Valuation of Ecosystem Goods & Services

(Pilot study in select districts of Karnataka)

[UNSD, MoSP - Karnataka Initiative]

EWRG, CENTRE FOR ECOLOGICAL SCIENCES,
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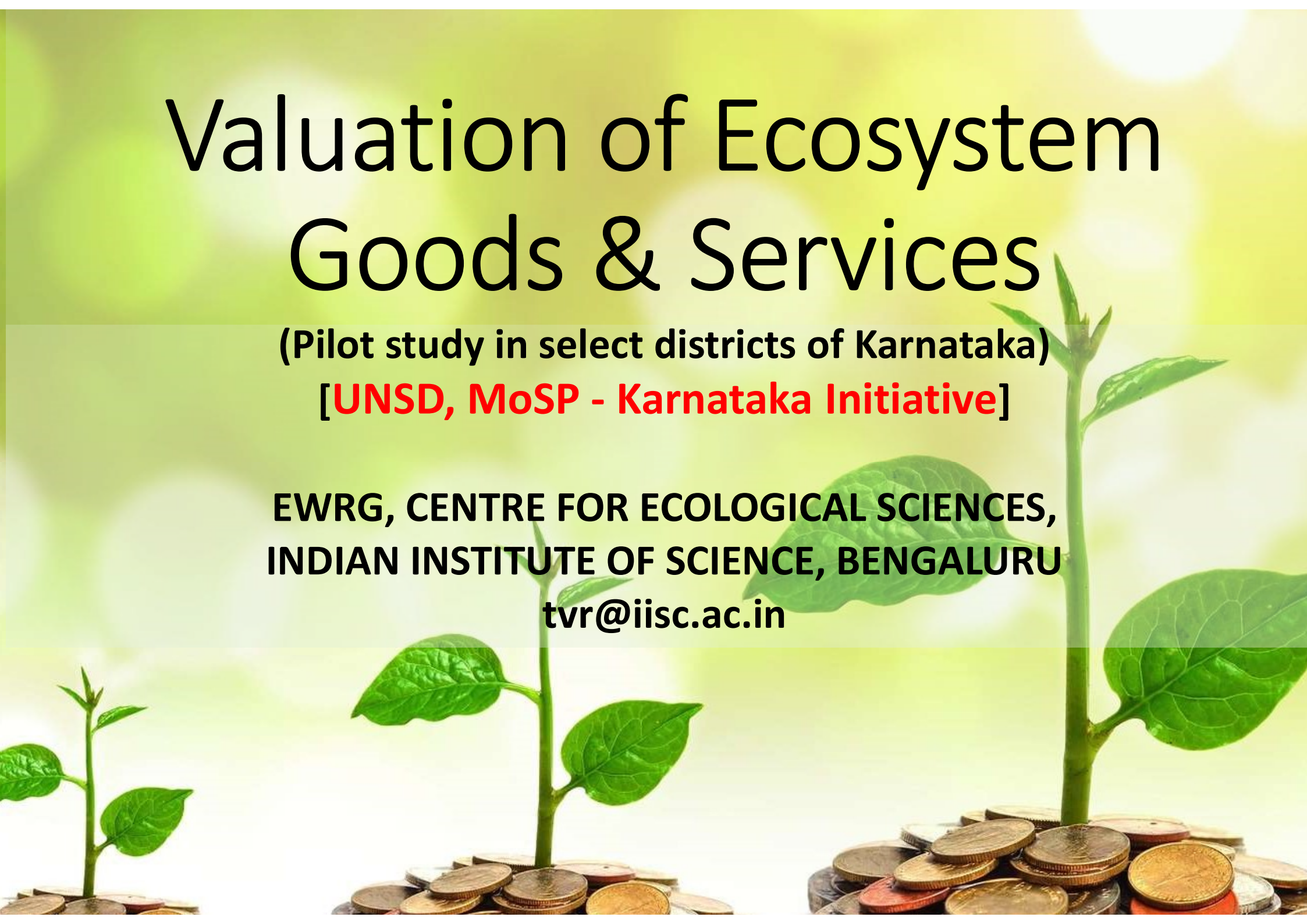
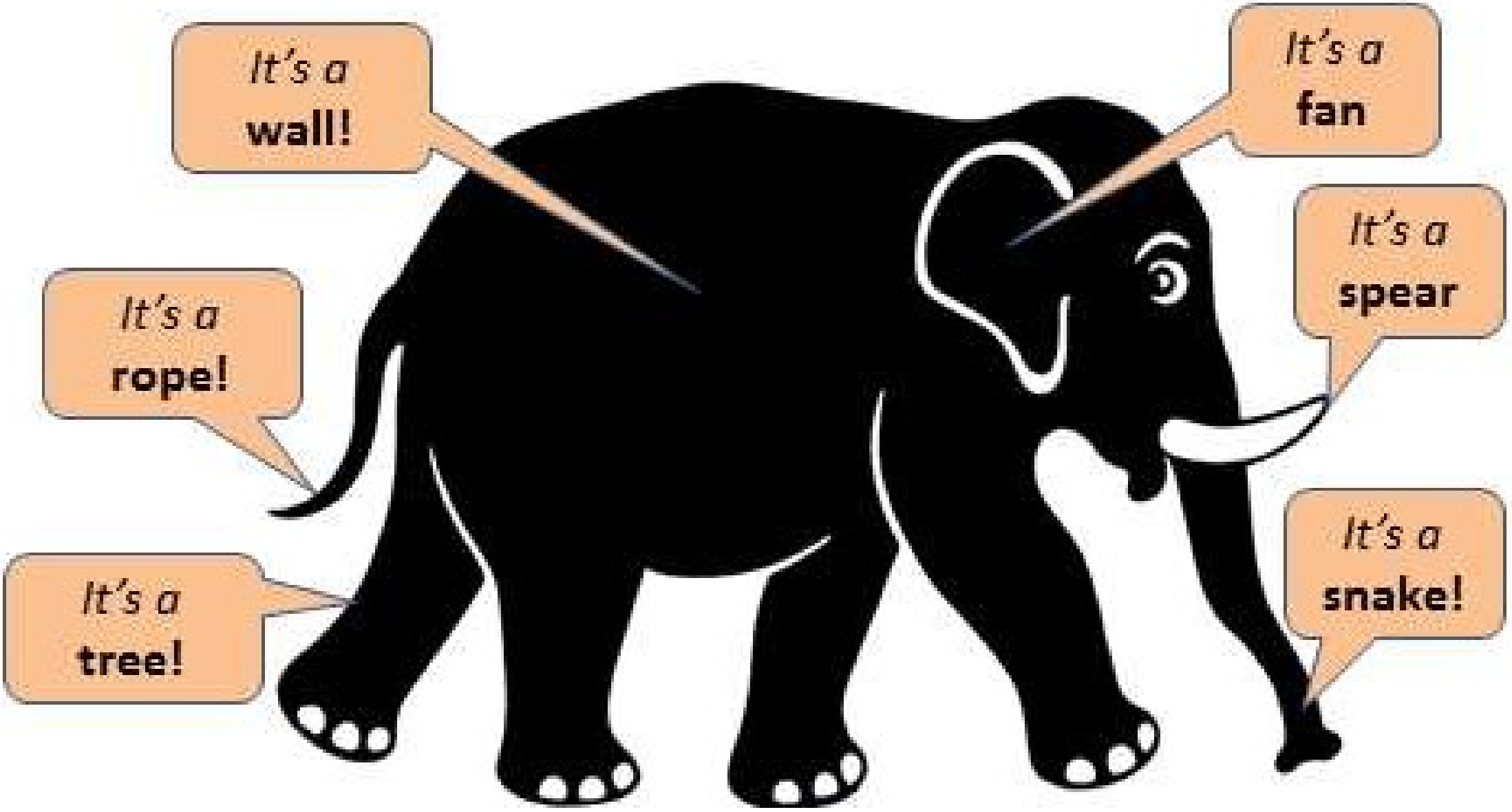


Goal: to develop the ecosystem accounts in Karnataka, India, and provide demonstration effects of their utility to inform policy decision-making

- (i) extent and condition accounts for Karnataka State through temporal remote sensing data with collateral data;
- (ii) services supply accounts for Karnataka as per the SEEA-EEA technical guide where ecosystems services are defined as the contributions to benefits;
- (iii) Valuation of the modeled ecosystem services and ecosystems;
- (iv) Scenario-based assessment of policy interventions.

