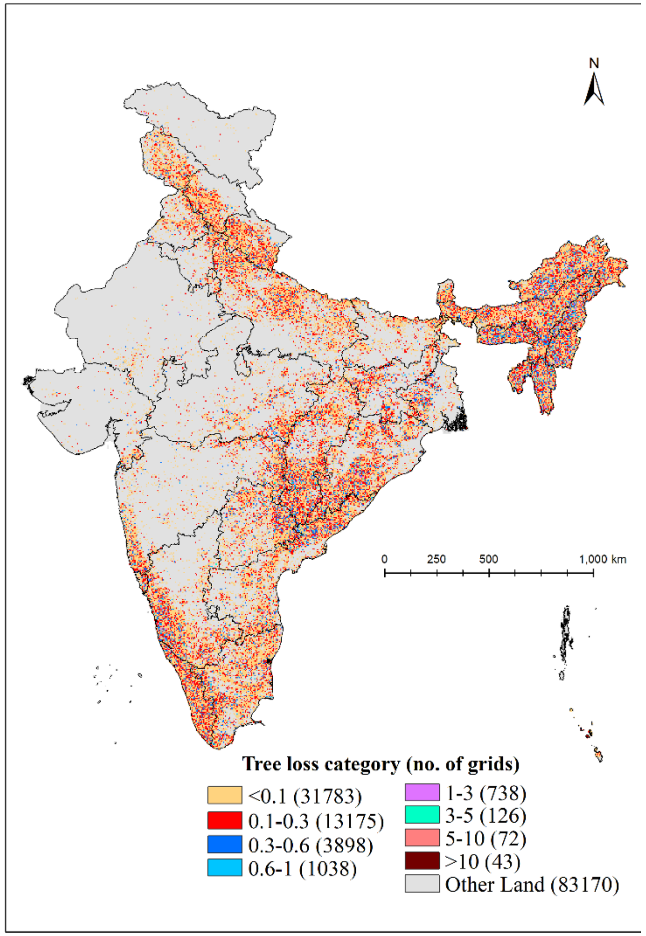


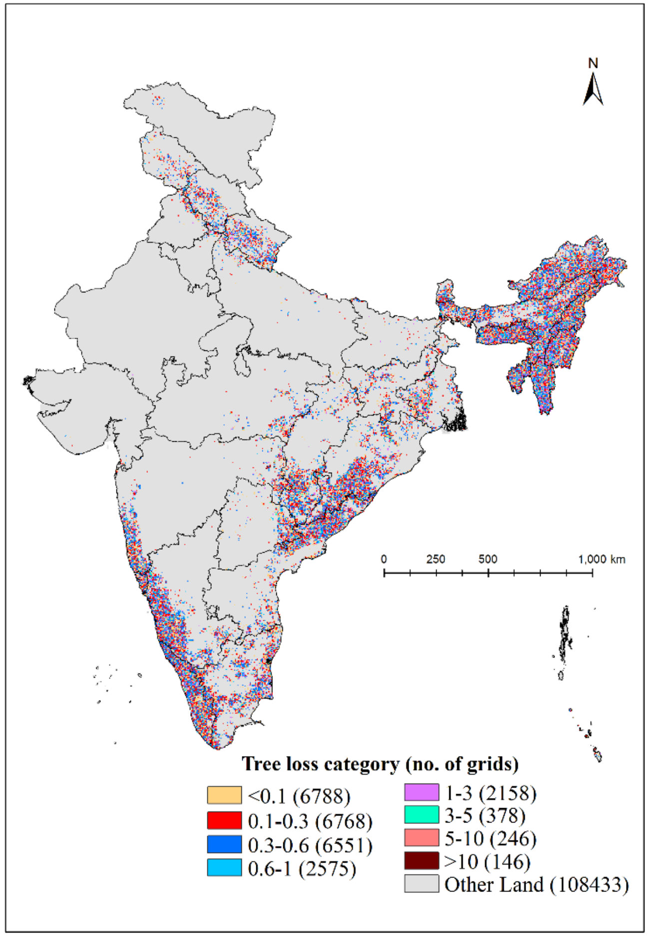
Spatial Visualization of Tree Loss (2001-2020)

- Spatial Framework in GIS of 5x5 km and 1x1 km grids adopted
- Useful for integration of multiple themes & inputs and modeling









FOREST VEGETATION C POOL

Vegetation Carbon Pool : Challenges

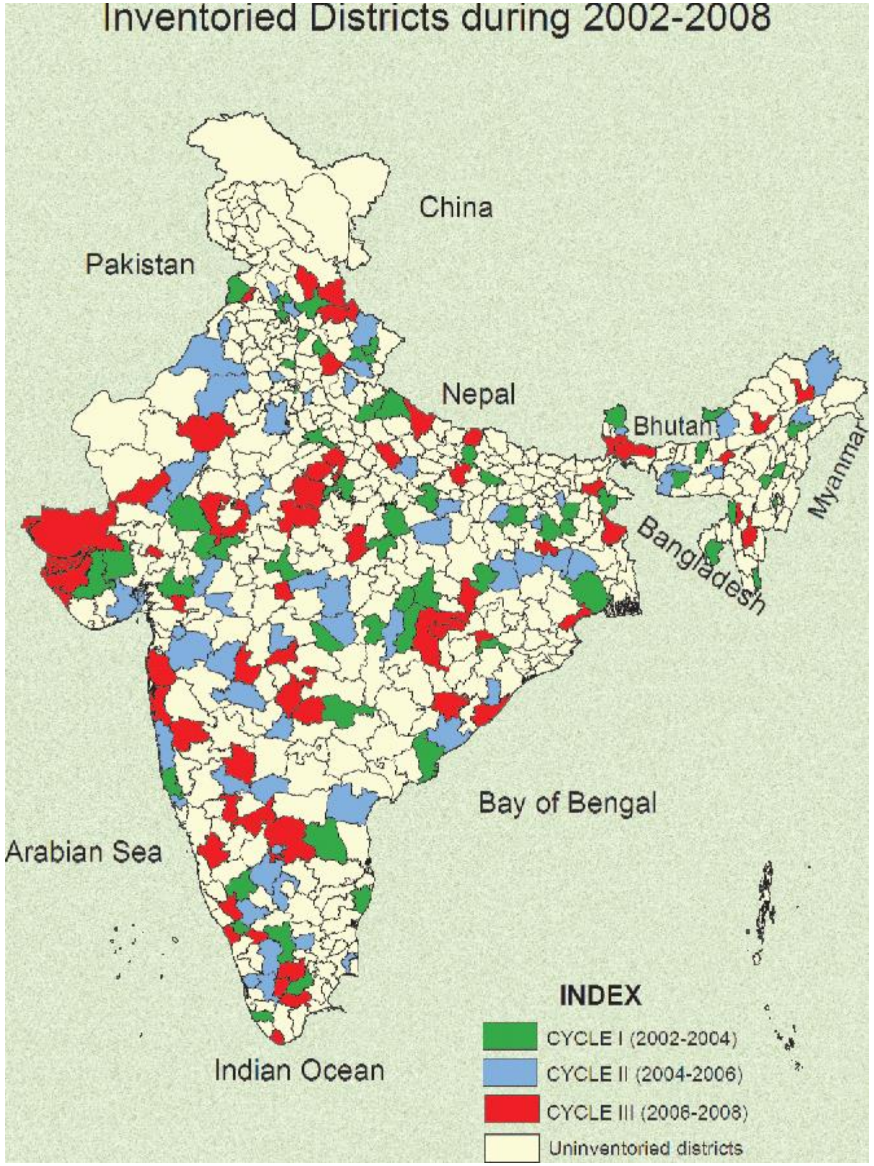
- Sample Plot
  - Size (0.1 – 1ha/Trans); Parameters (GBH, Ht, ..); Vol. eq (Local/Regional)
- Sampling Plan (Number, Location)
  - Admin./Forest Type ; Rotation-Gridded vs,. Stratified Sampling
- Estimation
  - Averaging (Zonal); RS Forest Type Area (with/without density strata)
- RS-based Model
  - VIS-NIR Spectral Models (Pixel Size/ Saturation)
  - Microwave Models (L-band)
  - High Resolution Texture & LIDAR height
  - Multiple Input Integration/ Modeling

- ***Challenge of Historical Biomass Maps, Pixel-level uncertainty for C-pool change mapping***

National Forest Inventory - Evolution

- Forest Survey of India is responsible for NFI in collaboration with State Forest Departments
- Pre-FSI – Growing Stock estimation of dominant/productive forested regions
- Approach 1
- Approach 2 – District level sampling with 14 physiographic regions as strata
- Approach 3 – 5x5 km national grid common framework for forests and TOF, circular sample plot adopted

NFI – FSI - Evolution



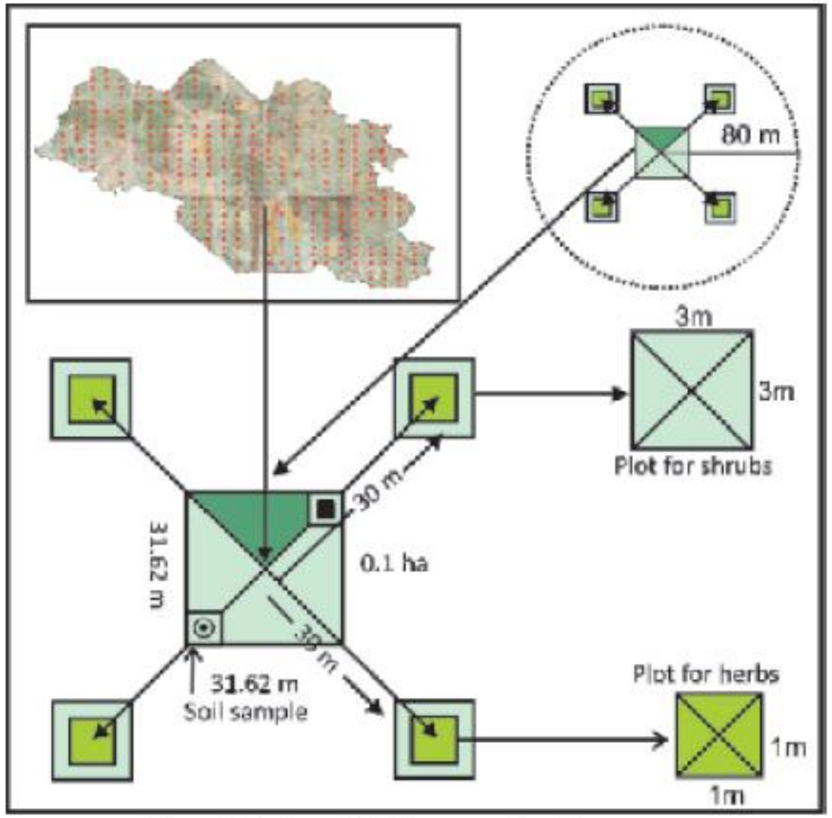
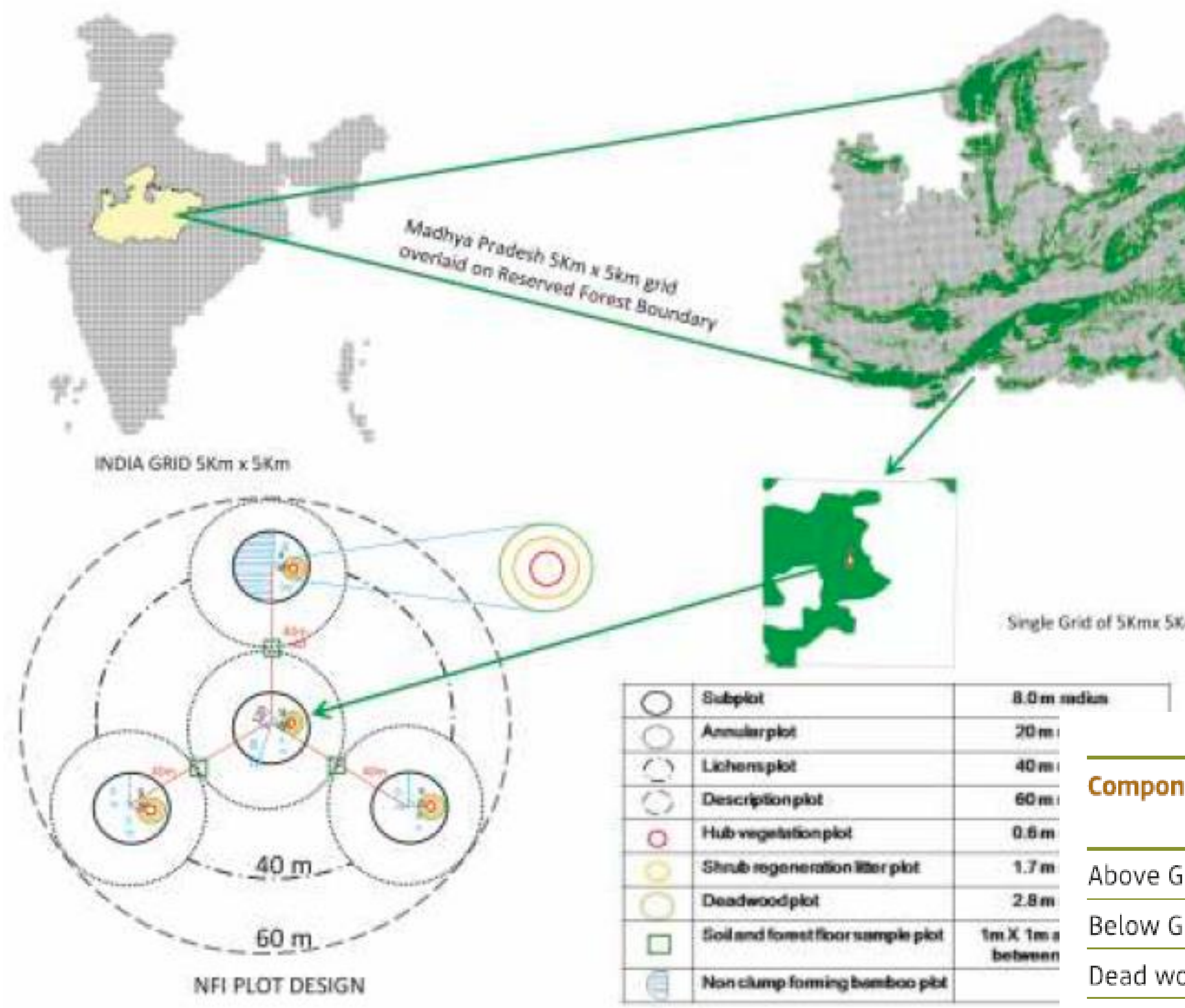
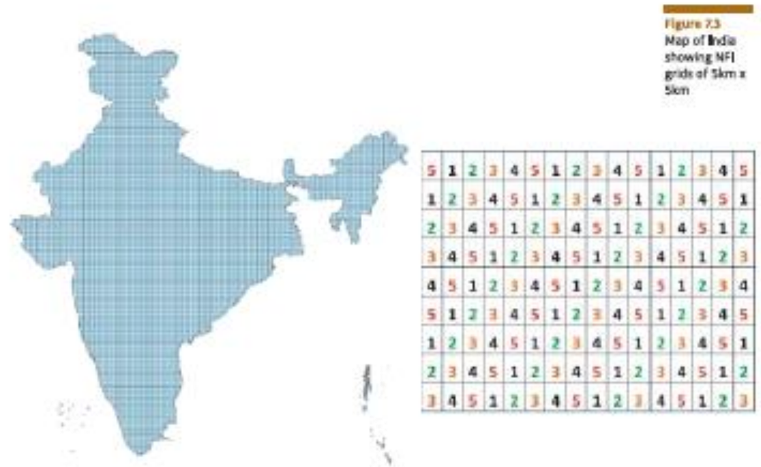