Without understanding ecosystem and interactions, valuation will be interpretation of elephant by Blind men



ECOSYSTEM GOODS & SERVICES

- Ecosystem goods and services are the **tangible/intangible benefits** derived by humans from ecosystems and their functioning (flows) that possess **direct/indirect value**

- A **single ecosystem asset** will generate a range of ecosystem services, thus contributing to the **generation of a number of benefits**

- The concept of **valuating ecosystem services** is central in **connecting characteristics of ecosystem assets** with the **benefits received from ecosystems by people** through economic and other human activity

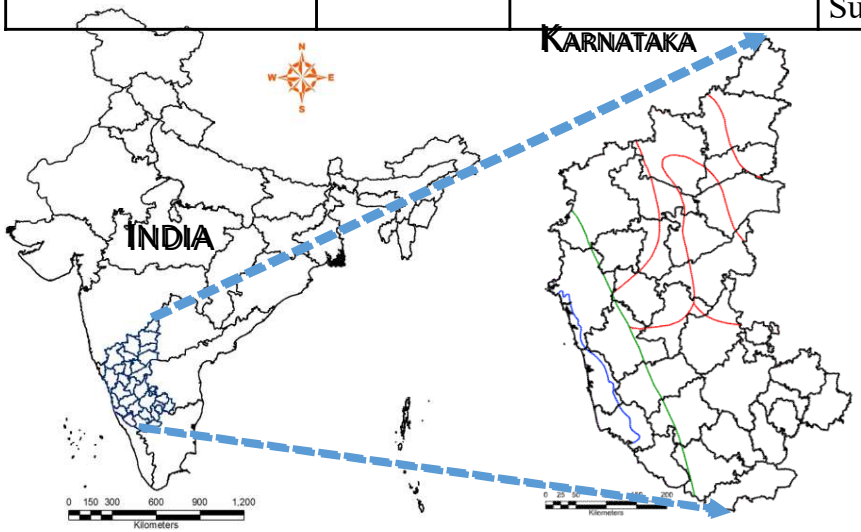
Ecosystem Services Selected

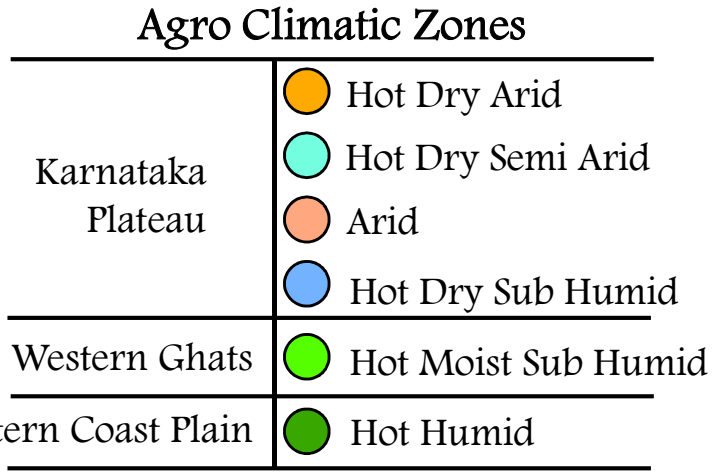
- **Provisioning Services**
  - Food
  - Raw Materials
  - Fresh Water
  - Medicinal resources
- **Regulating Services**
  - Carbon sequestration
  - Local Climate Air quality
  - Soil Erosion prevention
  - Pollination
- **Cultural Services**
  - Tourism
  - Aesthetic appreciation and inspiration for culture, art design

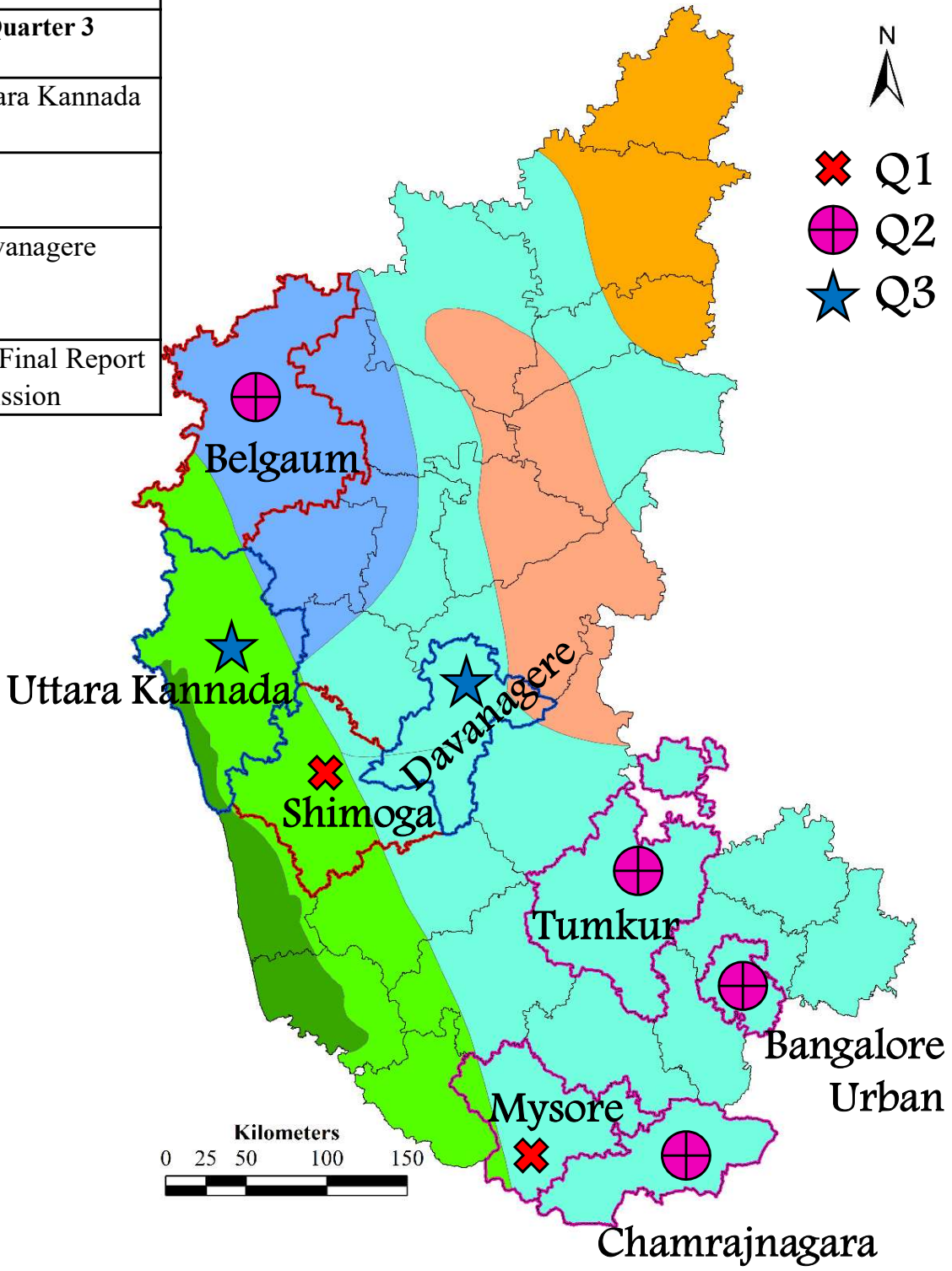
Ecosystem Services (as per the discussion during Bangalore Meeting – 15-16 Dec 2018)

Ecosystem services	Entity	Method	Models
Provisioning services	Raw material Food Fresh water Timber NTFP Litter Fishery Fuel wood	Market based approach [Field data collection; Data from govt. agencies (forest department), gate market price (at taluk)]	InVEST
Regulating Services	Local climate Air quality Carbon sequestration Erosion prevention Maintenance of soil fertility Pollination	Replacement cost method Replacement cost method Market based approach Damage cost avoidance Damage cost avoidance m Production function approach	InVEST
Cultural Services	Tourism Aesthetic appreciation and inspiration for culture, art and design	Travel cost method Contingent Valuation (WTP) Replacement cost method	InVEST recreation model

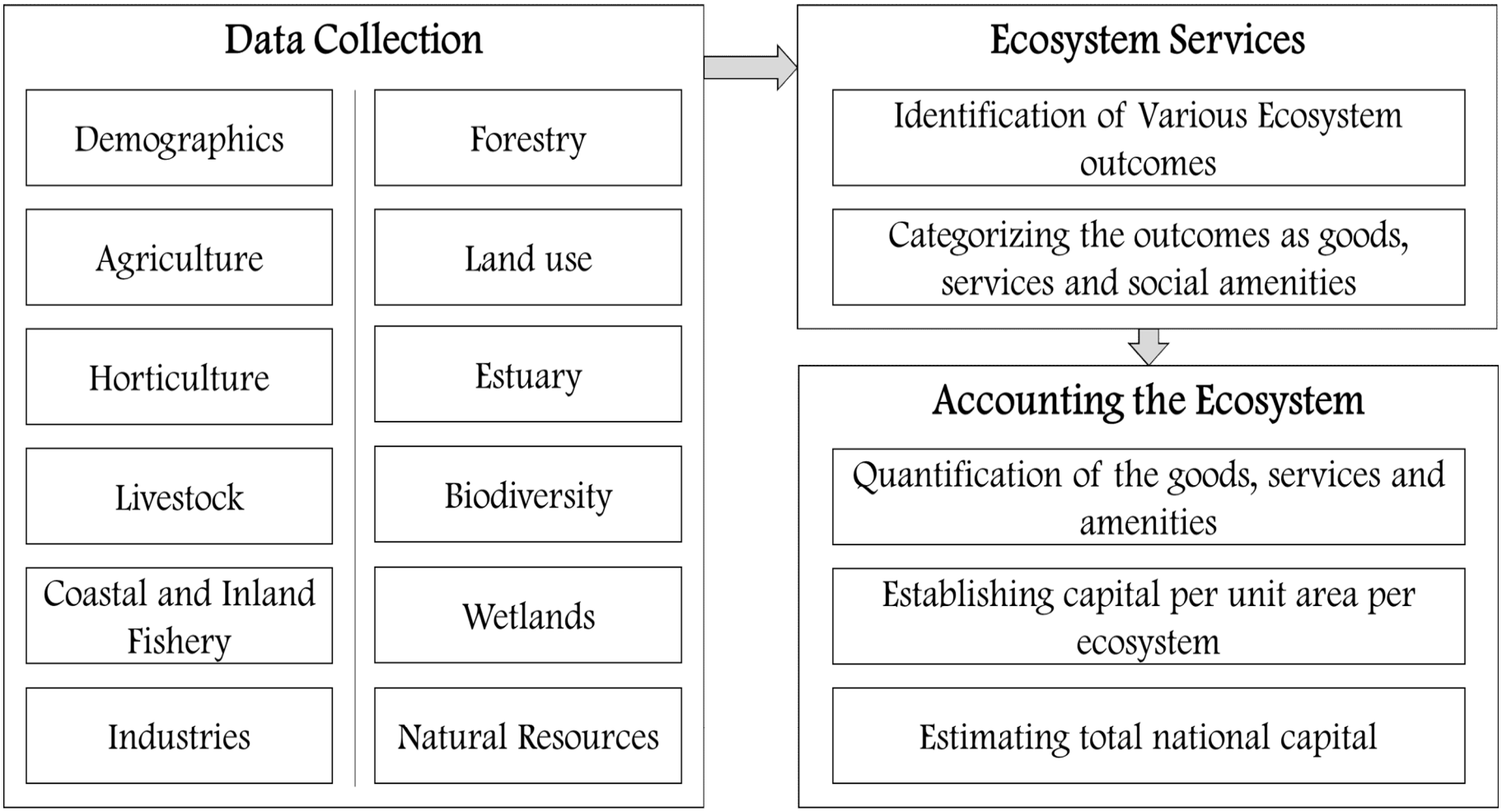
Year 2019-2020			
Agro climatic Zone	**Quarter 1**	**Quarter 2**	**Quarter 3**
Coast			7) Uttara Kannada
Ghats	1) Mysore 2) Shimoga	3) Belgaum	
Plateau		4) Chamrajnagara 5) Bangalore Urban 6) Tumkur	8) Davanagere
Validation		Q1	Q2 & Final Report Submission



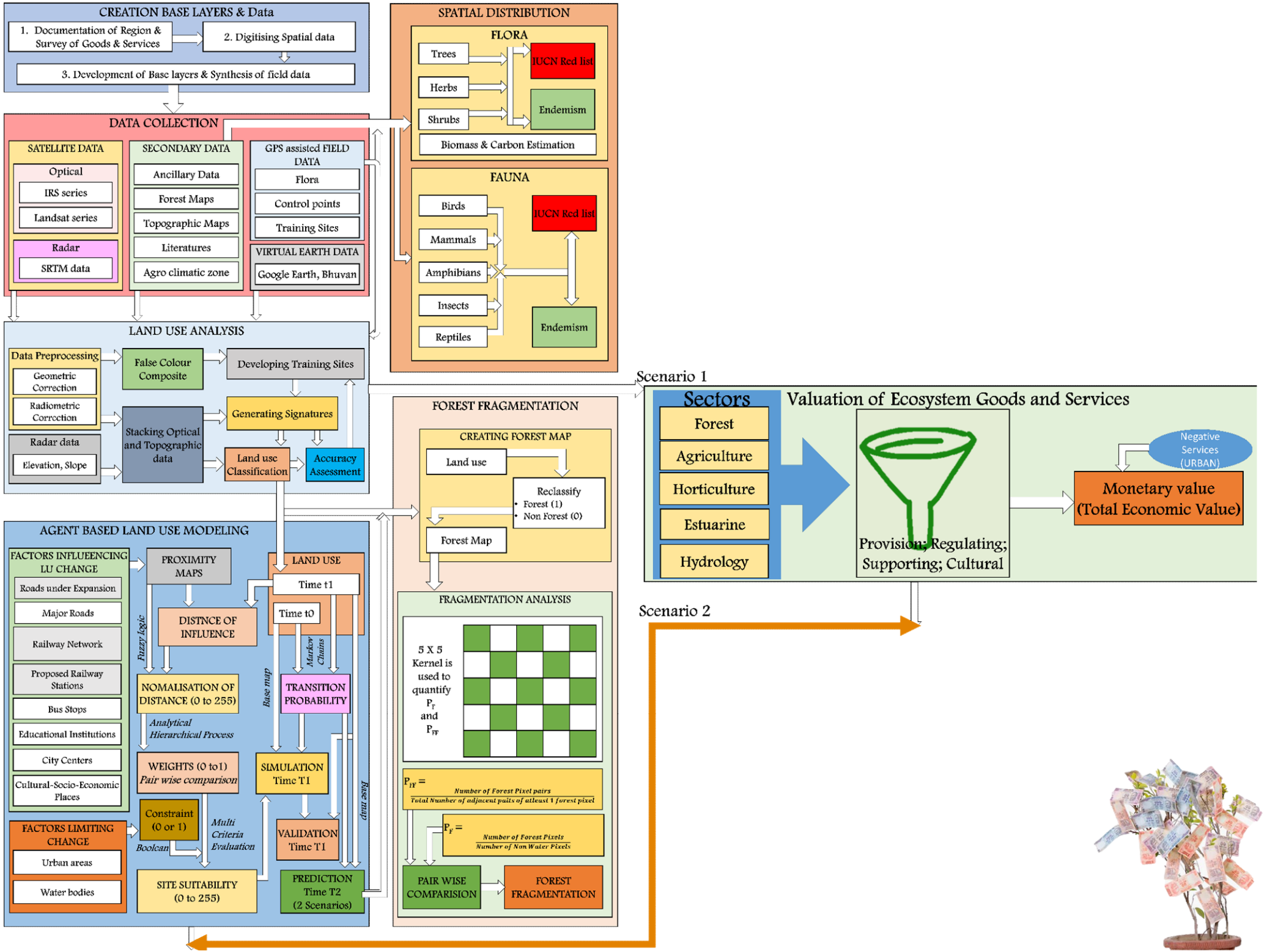




Data collection



METHOD


CREATION BASE LAYERS & Data
1. Documentation of Region & Survey of Goods & Services
2. Digitising Spatial data
3. Development of Base layers & Synthesis of field data
SPATIAL DISTRIBUTION
FLORA
Trees
Herbs
Shrubs
IUCN Red list
Endemism
Biomass & Carbon Estimation
FAUNA
Birds
Mammals
Amphibians
Insects
Reptiles
IUCN Red list
Endemism
DATA COLLECTION
SATELLITE DATA
Optical
IRS series
Landsat series
Radar
SRTM data
SECONDARY DATA
Ancillary Data
Forest Maps
Topographic Maps
Literatures
Agro climatic zone
GPS assisted FIELD DATA
Flora
Control points
Training Sites
VIRTUAL EARTH DATA
Google Earth, Bhuvan
LAND USE ANALYSIS
Data Preprocessing
Geometric Correction
Radiometric Correction
False Colour Composite
Developing Training Sites
Radar data
Elevation, Slope
Stacking Optical and Topographic data
Generating Signatures
Land use Classification
Accuracy Assessment
AGENT BASED LAND USE MODELING
FACTORS INFLUEENCING LU CHANGE
Roads under Expansion
Major Roads
Railway Network
Proposed Railway Stations
Bus Stops
Educational Institutions
City Centers
Cultural-Socio-Economic Places
PROXIMITY MAPS
DISTNCE OF INFLUENCE
Fuzzy logic
NOMALISATION OF DISTANCE (0 to 255)
Analytical Hierarchical Process
WEIGHTS (0 to1)
Pair wise comparison
FACTORS LIMITING CHANGE
Urban areas
Water bodies
Constraint (0 or 1)
Boolean
Multi Criteria Evaluation
SITE SUITABILITY (0 to 255)
LAND USE
Time t1
Time t0
Base map
Markov Chains
TRANSITION PROBABILITY
SIMULATION Time T1
VALIDATION Time T1
Base map
PREDICTION Time T2 (2 Scenarios)
FOREST FRAGMENTATION
CREATING FOREST MAP
Land use
Reclassify
Forest (1)
Non Forest (0)
Forest Map
FRAGMENTATION ANALYSIS
5 X 5 Kernel is used to quantify P_F and P_{FF}
P_{FF} = Number of Forest Pixel pairs / Total Number of adjacent pairs of atleast 1 forest pixel
P_F = Number of Forest Pixels / Number of Non Water Pixels
PAIR WISE COMPARISION
FOREST FRAGMENTATION
Scenario 1
Sectors
Forest
Agriculture
Horticulture
Estuarine
Hydrology
Valuation of Ecosystem Goods and Services
Provision; Regulating; Supporting; Cultural
Negative Services (URBAN)
Monetary value (Total Economic Value)
Scenario 2

Questionnaire for each ecosystem

- Agriculture
- Horticulture
- Livestock
- Wetland
- Forestry

Energy and Wetlands Research Group, Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012; http://ces.iisc.ernet.in/energy Tel: 91-080-22933099. E Mail: tvr@iisc.ac.in

SOCIO-ECONOMIC SURVEY: AGRICULTURE (use separate questionnaire for each crop)

NAME OF THE INVESTIGATOR _____ DATE: _____

NAME OF THE RESPONDENT: _____ AGE: _____ M/F _____

VILLAGE: _____ TALUK: _____ DISTRICT: _____

DEMOGRAPHIC INFORMATION

TOTAL NUMBER OF PERSONS IN HOUSEHOLD: ___

AGE 0-15 YEARS: ___ AGE 16-25 YEARS: ___ AGE 26-50 YEARS: ___ AGE 50+ YEARS: ___

OCCUPATION(S) OF HOUSEHOLD MEMBERS:

TOTAL HOUSEHOLD INCOME (Rs./yr):

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Tel: 91-080-22933099. E Mail: tvr@iisc.ac.in

SOCIO-ECONOMIC SURVEY: Wetlands (lakes/tanks)

NAME OF THE RESPONDENT: _____ DATE: _____

NAME OF THE INVESTIGATOR: _____ AGE: _____ M/F _____

VILLAGE: _____ TALUK: _____ DISTRICT: _____

DEMOGRAPHIC INFORMATION

TOTAL NUMBER OF PERSONS IN HOUSEHOLD: ___

AGE 0-15 YEARS: ___ AGE 16-25 YEARS: ___ AGE 26-50 YEARS: ___ AGE 50+ YEARS: ___

OCCUPATION(S) OF HOUSEHOLD MEMBERS:

TOTAL HOUSEHOLD INCOME (Rs./yr):

SOCIO-ECONOMIC SURVEY: AGRICULTURE (use separate questionnaire for each crop)

AGRICULTURE CROP:

NAME OF THE INVESTIGATOR _____ DATE: _____

NAME OF THE RESPONDENT: _____ AGE: _____ M/F _____

VILLAGE: _____ TALUK: _____ DISTRICT: _____

LAND (AREA) ACRE		
LAND PREPARATION	LABOUR No: Amount:	ANIMALS (cattle/Bullock): No MECHANISED: Type Capacity Cost:
SEASON		
SEED	TYPE	QUANTITY COST
SOWING	LABOUR AMOUNT:	ADDITIONAL WORK – DEWEEDING LABOUR AMOUNT
TRANSPLANTATION (FOR PADDY)	LABOUR TYPE	COST
MANURE /Fertiliser	Frequency: Type:	Quantity Cost:
IRRIGATION	TYPE: Frequency Electricity	Motor (HP) Duration Cost
PESTS PROTECTION (WILD PIG, BANDICOT, MONKEY, …)	PEST Type DAMAGE EXTENT	PROTECTION TYPE Cost
PESTICIDE / **HERBICIDE**	Type Frequency	Labour Cost

HARVESTING	**LABOUR**	**QUANTITY** **COST**
PRODUCTION	QUANTITY	VALUE
PROCESSING	TYPE WATER QUANTITY	FUEL - TYPE FUEL – QUANTITY COST
END PRODUCT	TYPE	QUANTITY VALUE

DO YOU PROCESS FURTHER

IF YES

TYPE (END PRODUCT)

QUANTITY

VALUE

FARM RESIDUES

TYPE	**QUANTITY**	**IF SOLD, VALUE:**
1.		
2.		
3.		