Figure 3.4: Layout of the sample plot

NFI – FSI : Current Sampling

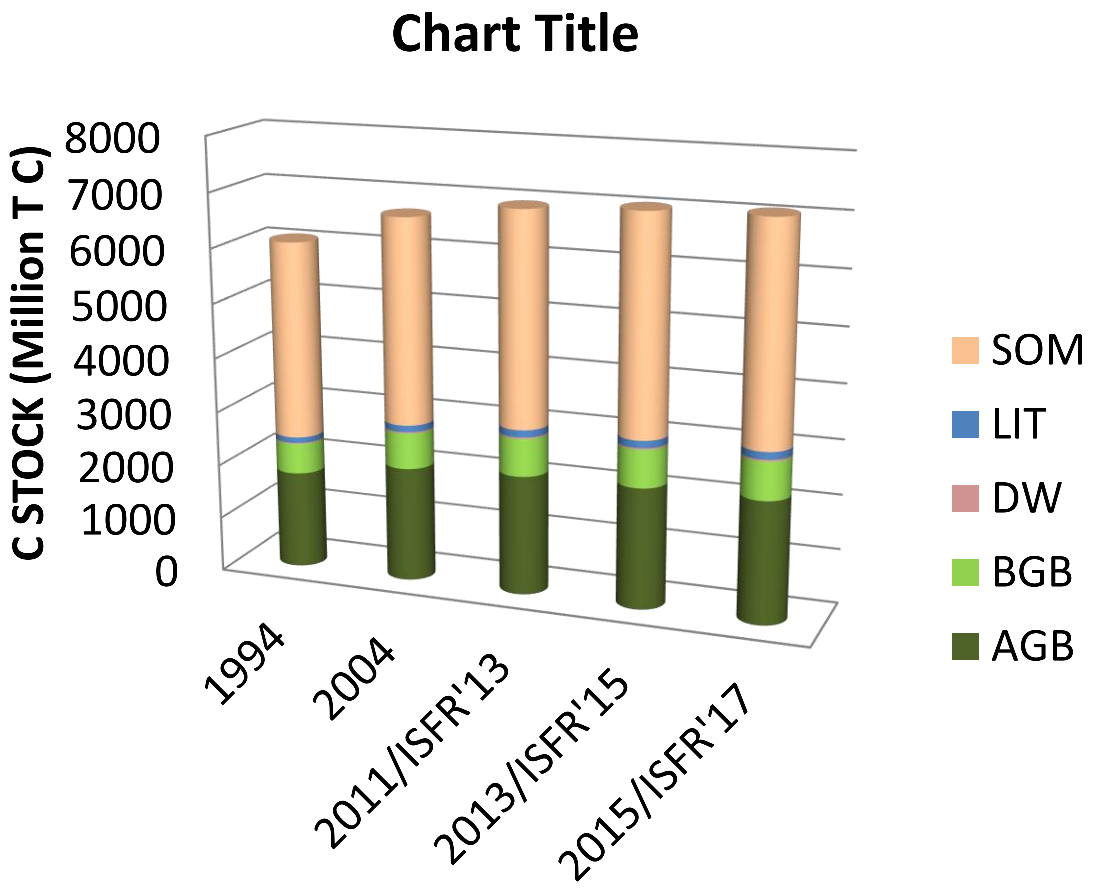




(in million tonnes)

Component	Carbon Stock in forest in 2021	Carbon stock in forest in 2019	Net change in Carbon stock	Annual change in Carbon stock
Above Ground Biomass	2,319.9	2,256.5	63.4	31.7
Below Ground Biomass	718.9	700.8	18.1	9.1
Dead wood	47.7	35.8	11.9	6.0
Litter	107.3	127.9	-20.6	-10.3
Soil	4010.2	4,003.6	6.6	3.3
Total	**7,204.0**	**7,124.6**	**79.4**	**39.7**

Indian Forest Carbon Pools (FSI)



CHALLENGE(S):

- **GROSS changes +ve still have substantial deforestation**
- **No net change still has C pool reduction**
- **Forest Growth not explicitly accounted**

Indian Forest Carbon Density

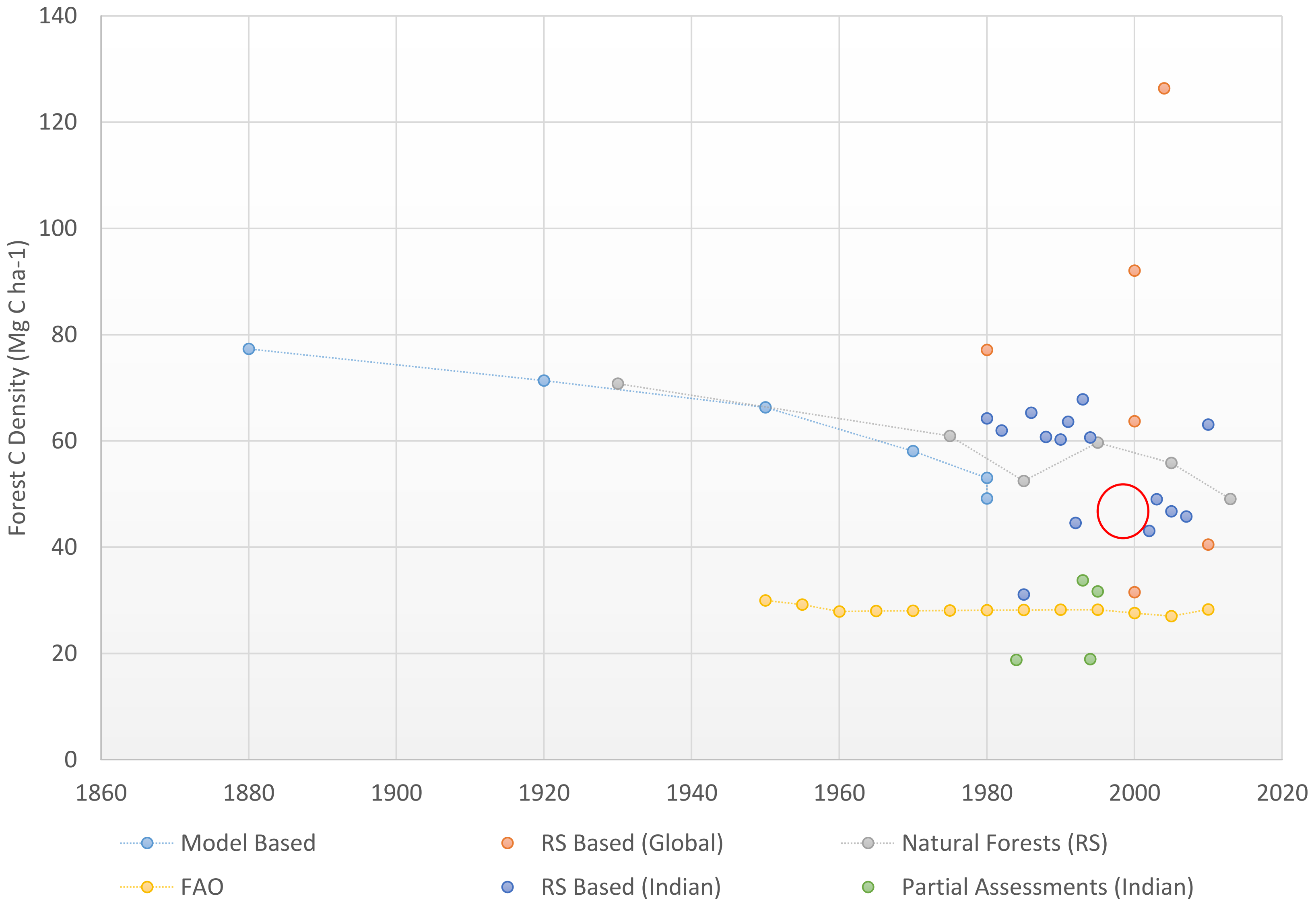
- Wide Range of Estimates.