PROBLEMS (IF ANY) FACED WHILE PRACTICING AGRICULTURE

MARKET

TYPE	**QUANTITY**	**VALUE**

Date

Collected by:

Signature

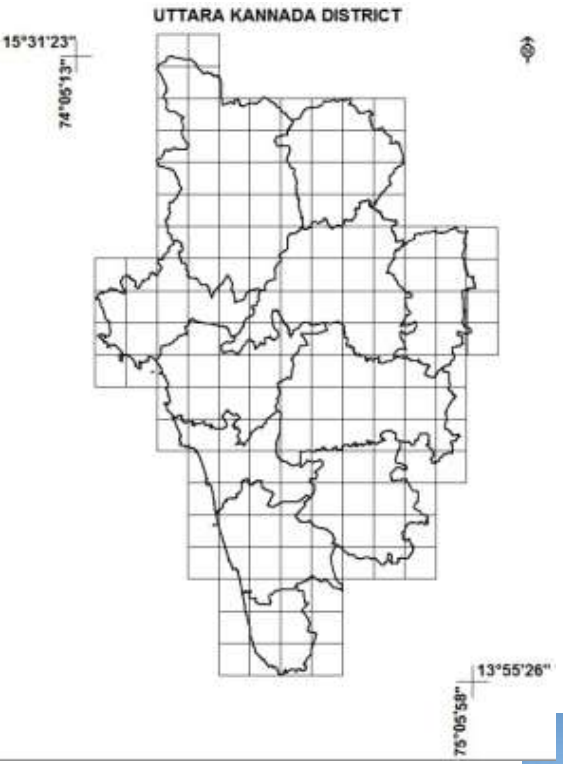
Tools for valuation

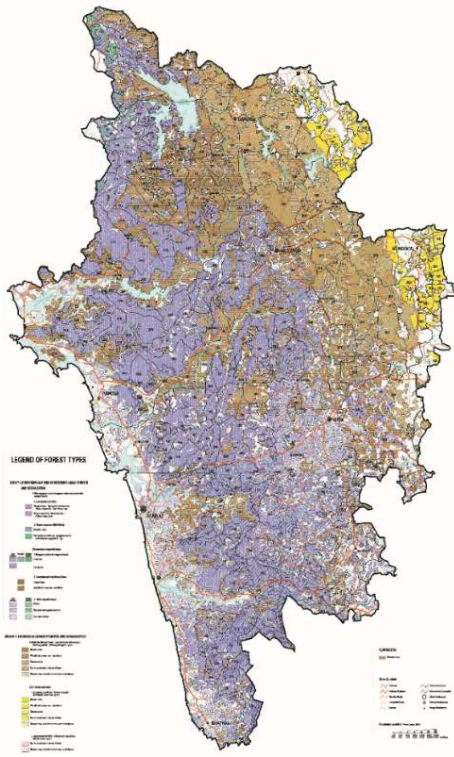
Ecosystem	Service	Approach & Tools to be used	Comment
Forest; Hydrology; Coast; Agriculture; Horticulture; Estuarine	Provisional	Market based approach; Statistical analysis; Geographical Analysis Resource Support System (GRASS); Quantum (Q) GIS	Field data collection; Data from regulatory agencies
	Regulating	InVEST; GRASS; QGIS; Revised Universal Soil Loss Equation (RUSLE); Natural Resource Conservation Series (SCS-curve number); Field estimates-statistical analysis	Analysis of high resolution land use land cover data;
	Cultural	InVEST recreation model; Cellular Automata-MARKOV chains; Travel cost method; Multi Criteria Evaluation, Analytical Hierarchical Process (AHP)	LULC; Data from Government of Karnataka Tourism Department

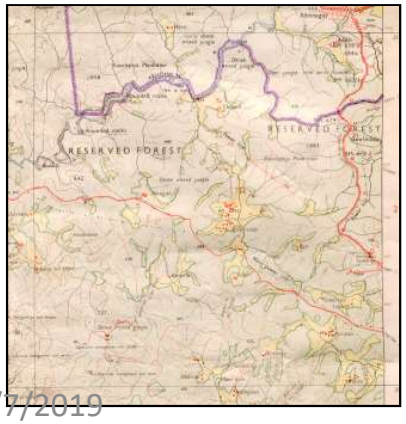
Task 1

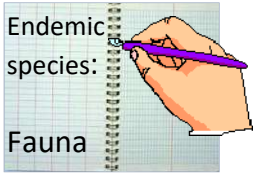
I. Extent and condition accounts for Karnataka State through temporal remote sensing data with collateral data;

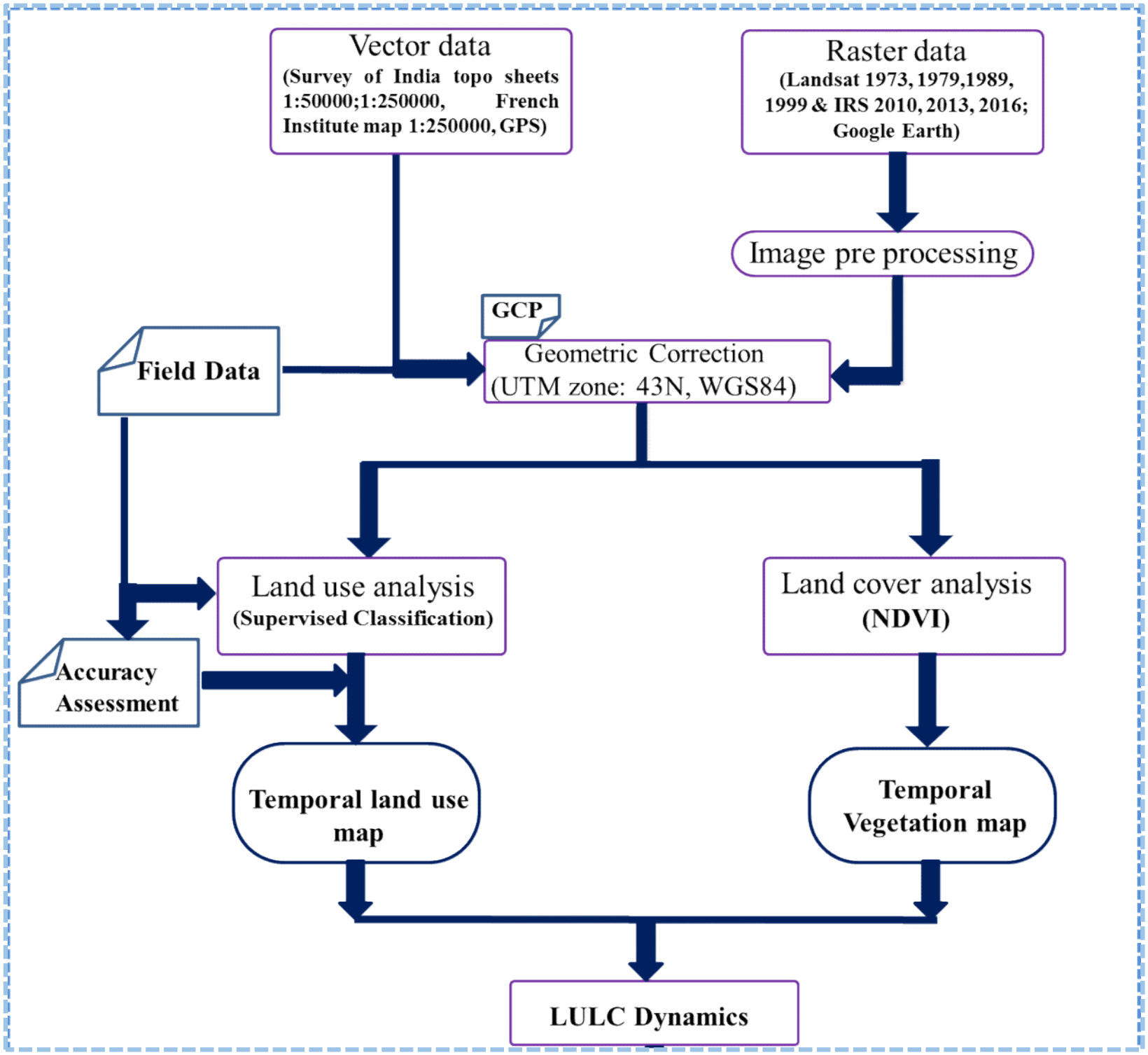
Field data collection



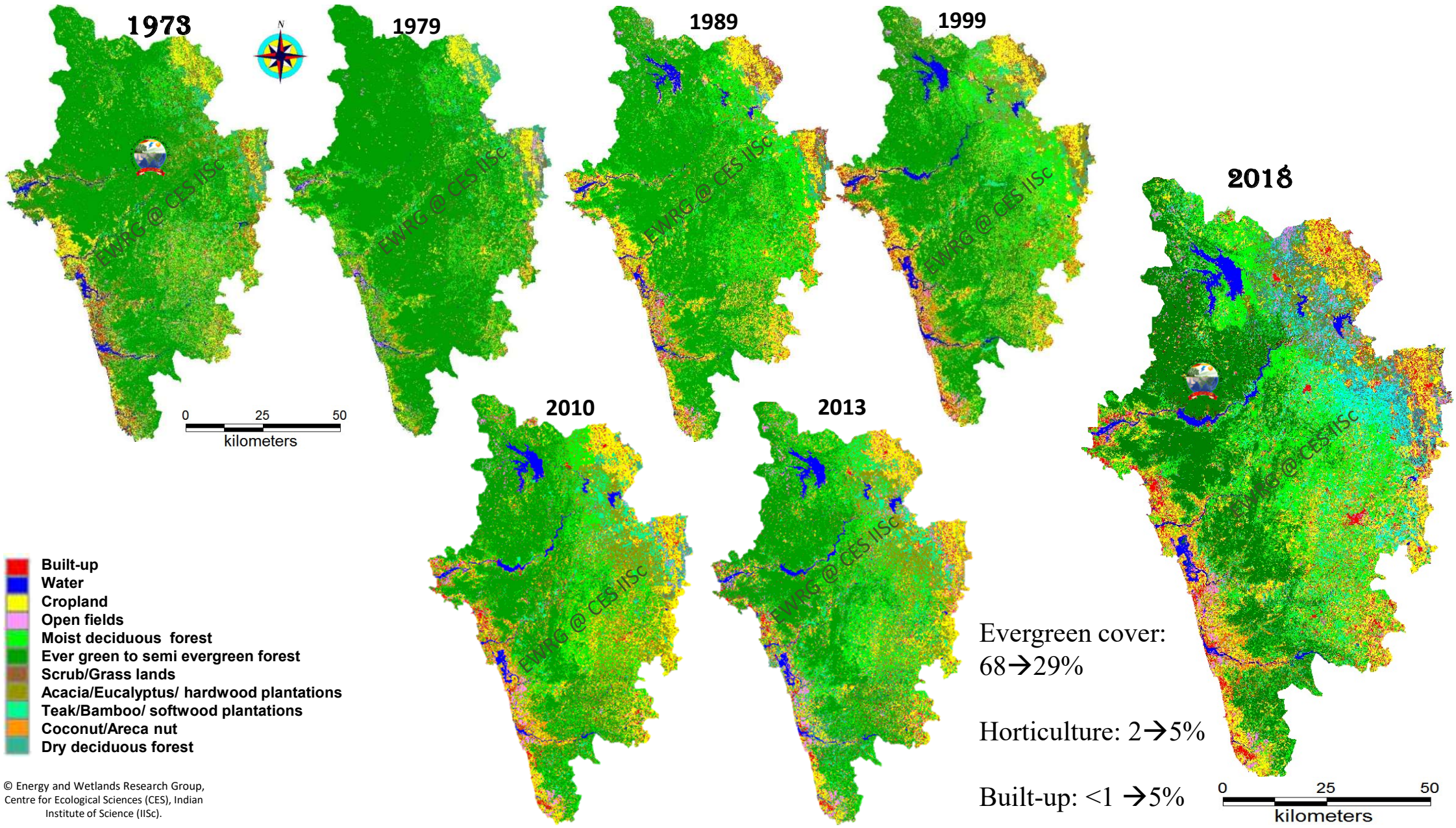







Vector data
(Survey of India topo sheets 1:50000;1:250000, French Institute map 1:250000, GPS)
Raster data
(Landsat 1973, 1979,1989, 1999 & IRS 2010, 2013, 2016; Google Earth)
Image pre processing
GCP
Field Data
Geometric Correction
(UTM zone: 43N, WGS84)
Land use analysis
(Supervised Classification)
Land cover analysis
(NDVI)
Accuracy Assessment
Temporal land use map
Temporal Vegetation map
LULC Dynamics