- After 1990's,

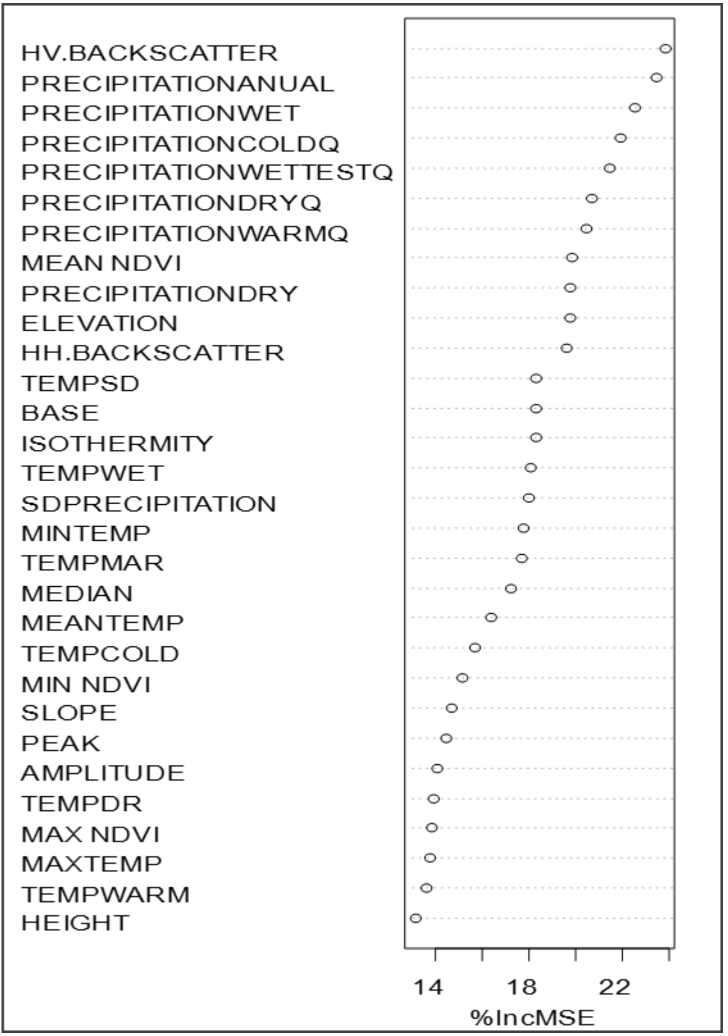
C Density : 19 – 126 Mg C ha^{-1}

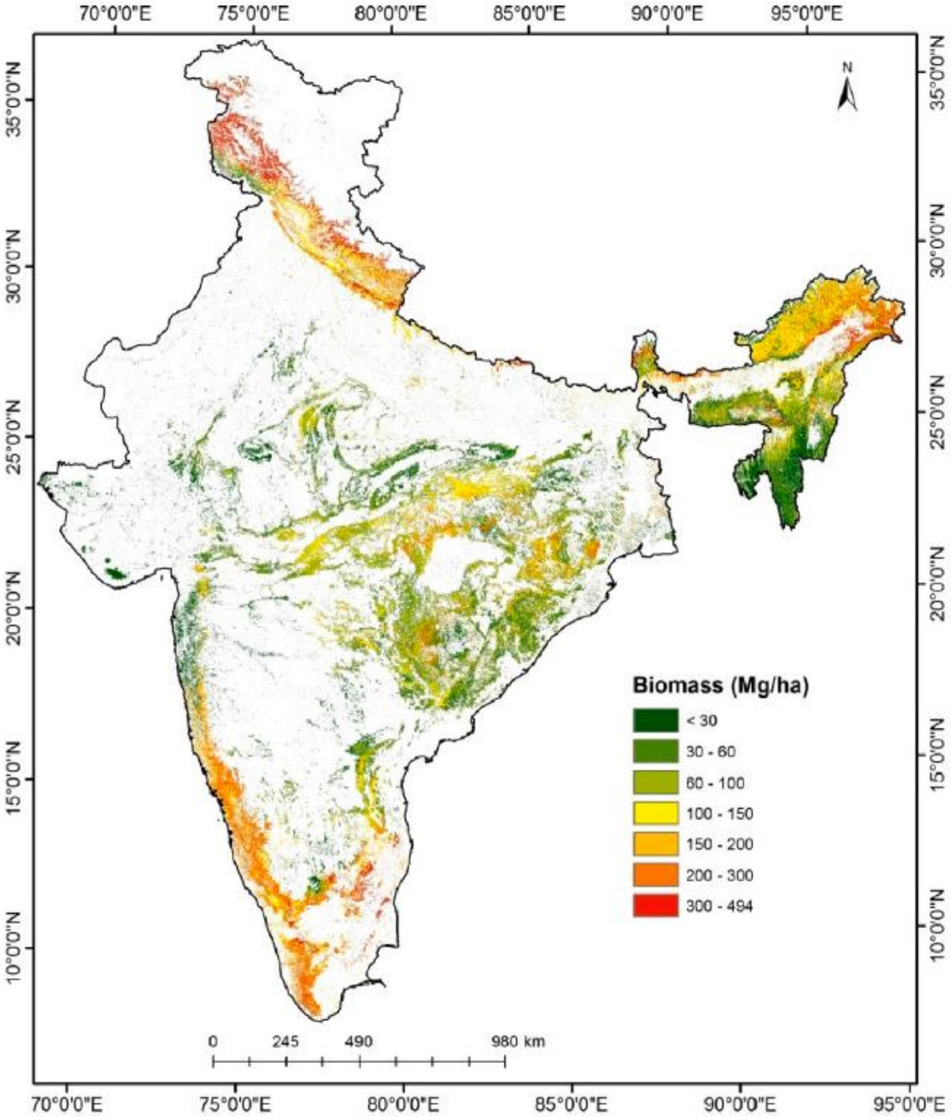
Median : 46.24 Mg C ha^{-1}

- Avitabile 2016 Estimate and FAO 2000 estimate are similar. (Highlighted in Red).



Forest Biomass Carbon Density : Spatial Layer *(250m)*





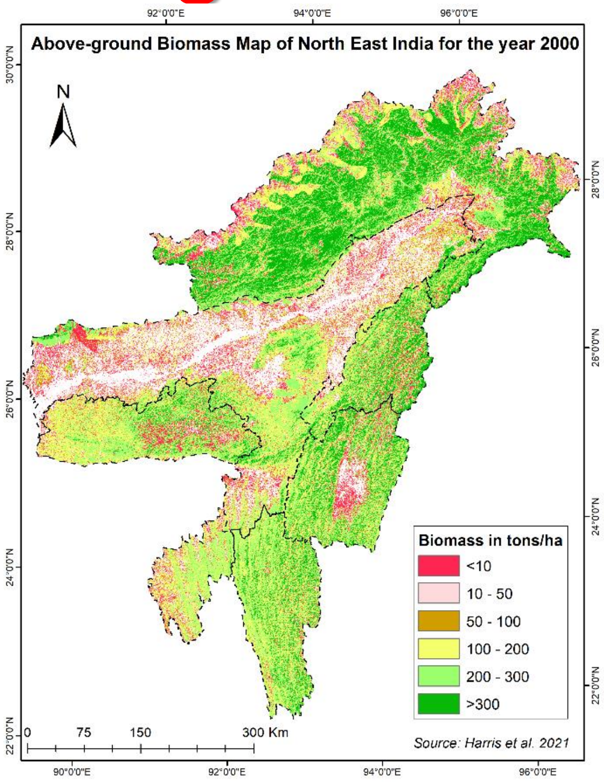
National Forest Biomass Density Map
(Multiple Data Fusion Approach)

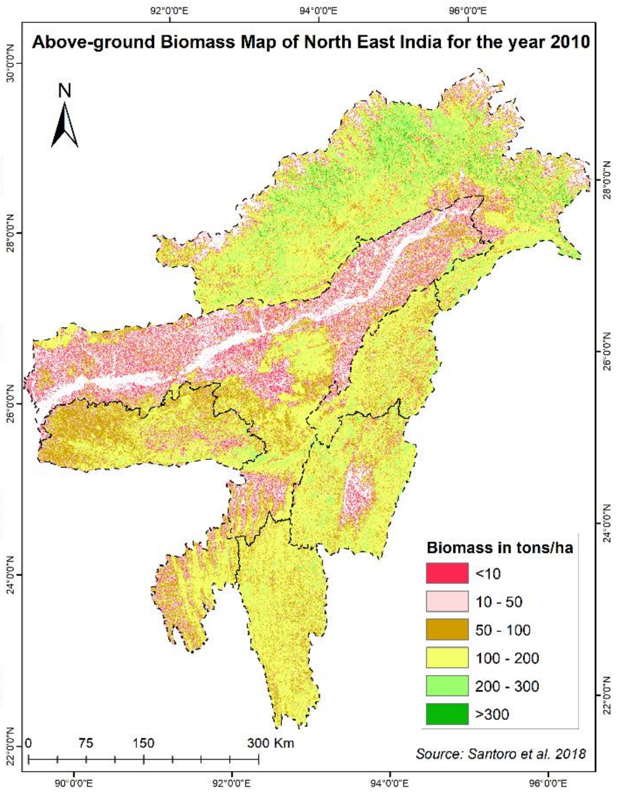
Source: Fararoda, Reddy, Rajashekar, Kirn Chand, Jha & Dadhwal (2021) Ecological Informatics, 65, 101392

NE Study: EO Forest Aboveground Biomass

- Early EO based forest AGB were coarse resolution (1km or coarser)
- New models and inclusion of SAR and LIDAR have led to fine resolution (upto 30m) biomass maps
- Utility of such maps for biomass (carbon) change is being investigated
- Recent outputs from Harris et al (2021) at 30m and Santoro et al (2018) 100m are being evaluated

- Constraints
- Layers calibrated with global inputs. However for best outputs local calibrations are critical
-





Estimating change in Forest Biomass

- Change in Biomass or C-pool between t1 and t2 estimated as
  - Area(t2)*Mean Biomass Density(t2) – Area(t1)*Mean Biomass Density(t1)
  - Adopted by FSI / Conceptual challenges
- Forest biomass gain and loss method
  - Simplified accounting at state/regional scale, missing data on use, extraction, growth
  - Bookkeeping models of AFOLU
- Forest Growth Models
  - Non-spatial models as patch/cohort model for specific species e.g. CO2FIX
  - Spatial models with EO to integrated biosphere models at coarse grid
- EO Driven forest change and biomass density spatial layers integration
  - Sensitivity of biomass change detection at fine resolution

Carbon Stock change from deforestation

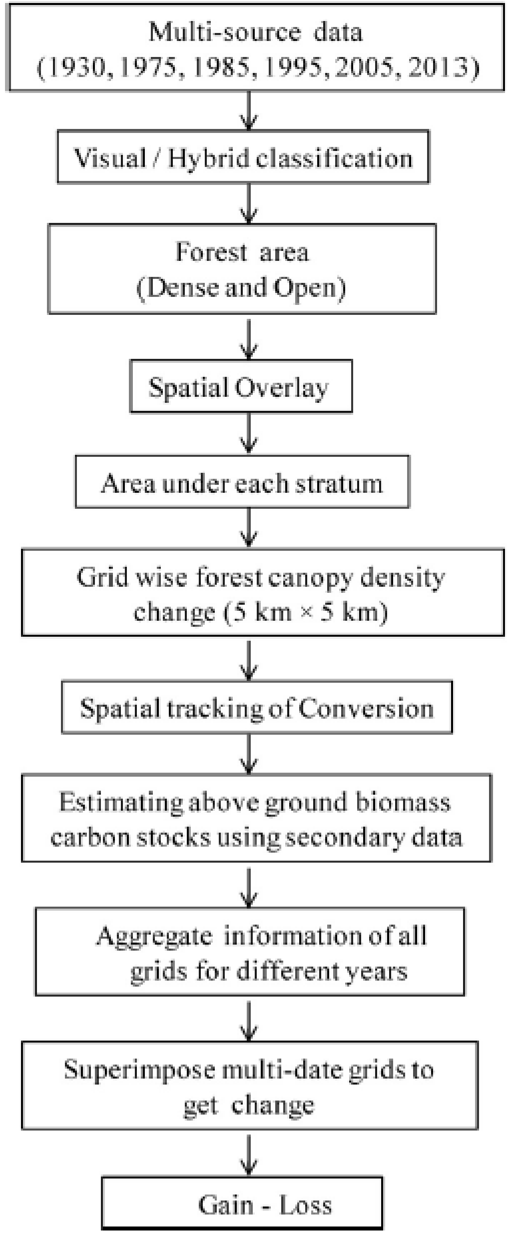


Fig. 1. Flow chart of methodology.

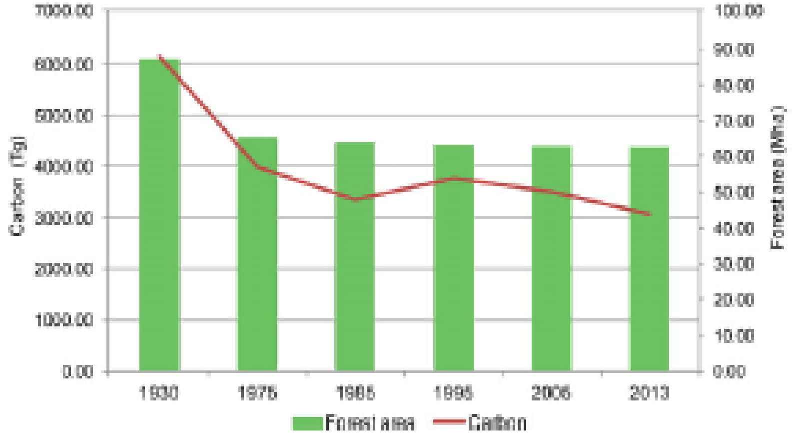


Fig. 2. Forest area and Above Ground Carbon biomass stocks in India: 1930 to 2013.

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Geospatial assessment of long-term changes in carbon stocks and fluxes in forests of India (1930–2013)

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

National Remote Sensing Centre, Indian Space Research Organisation, Balanagar, Hyderabad 500 037, India

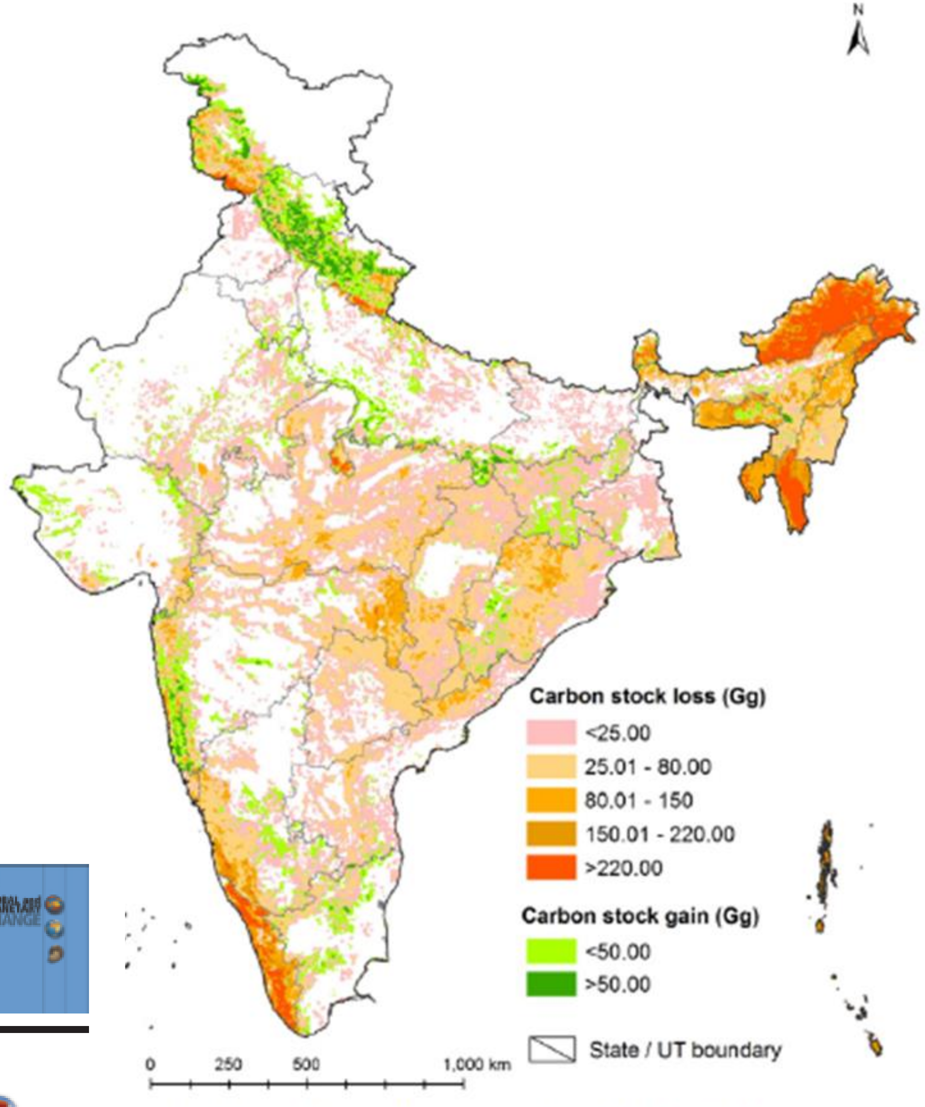
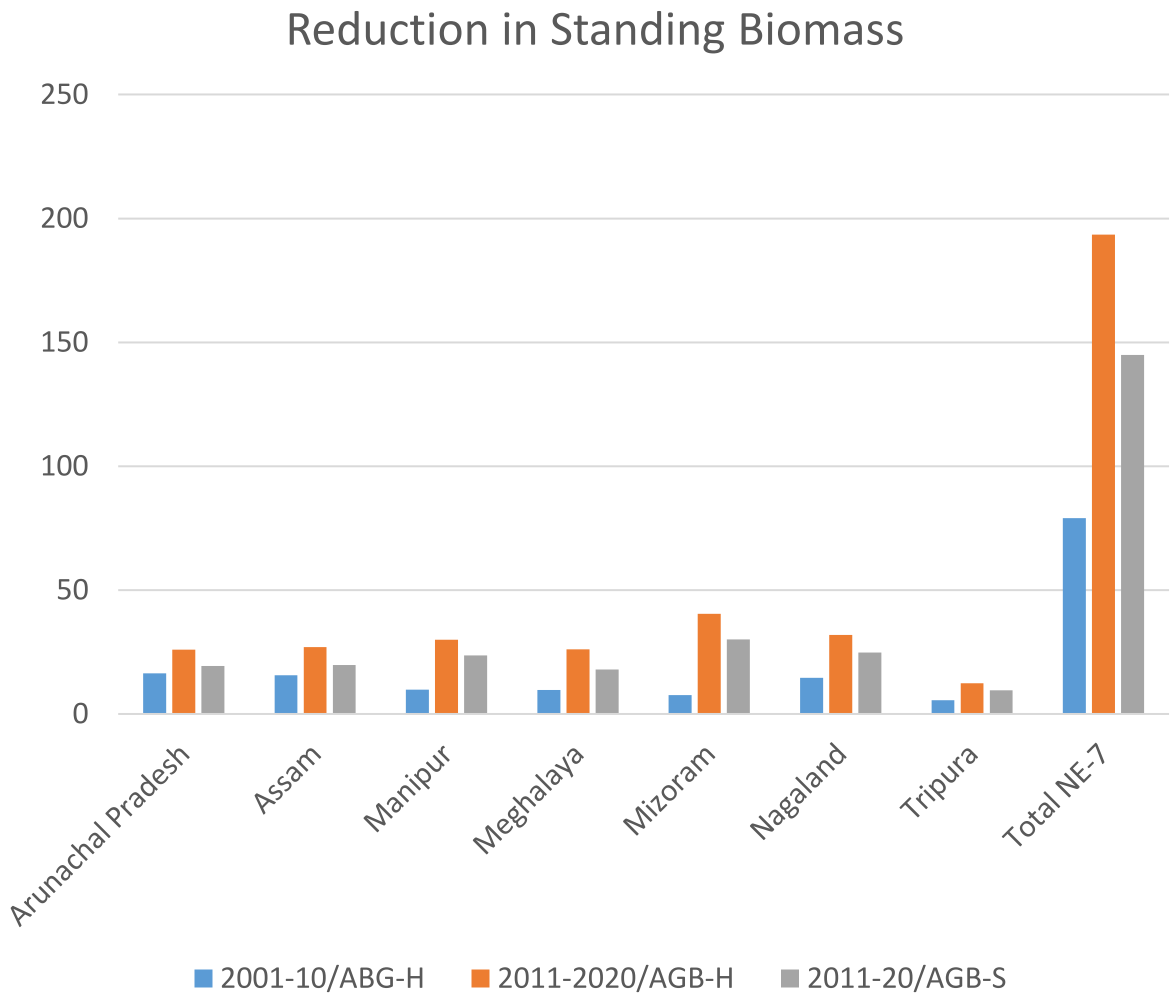


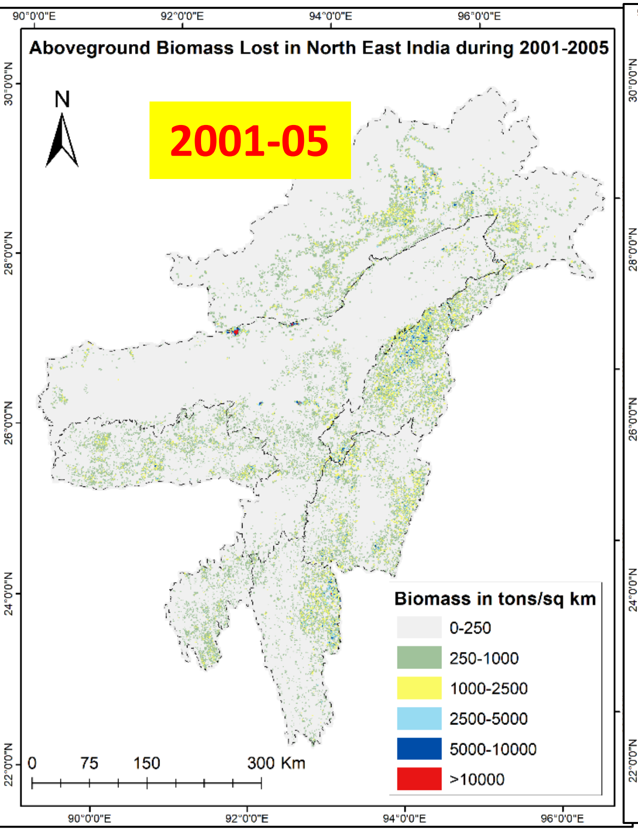
Fig. 9. Change in above ground biomass carbon stock in India from 1930 to 2013.

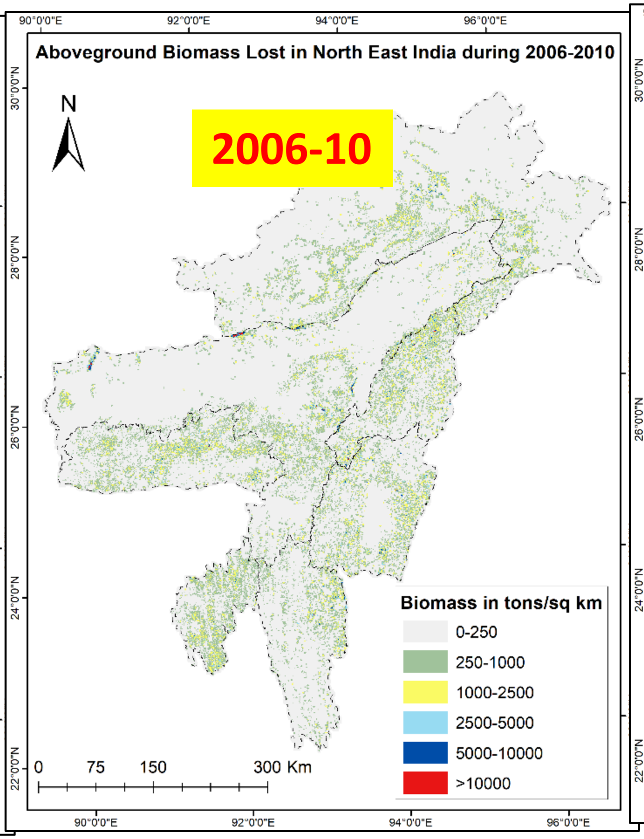
Reduction in Standing Biomass due to Tree loss (2001-20) in North East

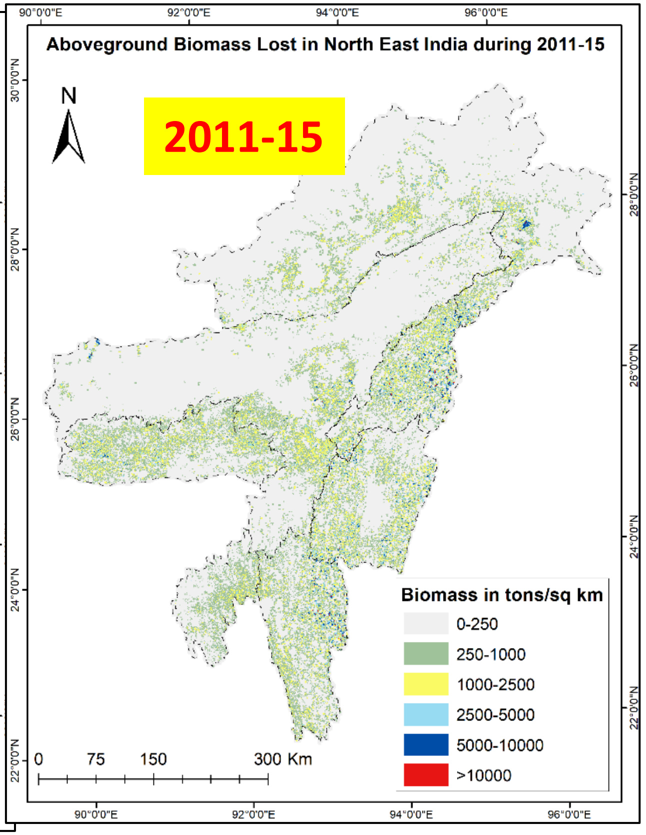
- EO derived spatial layers of woody aboveground biomass
  - Source 1: Harris et al (2021) for Year 2000
  - Source 2: Santoro et al (2018) for Year 2010
- With Harris (2021) AGB reduction was 7.8 Mt/year during 2001-20 and increased to 19.4 Mt/yr during 2011-20
- With Santoro (2018) AGB for 2010, during the 2011-20, annual reduction estimated as 14.4 Mt/yr
- Challenges:
  - EO data derived AGB layers must have lower uncertainty and time series of AGB is needed
  - Estimation of Reduction in carbon would require inclusion of SOC loss.
  - SOC densities are higher than AGB, and SOC loss continues slowly for a longer period

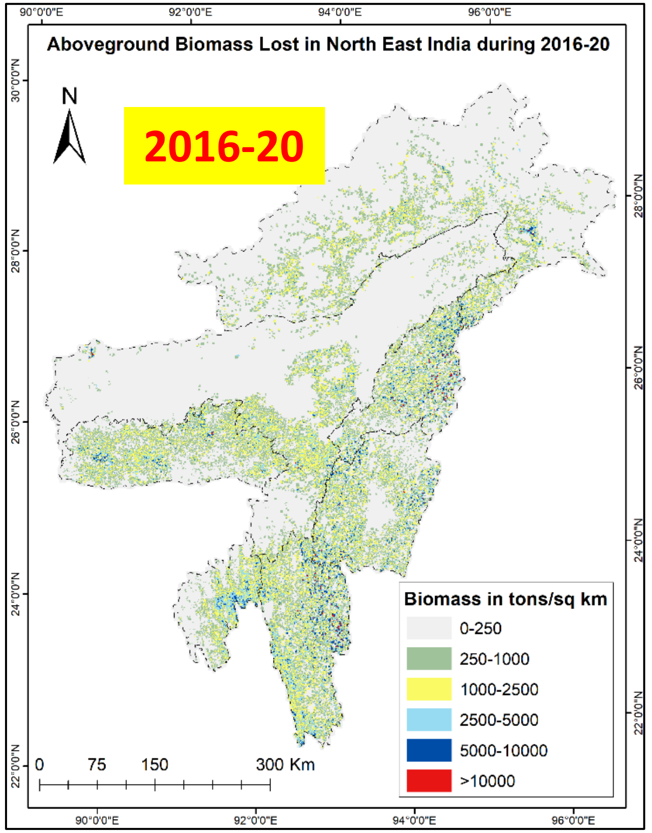


Spatial Visualization of AGB Reduction in NE(2001-2020)