Landscape dynamics-Uttara Kannada



YEAR & FOREST COVER

1973 83.17 %

1979 75.87 %

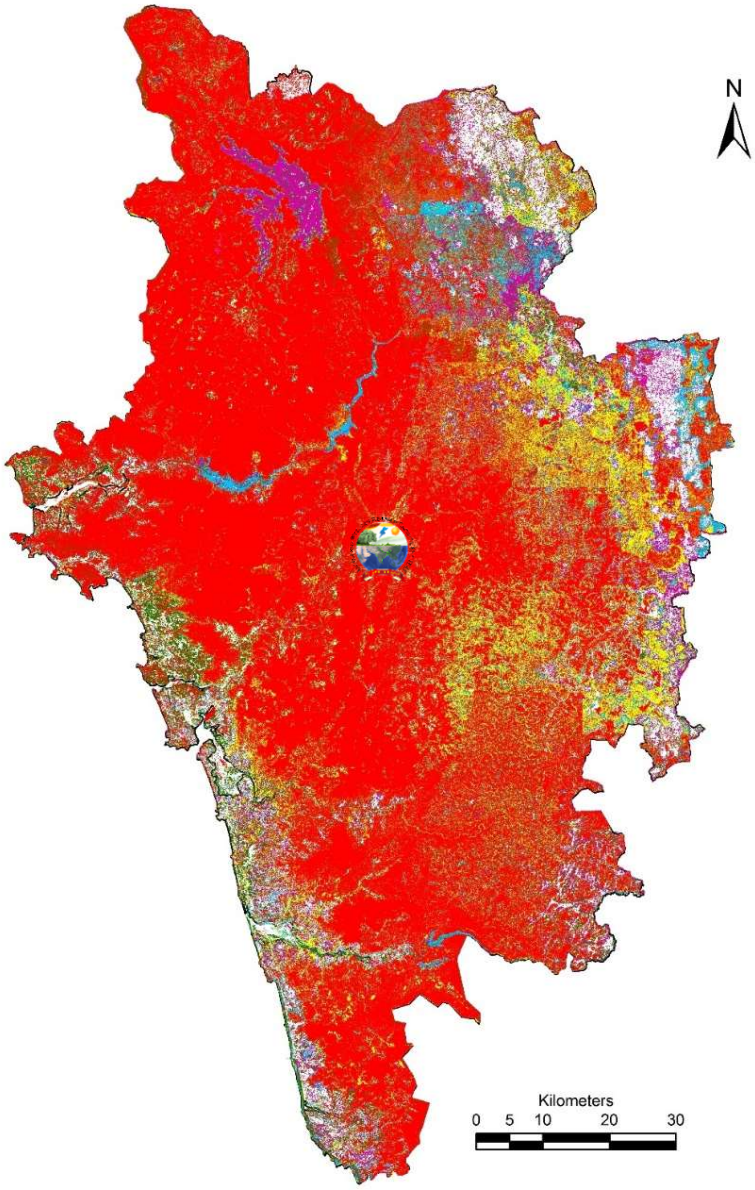
1989 71.3%

1999 63.93%

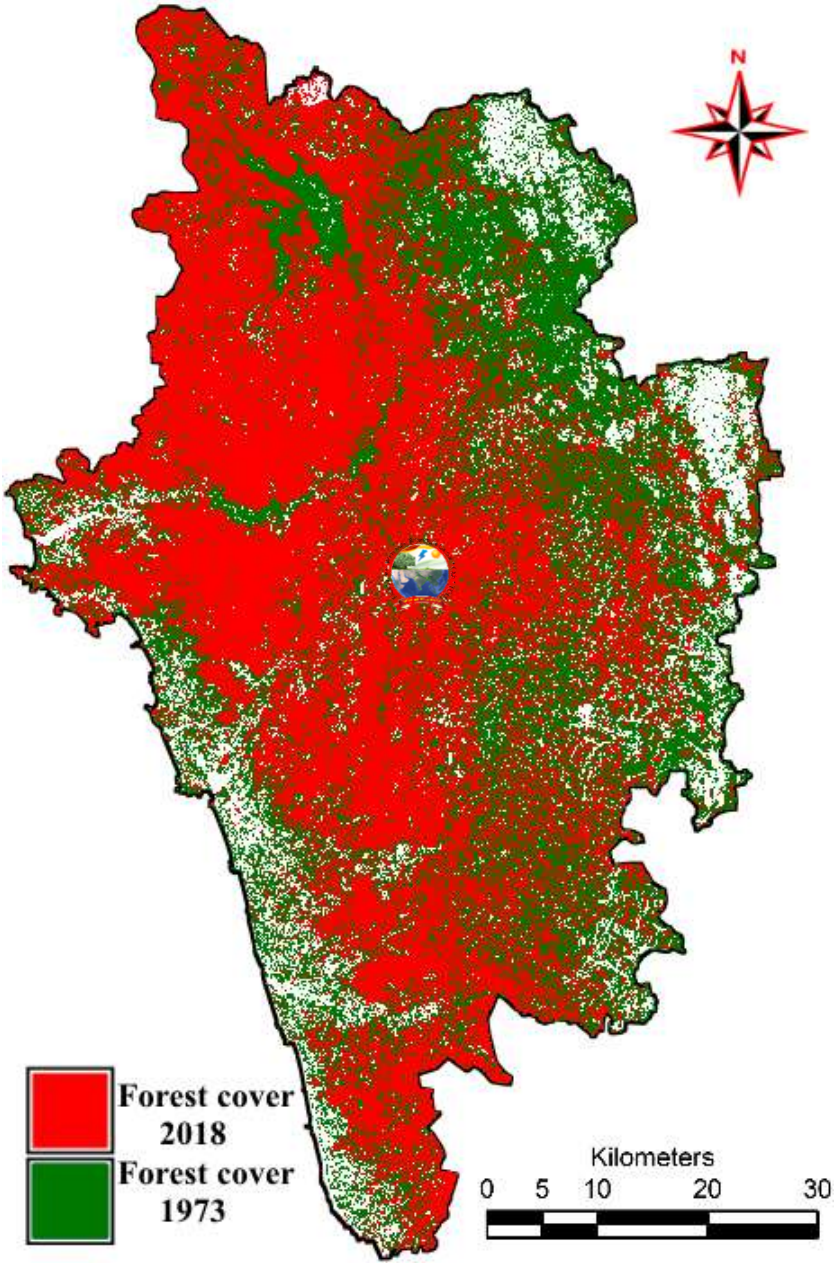
2010 56.12%

2013 52.71%

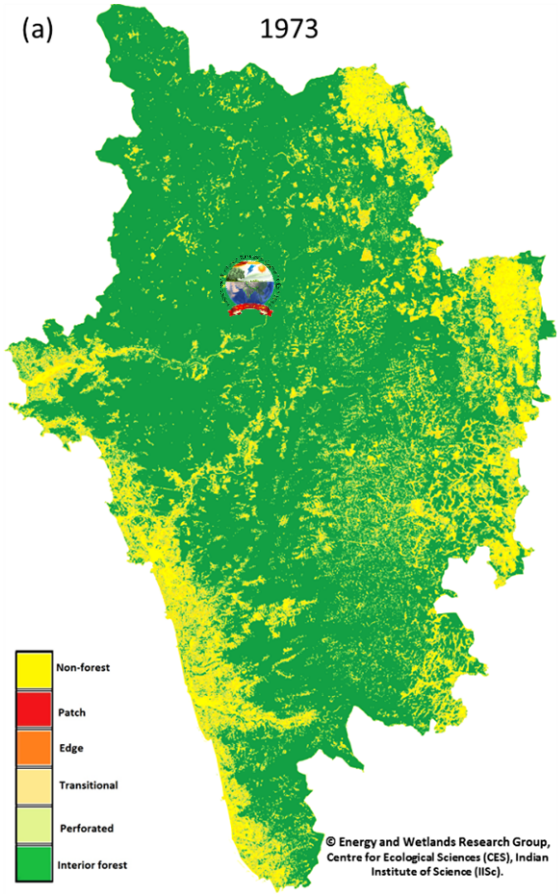
2018 50.22%

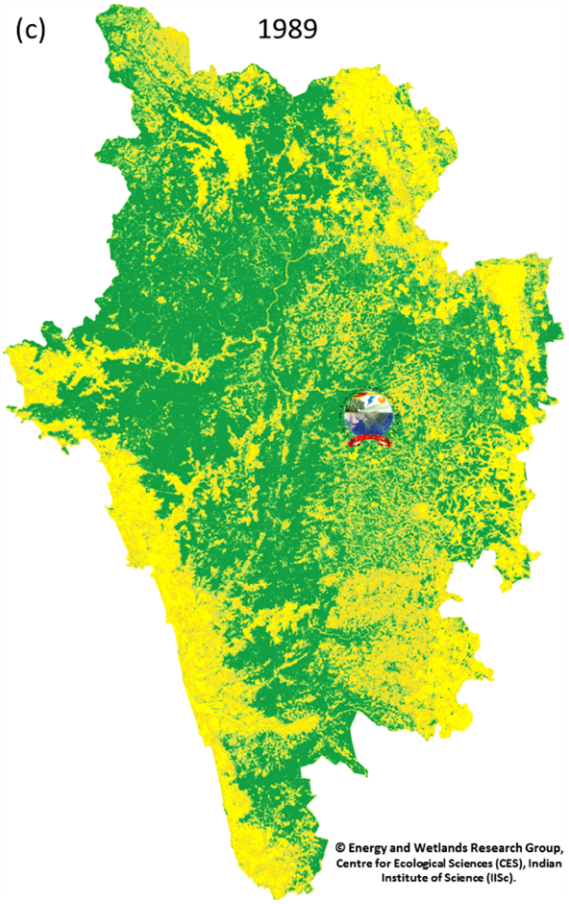


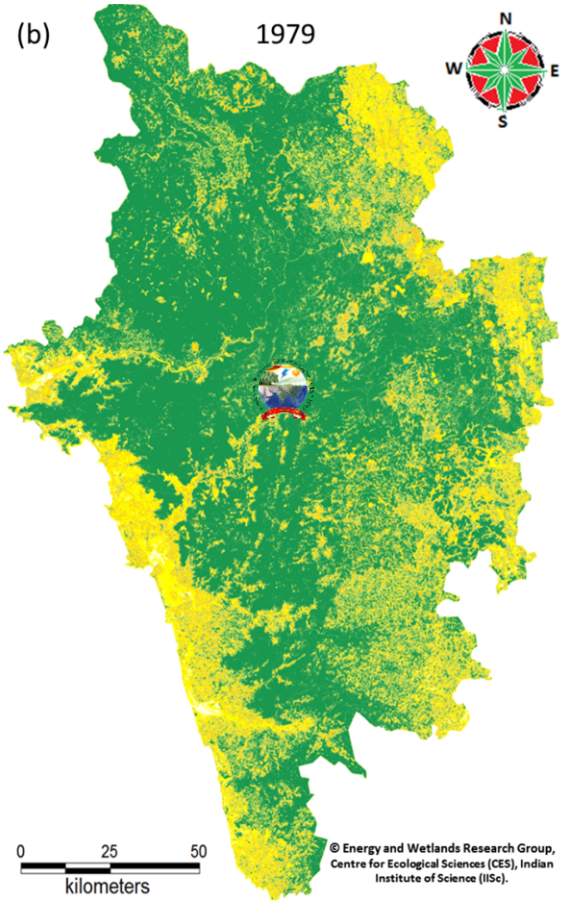
Forest cover loss→ 32.9%
(1973 to 2018)