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- Linking forest cover (plantation) change with age-class
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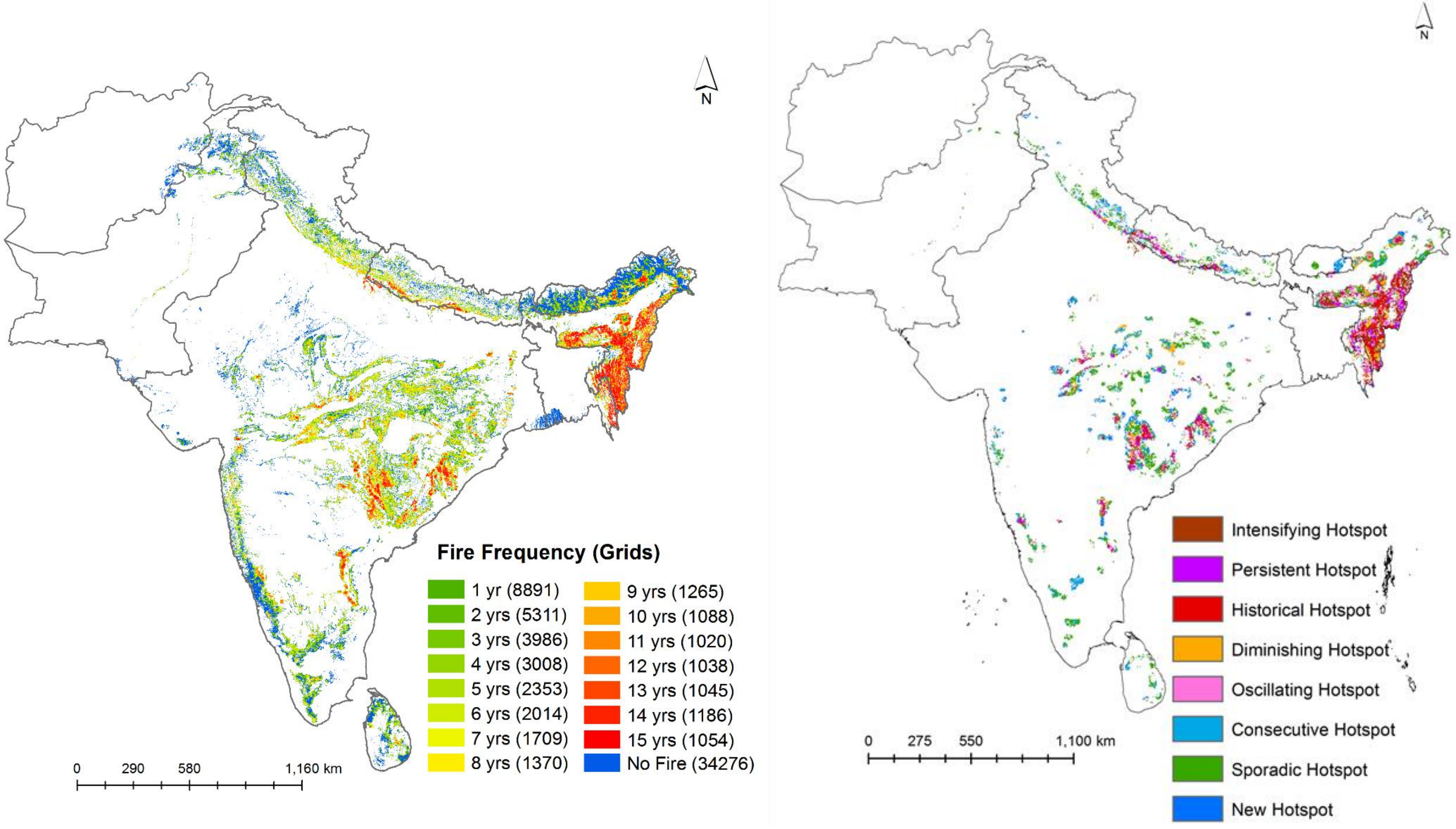
- Link forest cover with forest fire including temporal dimension
    - Fire number, burnt area, (intensity – RFI)
    - Trends & Recovery
    - Fire and linkage with shifting cultivation

Estimates of C emissions (deforestation, LUC)

(Reddy, Rakesh, Jha, Athira, Singh, Alekhya, Rajsekar, Diwakar, DADHWAL, 2016, Global Planet Change, 146:50)

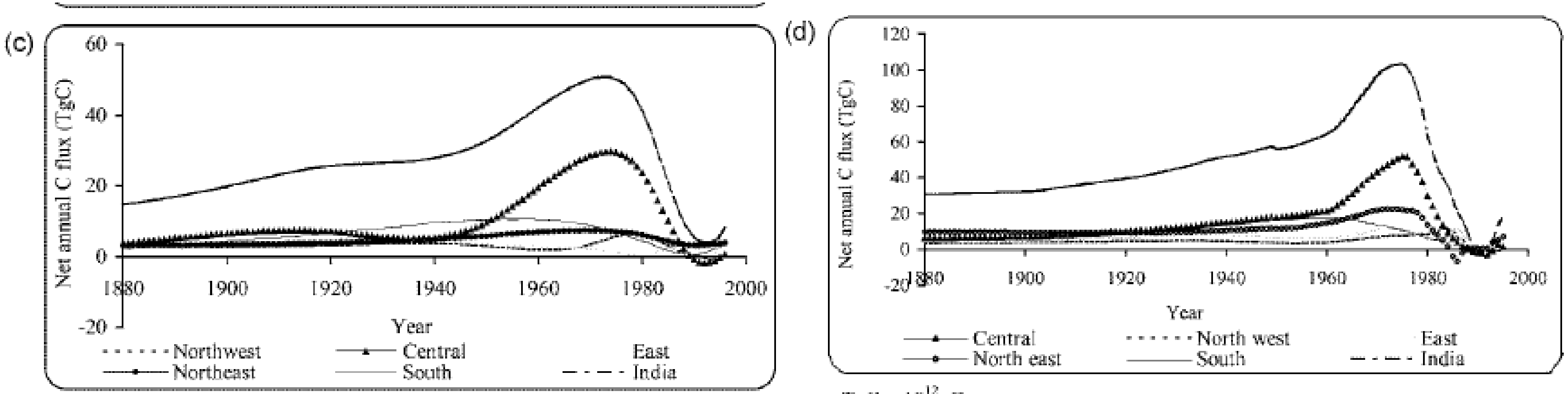
Period	Net C release ($Tg\ C\ yr^{-1}$)	Remarks	Reference
1980	−3.98	Volume based biomass estimates using net C flux model	Hall and Uhlig (1991)
1980	41.3	0.75 of forest phytomass in deforested area	Hingane (1991)
1980	33	Model of land use transformation	Houghton et al. (1987)
1980	20.2	As % of global net C release using deforestation rate	Ahuja (1991)
1985	42.52	Estimates from fire, firewood, shifting cultivation and deforestation	Mitra (1992)
1985	25.7	Comprehensive inventory of greenhouse gas emission	Subak et al. (1993)
1986	−5	Net difference between emissions (63.g Tg) and removals (68.9 Tg C)	Ravindranath et al. (1997)
1987	38.21	Net emission from deforestation and logging	WRI (1990)
1989	32.75	Net C release from deforestation and logging	WRI (1992)
1990	0.4	IPCC revised 1996 guidelines	ALGAS (1998)
1991	5.73	IPCC revised 1996 guidelines	WRI (1994)
1994	12.8	Estimates based on fluxes between forest biomass (live or dead), soils, forest products and atmosphere	Haripriya (2003)
1994	3.86	IPCC revised 1996 guidelines	NATCOM, 2004
1982–1992	5.65	IPCC revised 1996 guidelines	Kaul et al. (2009)
1985–1996	9	Using a simple book keeping MBL model estimates from deforestation, afforestation and phytomass degradation	Chhabra and Dadhwal (2004)
1880–1996	47.00	Using a simple book keeping MBL model estimates from deforestation, afforestation and phytomass degradation	Chhabra and Dadhwal (2004)
1992–2002	−1.09	IPCC revised 1996 guidelines	Kaul et al. (2009)
2003–2005	50.7	IPCC revised 2003 guidelines	Sheikh et al. (2011)
2005–2007	31.1	IPCC revised 2003 guidelines	Sheikh et al. (2011)
1930–1975	48.19	IPCC revised 2006 guidelines	Present study
1975–1985	63.18	IPCC revised 2006 guidelines	Present study
1985–1995	−41.4	IPCC revised 2006 guidelines	Present study
1995–2005	26.23	IPCC revised 2006 guidelines	Present study
2005–2013	53.97	IPCC revised 2006 guidelines	Present study

Forest Fire Regimes and Hotspots(2003-2017)



Reddy, C.S., Grace Bird, N., Sreelakshmi, S., Manikandan, T.M., Asra, M., Hari Krishna, P., Jha, C.S., Rao, P.V.N. & Diwakar, P.G. 2019. Identification and characterization of spatio-temporal hotspots of forest fires in South Asia. *Environmental Monitoring and Assessment*, DOI: 10.1007/s10661-019-7695-6.

C-emission from land transformation



TgC = 10^{12}gC

Cumulative net carbon flux [PgC] from Indian forests due to landuse changes (1880–1996) under different scenarios

	India	Central	East	NE	NW	South
Scenario 1	2.34	–	–	–	–	–
Scenario 2	3.24	–	–	–	–	–
Scenario 3	3.25	1.14	0.417	0.55	0.37	0.76
Scenario 4	5.45	1.75	0.75	1.24	0.52	1.17

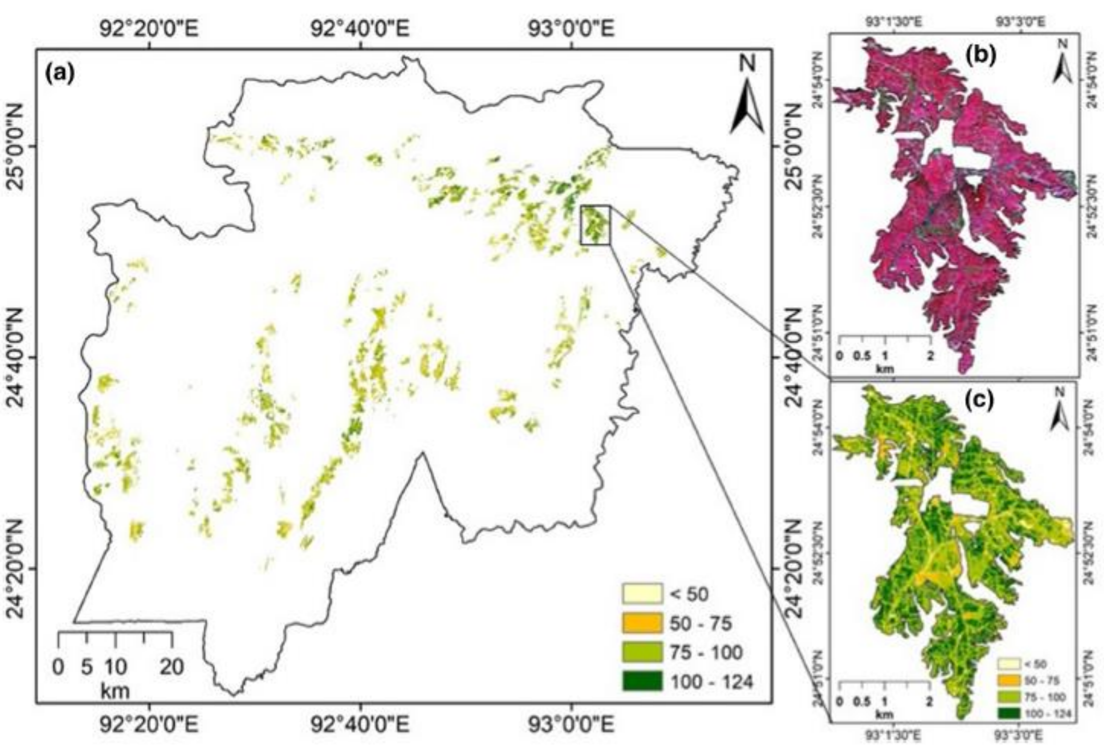
NE: Northeast region; NW: Northwest region.
Scenario 1: deforestation + afforestation, low biomass.
Scenario 2: deforestation + afforestation, high biomass.
Scenario 3: deforestation + afforestation, variable biomass (regional level).
Scenario 4: deforestation + afforestation + phytomass degradation, variable biomass (regional level).

Chhabra & Dadhwal, 2004, Climate Change, 64: 341-360

Tree Agroforestry Biomass Mapping : Barak Valley, Assam

Range of AGB = 39 – 150 Mgha-1
Mean AGB = 72.4 Mgha-1
Source: Kalita et al., 2022, Agroforestry Systems

Agroforest Syst



Agroforest Syst

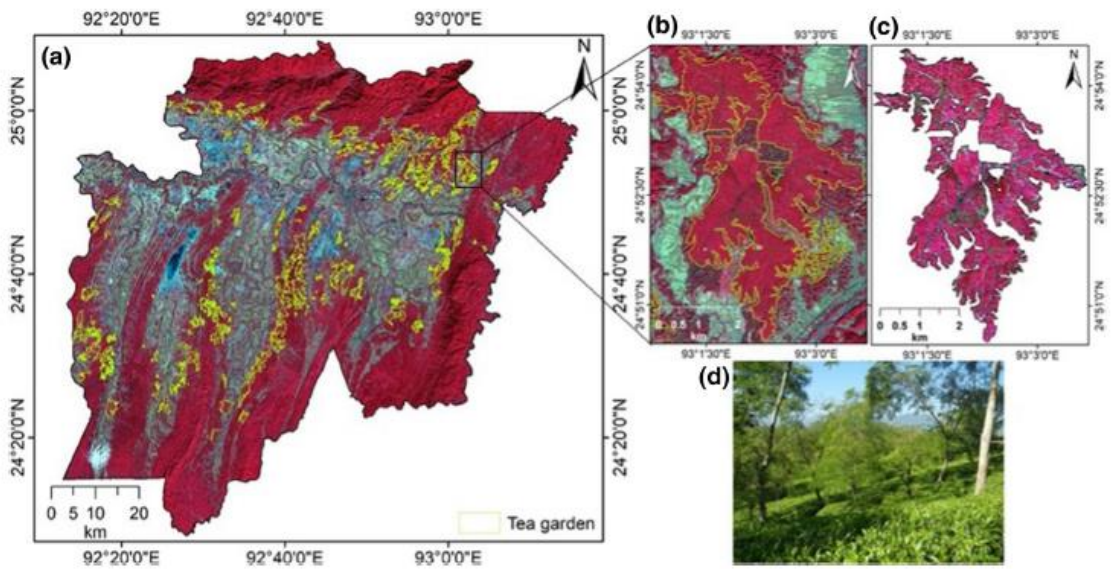


Table 2 Stem density and basal area of shade trees and tea bushes in the study area for different aged tea plantations in Barak valley, northeast India