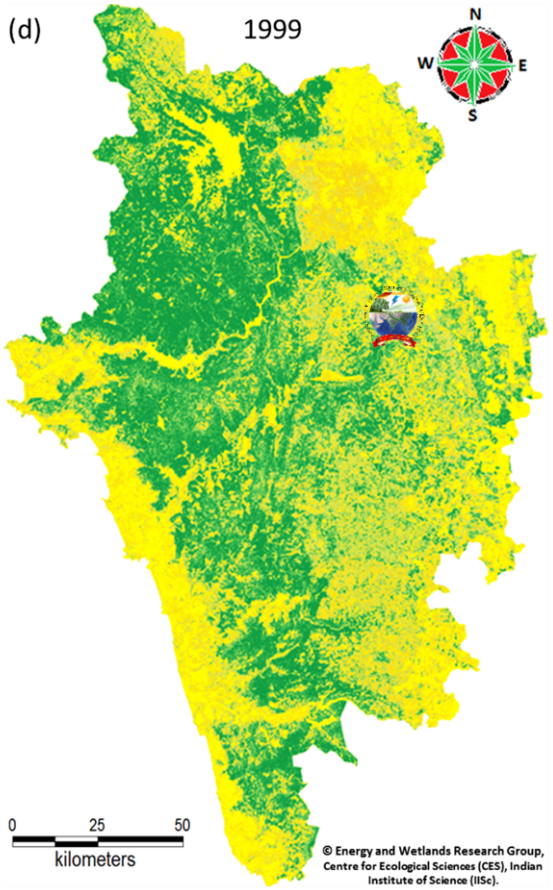


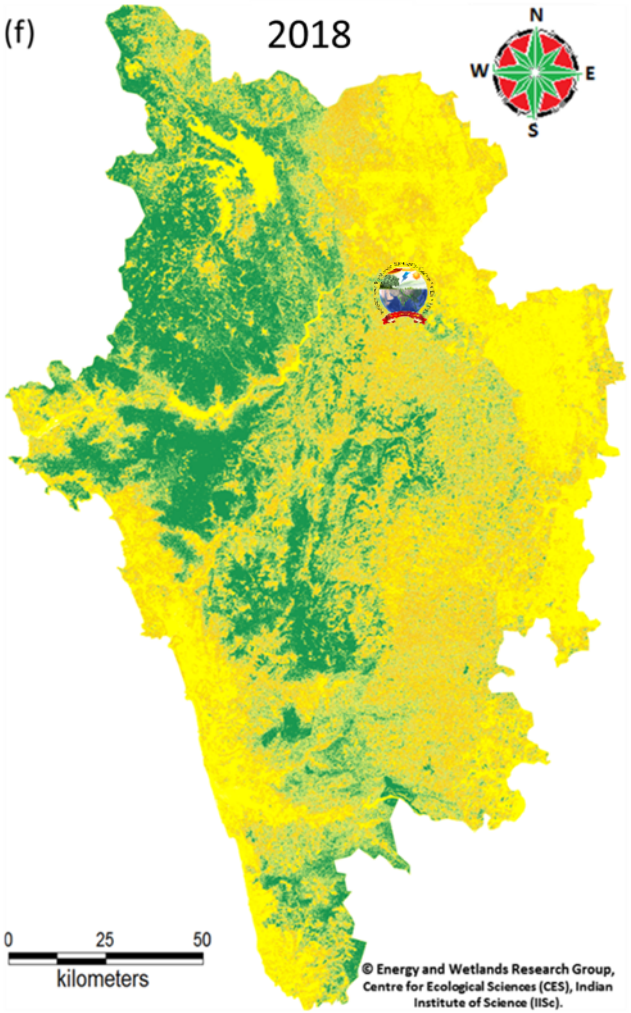
Temporal forest Fragmentation

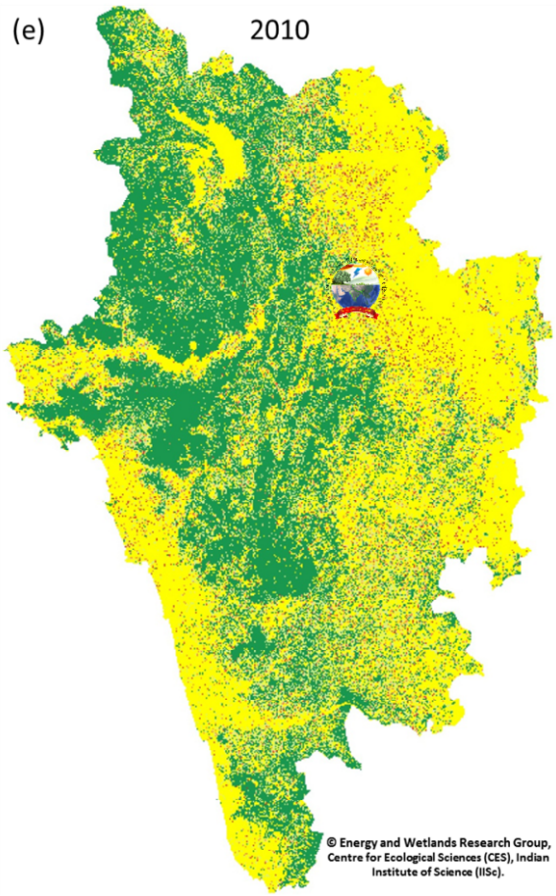


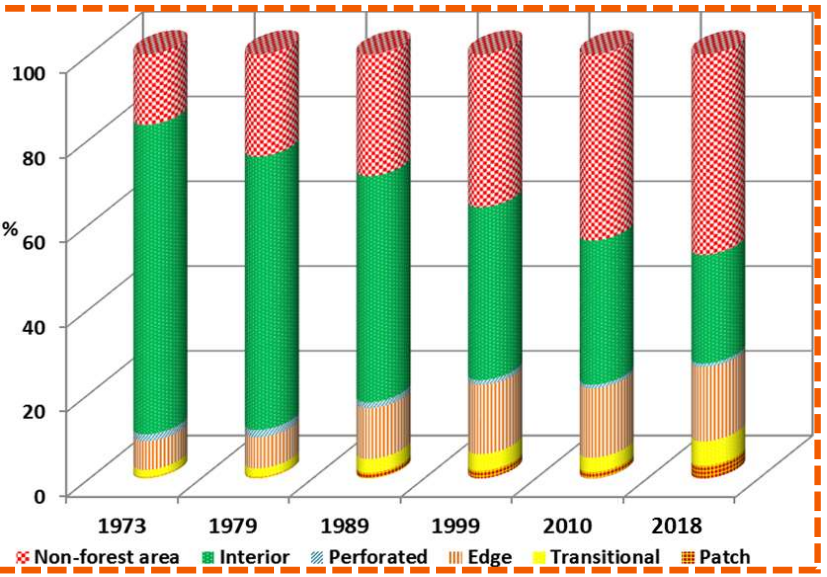






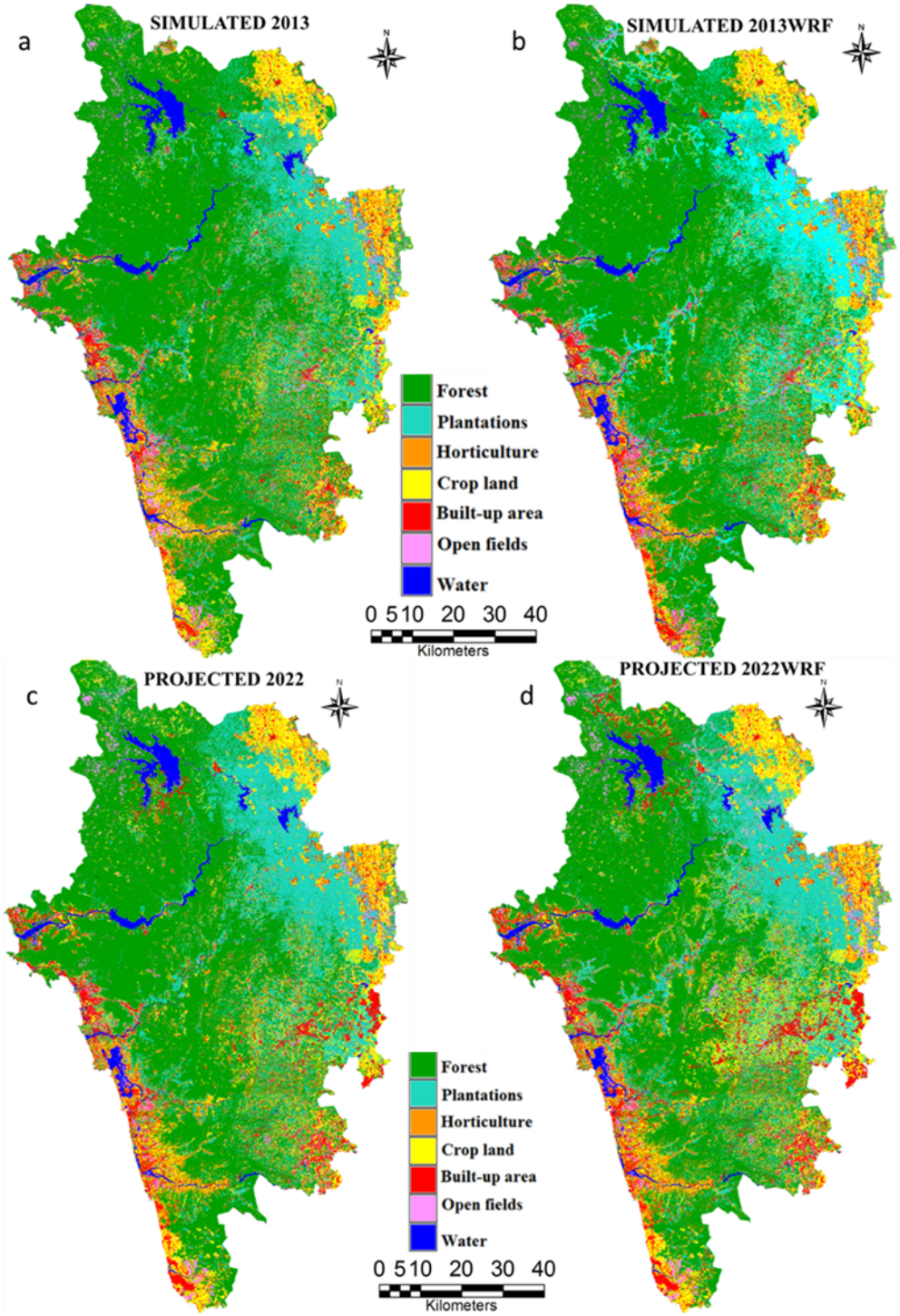






Interior forest cover lost from 73 to 23% (1973-2018)