Plantation age (years)	< 10	10–20	> 20
Shade tree density (stems ha^{-1})	230 (8)	205 (13)	182 (20)
Shade tree basal area (m^2 ha^{-1})	7.09 (0.26)	6.98 (0.49)	7.29 (0.62)
Tea bush density (stems ha^{-1})	18,400 (837)	17,000 (1338)	11,400 (1034)
Tea bush basal area (m^2 ha^{-1})	42.06 (2.51)	47.48 (2.32)	51.08 (5.06)

Figures within parentheses are standard errors of mean

SOIL ORGANIC CARBON

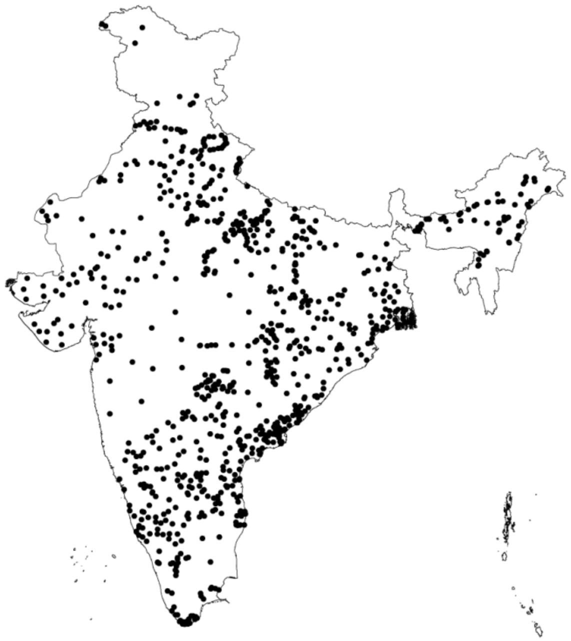
SOIL ORGANIC CARBON POOL ASSESSMENT

i. BUILDING A SOC BIG DATA FROM SOIL HEALTH CARD (SHC) SCHEME OF MINISTRY OF AGRICULTURE
ii. SPATIAL MAPPING OF SOIL ORGANIC CARBON FOR AGRICULTURAL LAND USING SHC SCHEME DATA

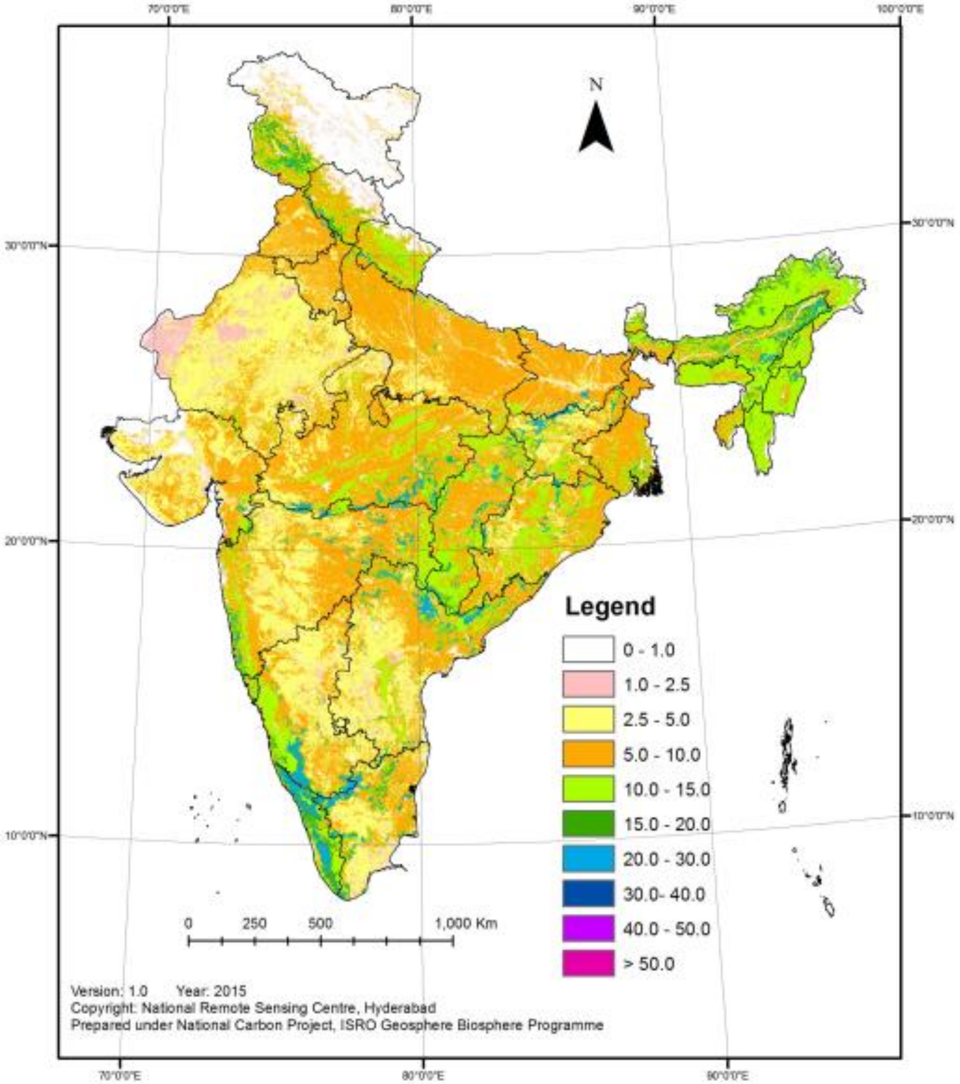
Assessment of Soil C pool

- Soil C pools have been estimated using soil maps only (Static !!!!)
- Models track soil C over cover change & recovery
- Forest C pool have more relied on mean OC density by forest type
- NCP adopted independent sampling with recent protocols & CHN analyser

Umbrella programme: NCP under IGBP
No. of soil profiles: 1318
Soil Samples Analyzed: 6040
Soil C Stocks for 0-30, 30-50 and 50-100 cm soil depth
Random Forest model



Location of sampling sites



Soil Organic Carbon stock – 22.7 Pg

Soil Organic Carbon : Challenges

- Integrating historical SOC point data with new inventory
  - Poor geo-location, analytical technique (wet oxidation, LOI) underestimation, site details (soil/vegetation), different depths (conversion factors for harmonizing analytical techniques)

- Improved SOC mapping at landscape level (current are regional/national maps)
  - Integrating remote sensing, topography and geostatistical techniques (e.g. case studies)

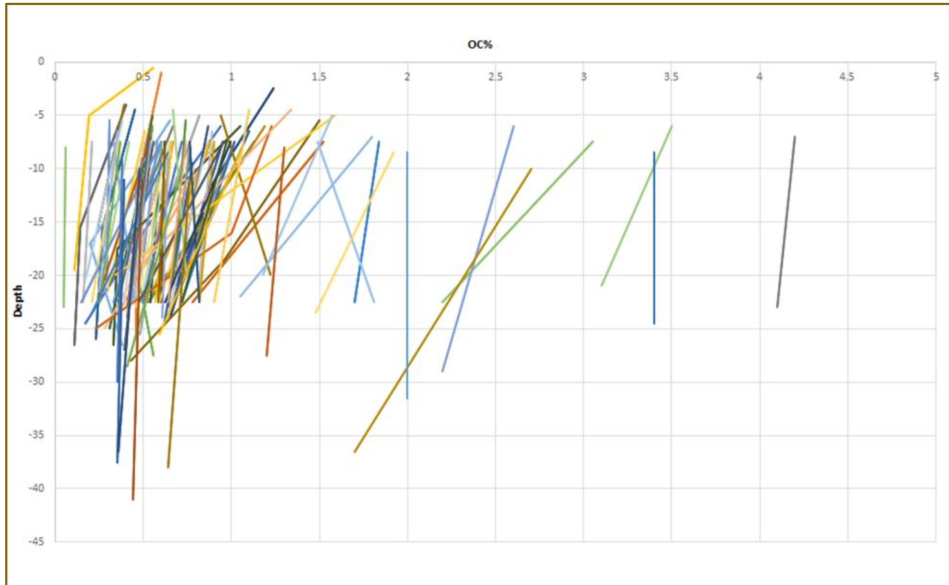
- SOC estimation linked to vegetation/forest growth
  - Models calibrated for Indian natural and plantation trees (e.g. CO2FIX)

- Spatial-temporal model for SOC with vegetation type, interannual productivity and land cover/use changes
  - Preliminary studies with biosphere models (e.g., SOC from CASA)

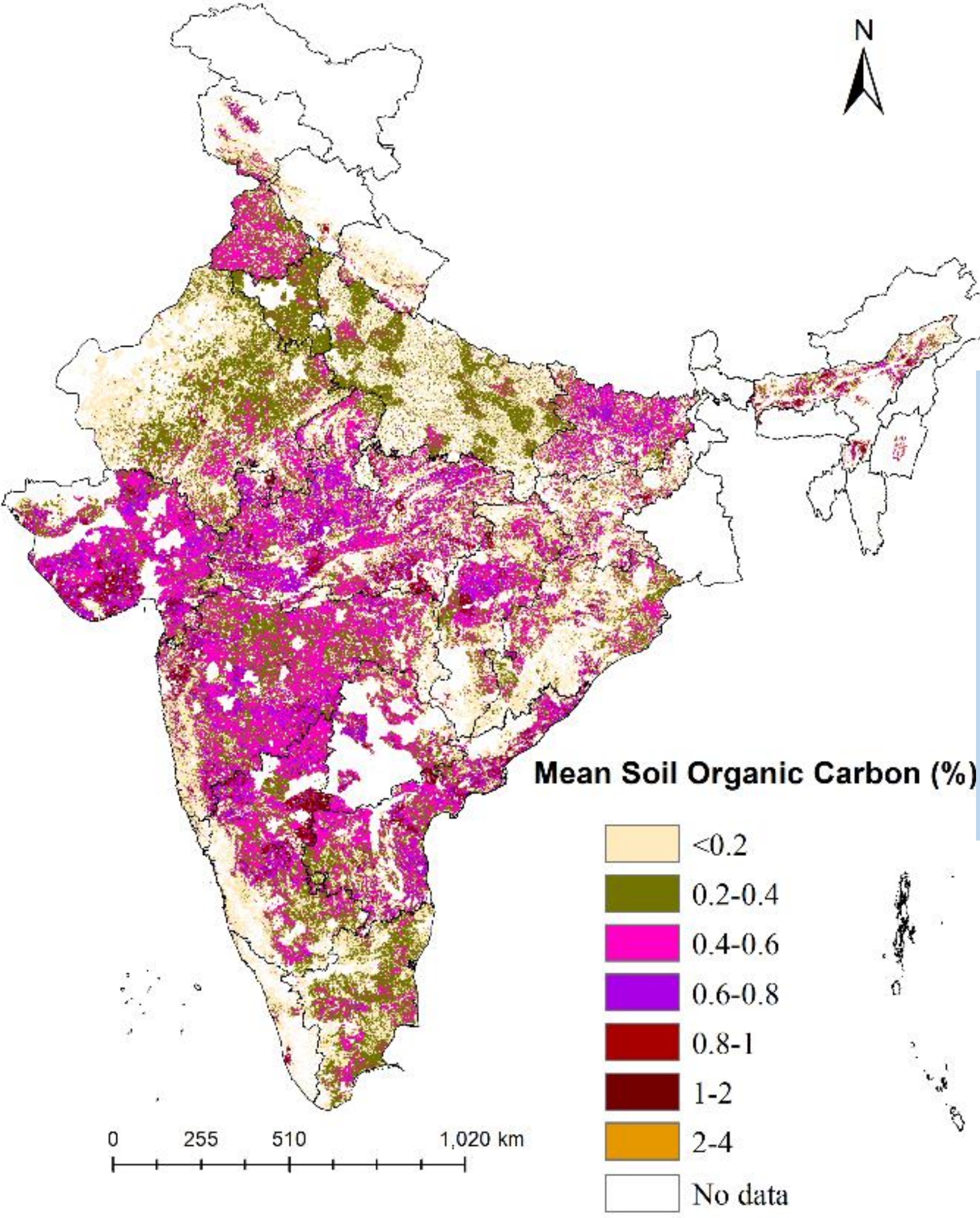
- *…(many additional)*

Soil Health Card : Utility for SOC

- SHC aims to improve fertilizer advisory with farmer specific field measurements. Scheme in operation since 2015. Nearly 140 million SHC issuedbased on 40 million unique samples,
- SHC data are openly accessible big data with 12 soil parameters. SOC is presented as % units. For 15-20 cm depth and agricultural land use only
- Challenges are in conversion of %C to SOC pool (t/ha), integrate over 0-30cm depth and filli in other land cover class SOC.
- SHC have been converted to national agricultural SOC % layer at 250m resolution with mean value for each village
- Procedures for conversion to SOC pool are being developed.
- Case study 1: Convert 15-20cm to SOC(0-30)
- **CF 31.28 (se 0.27;nobs =112)**
- Case Study 2: ESIP MP merge agricultural and forest SOC pools.

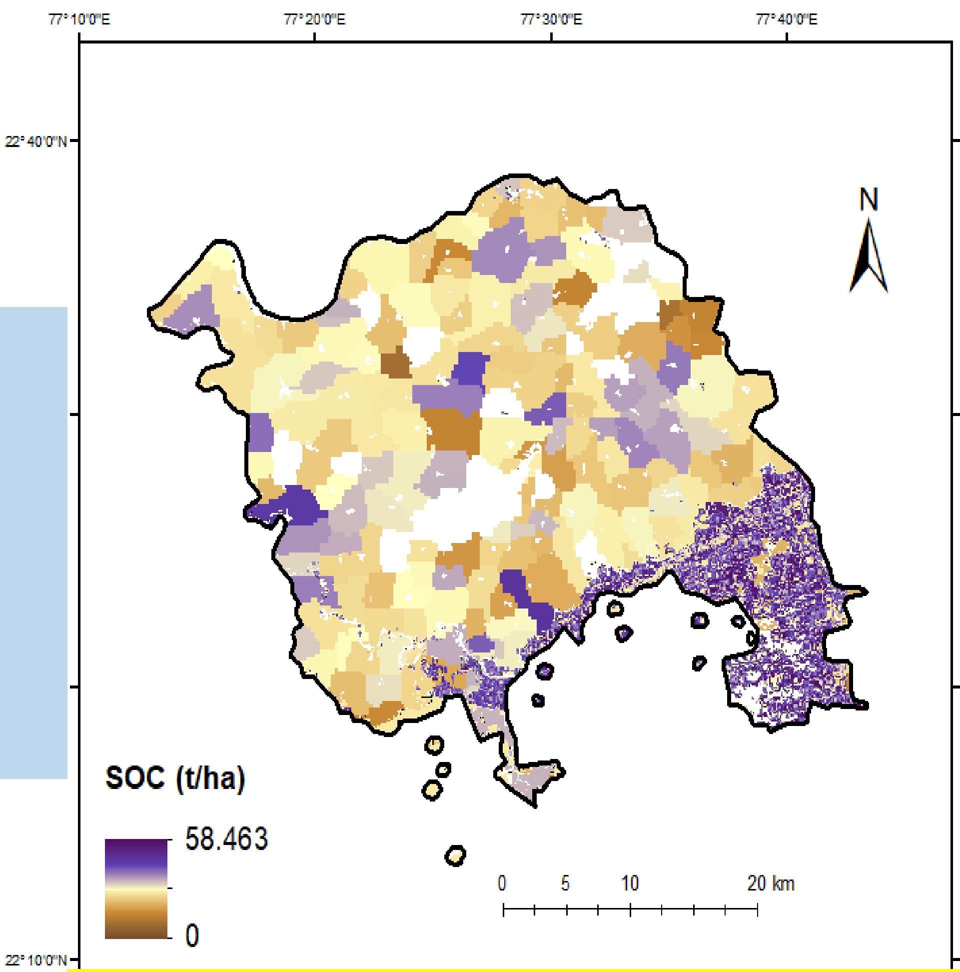


SHC : Utility for SOC assessment



CHALLENGES

- Data Quality
- Layer to profile
- Fill for non-agriculture



Harmonized agriculture and forest SOC map for Seoni Mawa taluk, MP

CARBON FLOW IN FOREST ECOSYSTEM

i. COMPREHENSIVE DATABASE OF TOTAL AND LEAF LITTERFALL MEASUREMENTS IN INDIA
ii. MODELING SPATIAL PATTERN OF FOREST LITTERFALL IN UTTARAKHAND USING MACHINE LEARNING TECHNIQUES

RS Model estimate of Indian NPP by Land cover

Table 3 Mean (gC m^{-2} year^{-1}) and total NPP (Pg C year^{-1}) estimated over different land use/land cover types in India (comprises of 3.29 million hectares) based on present CASA model estimate versus C-Fix- and MODIS-based estimates

Land use/land cover	CASA mean NPP (total NPP)	C-Fix mean NPP (total NPP)	MODIS mean NPP (total NPP)	% contribution of total national NPP budget		
				CASA	C-Fix	MODIS
Irrigated cropland and pasture	690 (0.358)	600 (0.302) 20	484 (0.252)	22.8	20	19
Mixed dry/irrigated cropland mosaic	450 (0.525)	505 (0.560) 38	376 (0.440)	33.6	38	33
Cropland and wood land mosaic	898 (0.044)	488 (0.025)	1006 (0.054)	2.8	1.3	4
Grassland	267 (0.019)	140 (0.156)	182 (0.014)	1.2	10	1
Shrubland	114 (0.004)	84 (0.003)	80 (0.003)	0.3	0.2	0.2
Mixed shrub and grassland	366 (0.130)	413 (0.143)	307 (0.105)	8.3	9	8.0
Savanna	789 (0.004)	591 (0.002)	873 (0.004)	0.3	0.1	0.3
Deciduous broadleaf forest	632 (0.288)	515 (0.229)	476 (0.219)	18.4	15.2	17
Evergreen broadleaf forest	989 (0.156)	504 (0.080)	948 (0.153)	9.9	5.2	12
Evergreen Needle-leaf forest	557 (0.027)	309 (0.017)	609 (0.034)	1.7	1.1	2.6
Wooded wetland	597 (0.001)	996 (0.003)	376 (0.001)	0.1	0.2	0.1
Barren or sparse vegetation	371 (0.013)	410 (0.017)	306 (0.012)	0.8	1.2	0.9
All LU/LC	544 (1.57)	487 (1.47)	440 (1.30)	100	100	100

Environ Monit Assess (2010) 170:195–213
DOI 10.1007/s10661-009-1226-9

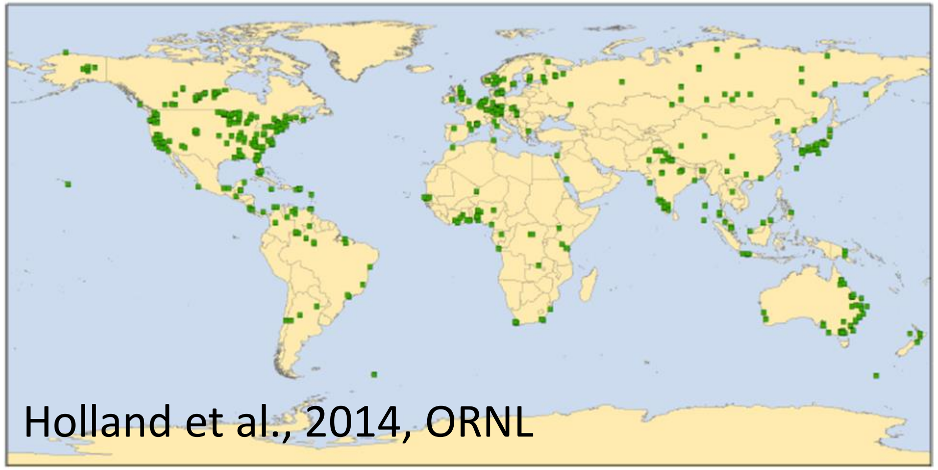
- RS models allow multiyear spatial NPP/NEP estimation
- Results indicate >20 per cent aggregate uncertainty with different inputs and models

Estimation and analysis of terrestrial net primary productivity over India by remote-sensing-driven terrestrial biosphere model

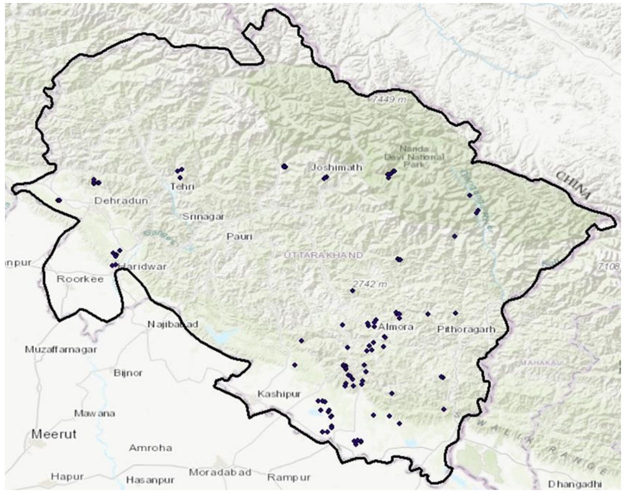
Rabindra K. Nayak · N. R. Patel · V. K. Dadhwal

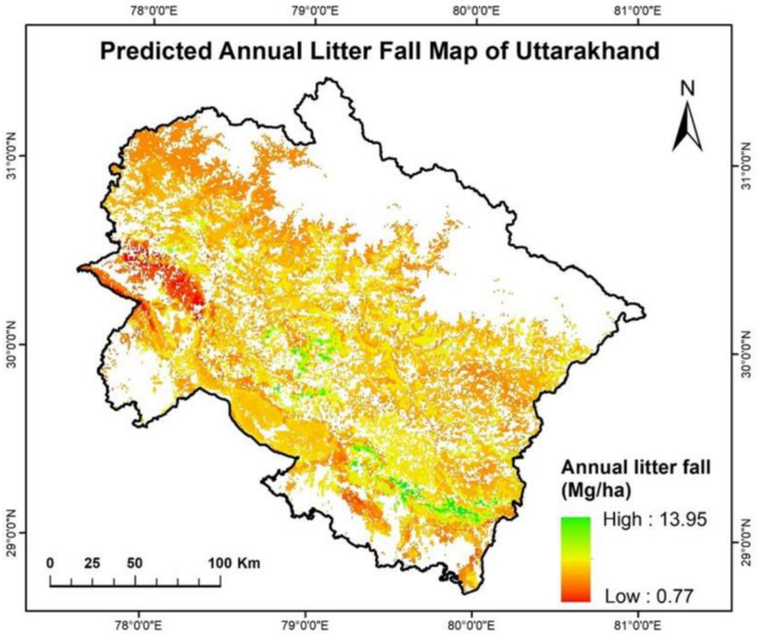
Spatial Assessment of Litterfall

- Litterfall estimates are by forest type and region from meta-analysis of science studies
- New approach for data-based and Machine Learning are under study
- Case study carried out for Uttarakhand
- Spatial predictors- 19 variables terrain, forest type, productivity
- Total results from aggregate and spatial are similar (12.5-14Mga-1)
- Need to prepare Indian measurement meta-analysis. Global data sets have unrepresented Indian data



Holland et al., 2014, ORNL

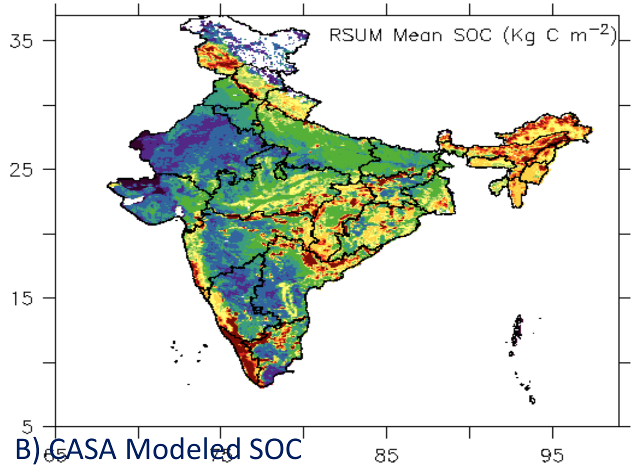




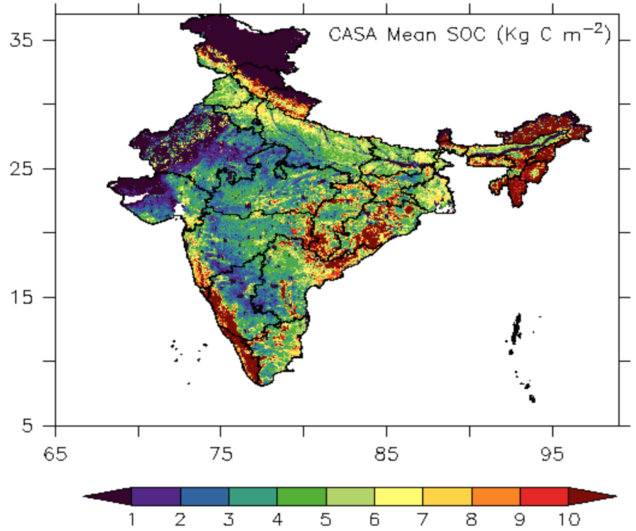
Source: Kripa & Dadhwal., 2022, Unpublished

Variability of Soil Organic Carbon (SOC) based on CASA model and in situ observation

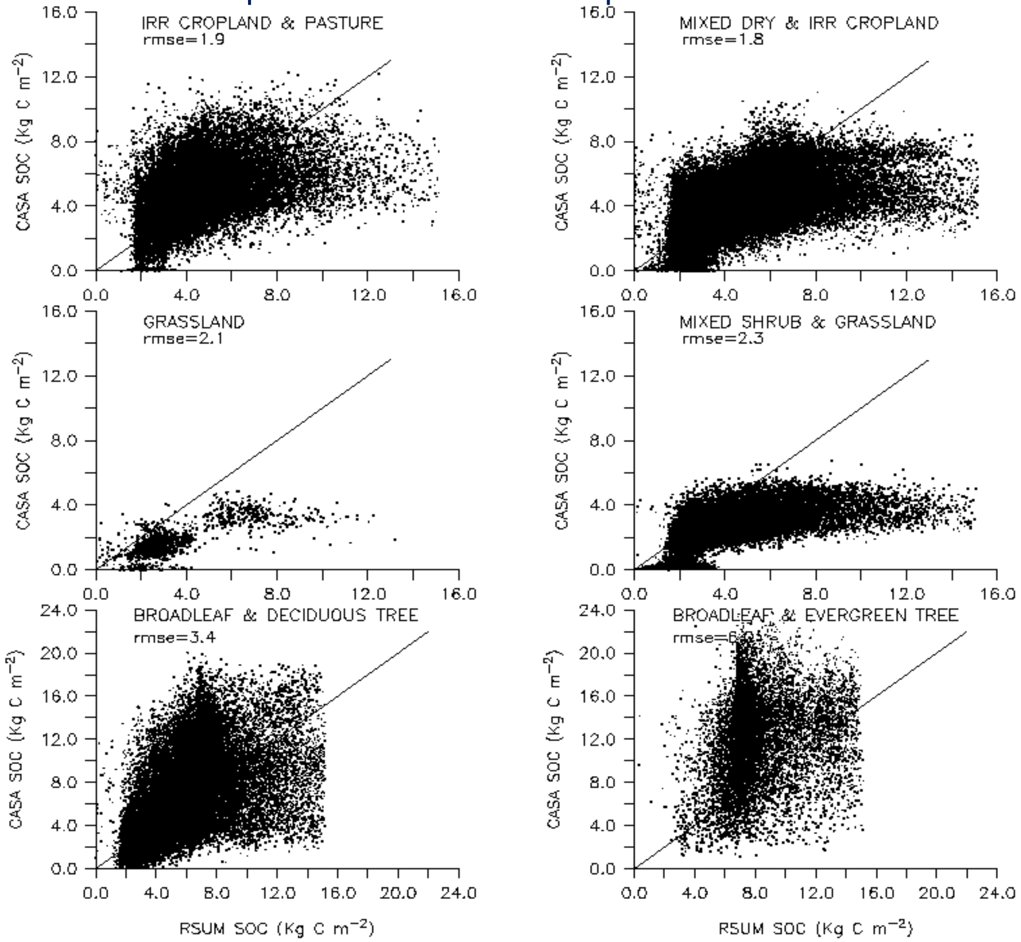
A) In-situ with RS up-scaled data



B) CASA Modeled SOC



SOC scatter plot CASA Vs in situ-rs upscaled



Source: Nayak et al., 2020 J Ind Soc Rem Sens

A). Spatial map of observed SOC prepared under the National carbon Project (NCP) of ISRO using the in situ samples collected across India between period 2008-2012 and remote sensing up-scaling procedure (RSUM).

B). Map of SOC content simulated by the CASA Terrestrial Ecosystem model during 2008-2015.

AGRICULTURAL PRIMARY PRODUCTIVITY

AGRICULTURAL PRIMARY PRODUCTIVITY

i. AGRICULTURE MODULATES PRIMARY PRODUCTIVITY IN COMPLES INTERACTION BETWEEN CROP, SOIL & CLIMATIC RESOURCES AND FARM INPUTS AND OPERATIONS
ii. HARVEST AND USE OF CROPS IS MOST IMPORTANT COMPONENT OF 'HUMAN APPROPRIATION AND PRIMARY PRODUCTIVITY' AAND SUSTAINABILITY INDICATORS
iii. REMOTE SENSING DATA CAPTURE GROSS PRIMARY PRODUCTIVTY
iv. A HYBRID REMOTE SENSING AND GROUND ESTIMATE CROP PRODUCTION HAS BEEN USED TO DEVELOP A NEW MULTI-YEAR DATA SET OF AGRICULTURAL PRODUCTIVITY
v. DATA SET WILL BE RELEASED IN SCIENTIFIC DATA ON ACCEPTANCE
vi. GANGOPADHYAY, SIRSATH, DADHWAL & AGGARWAL 2022 – Under Review

Improved Agricultural Primary Productivity Assessment

Fig. 4: The process flow for calibration (a) and validation (b).

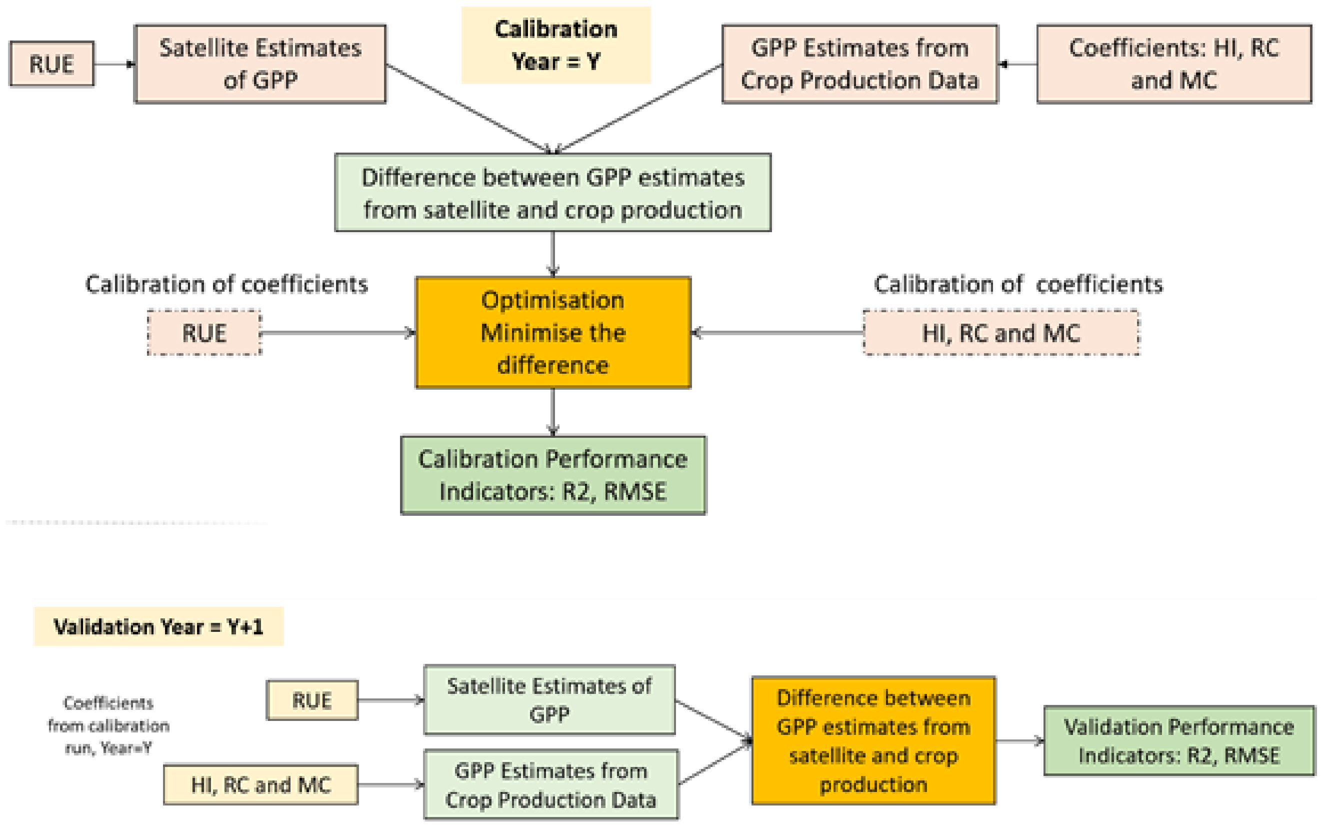
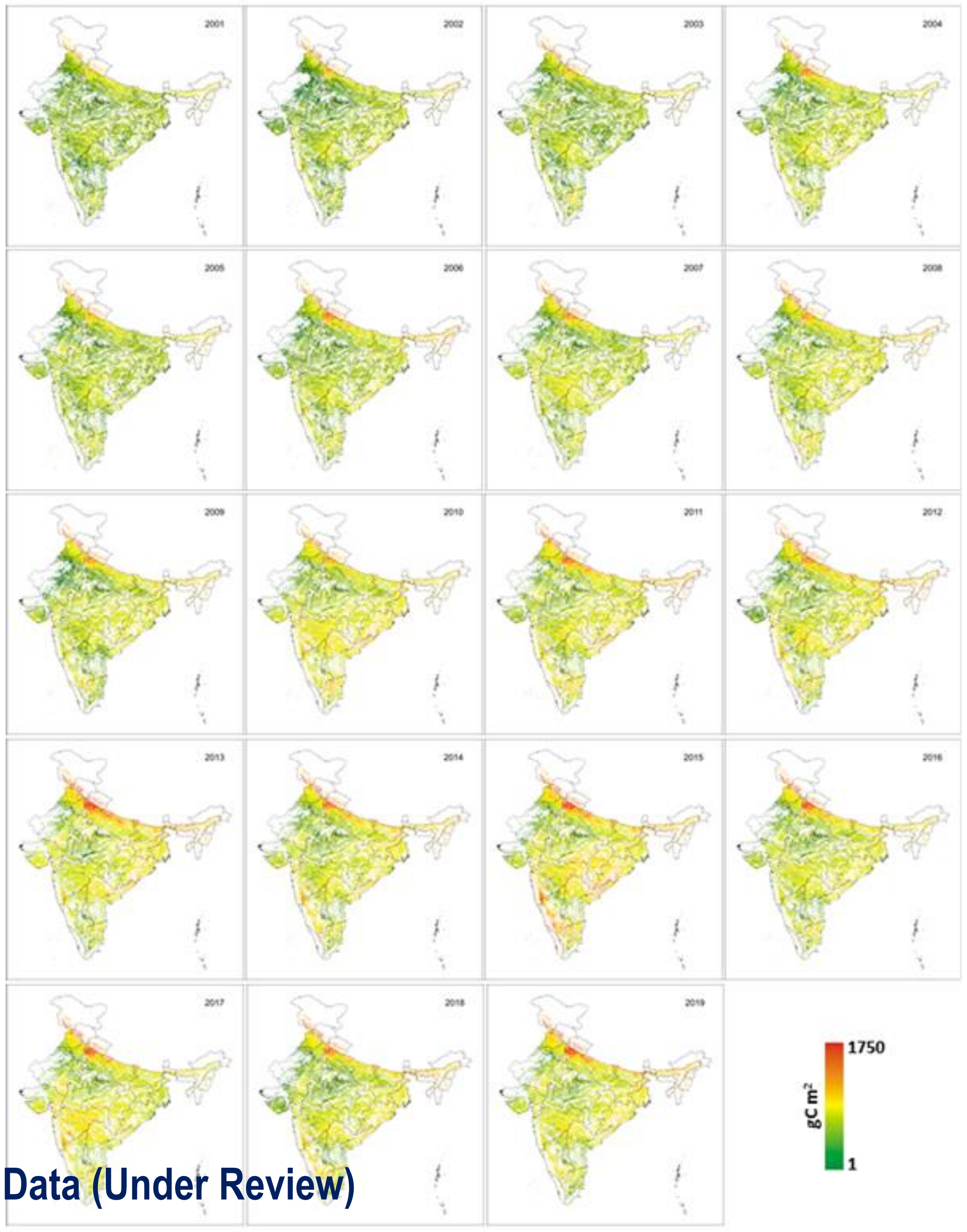


Fig. 5a: Agricultural GPP distribution over India in the monsoon season (June to October) from 2001 to 2019.



Source: GANGOPADHYAY, SIRSATH, DADHWAL & AGGARWAL 2022, Scientific Data (Under Review)

THANK YOU

Queries ?

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Land Use Pattern – Census – Village-level Data

- Land use and Irrigation: - The land use pattern in the Village Directory conform to the pattern of classification of land use as recommended by the Ministry of Agriculture, Government of India. The Ministry has recommended the
- maintenance of records of land use pattern under the following 9 categories. (i)-Column No. 103 -Forests:-This includes all lands classed as forest under any legal enactment dealing with forests or administered as forests, whether stateownedor private, and whether wooded or maintained as potential forest land.
- The area of crops raised in the forest and grazing lands or areas open for grazing within the forests remain included under the forest area.(ii)-
- Column No. 104- Area under non-agricultural use:-This includes all lands occupied by buildings, roads and railways or under water, e.g. rivers and canals and other lands put to uses other than agriculture.
- (iii)-Columns No. 105-Barren and un-culturable land:-This includes all barren and unculturable land like mountains, deserts, etc. land which cannot be brought under cultivation except at an exorbitant cost should be classed as unculturable whether such land is in isolated blocks or within cultivated holdings.
- (iv)-Column No. 106- Permanent Pastures and other Grazing Lands:-This includes all grazing lands whether they are permanent pastures and meadows or not. Village common grazing land is included under this head.
- (v)-Column No. 107-Land under Miscellaneous Tree Crops, etc.:- This includes all cultivable land which is not included in 'Net area sown' but is put to some agricultural uses. Lands under Causing trees, thatching grasses, bamboo bushes and other groves for fuel, etc. which are not included under 'Orchards' are classed under this category.
- (vi)-Column No. 108- Culturable Waste Land: - This includes lands available for cultivation, whether not taken up for cultivation or taken up for cultivation once but not cultivated during the current year and the last five years or more in
- succession for one reason or other. Such lands may be either fallow or covered with shrubs and jungles which are not put to any use. They may be assessed or unassessed and may lie in isolated blocks or within cultivated holdings. Land
- once cultivated but not cultivated for five years in succession is also included in this category at the end of the five years.
- (vii)-Column No. 109- Fallow Lands other than Current Fallows: - This includes all lands which were taken up for cultivation but are temporarily out of cultivation for a period of not less than one year and not more than five years.
- (viii)-Column No. 110- Current Fallows: - This represents cropped area, which is kept fallow during the current year. For example, if any seeding area is not cropped against the same year it may be treated as current fallow.
- (ix)-Column No. 111- Net Area Sown: -This represents the total area sown with
- crops and orchards. Area sown more than once; in the same year is counted