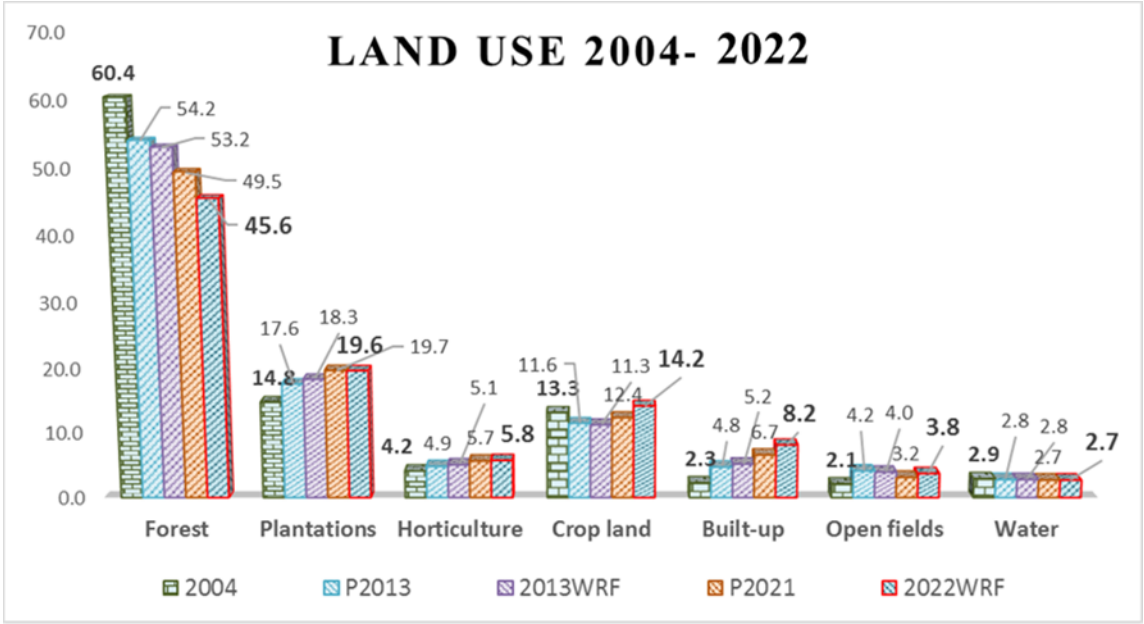
Modelling Landscape dynamics



Modelled LU change under two scenarios

1→ With Reserve Forest Protection

2→ Without Reserve Forest Protection



Valuation of Ecosystems Goods & Services

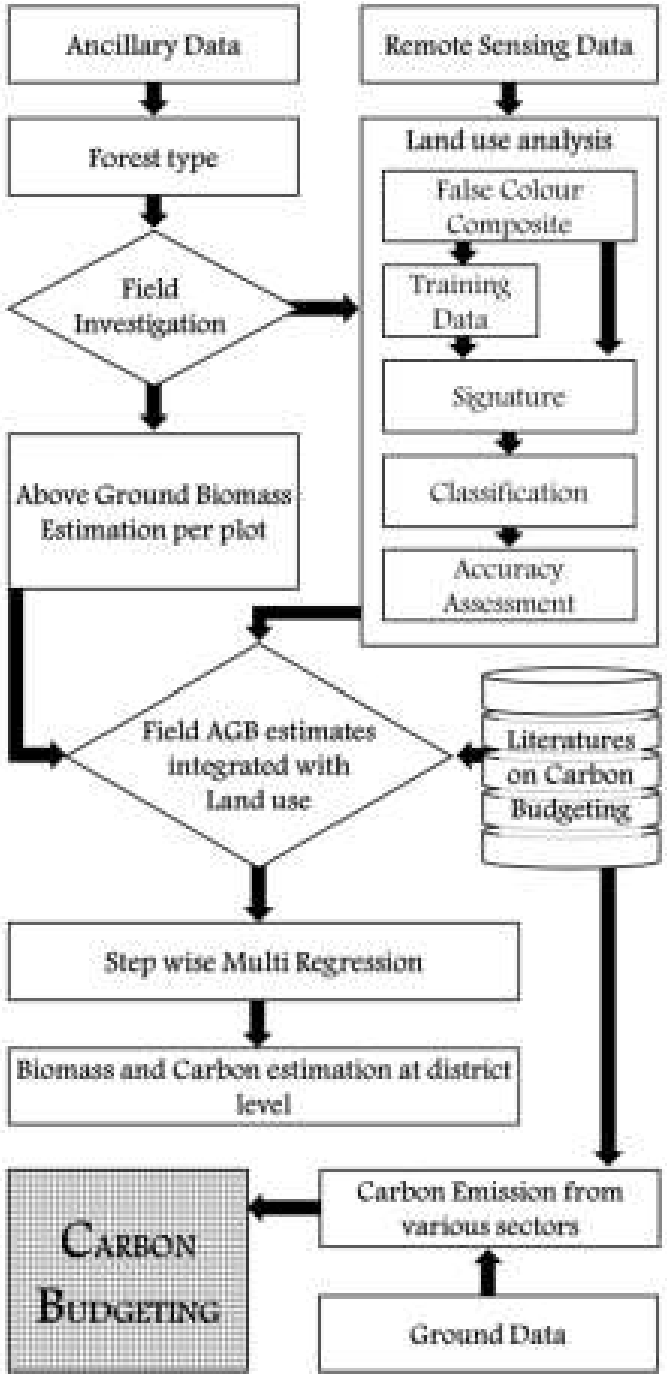
- Forests

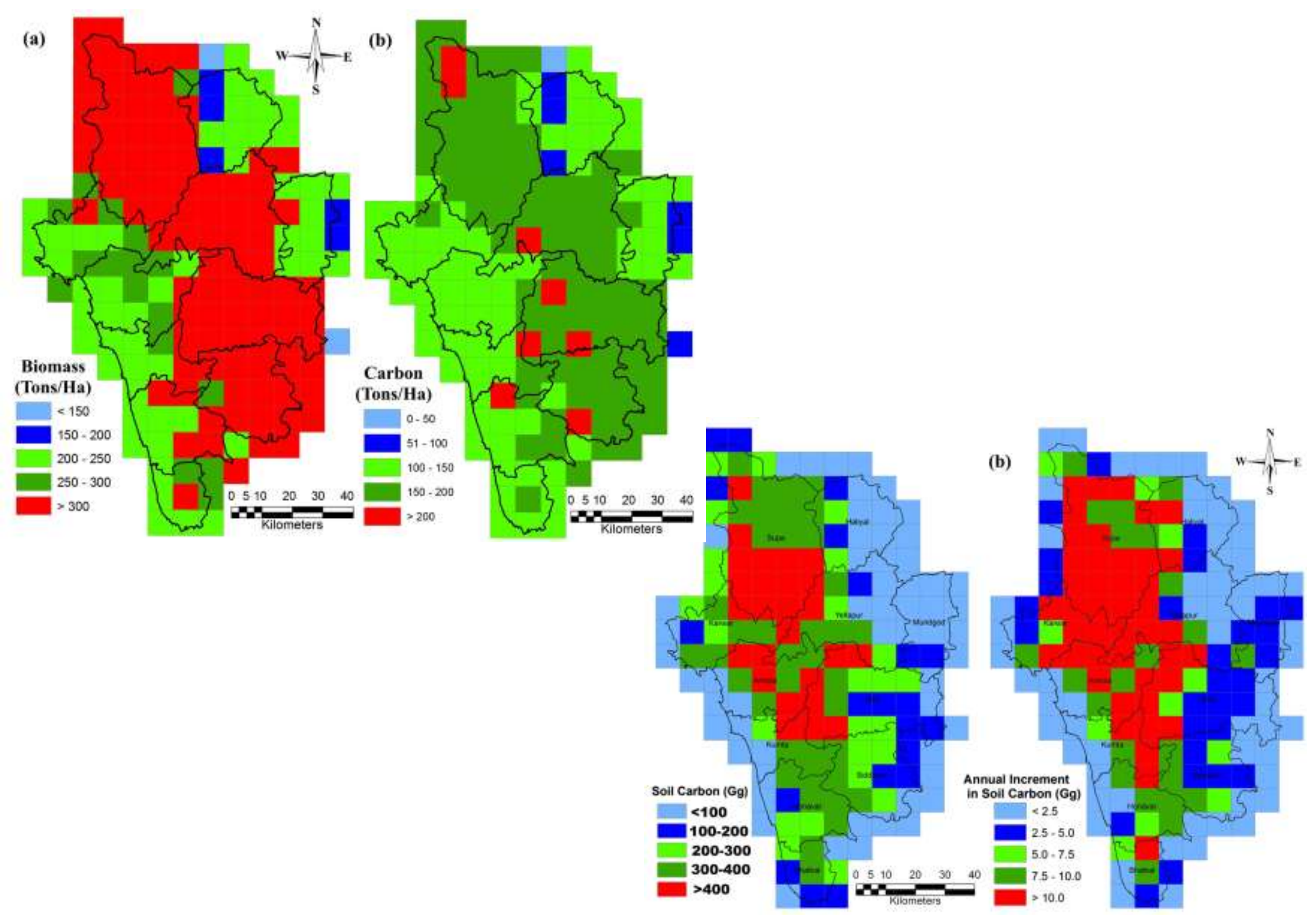
- Estuarine Ecosystem

Estimation of Carbon Sequestration

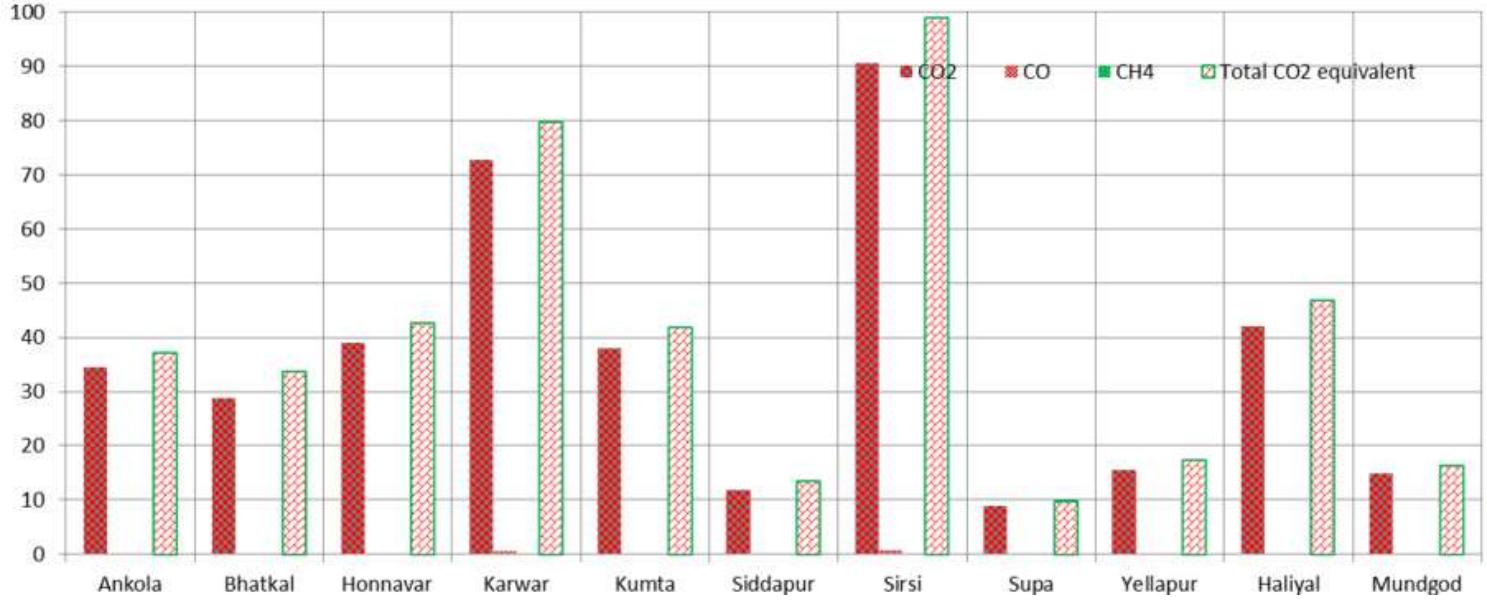
- Girth and height of trees across various forest types were measured.
- Above Ground Biomass, Below Ground Biomass, Carbon, Soil organic carbon were estimated using field measurements and standard literature.

Index	Equation	Significance	Region applied
Basal area (BA) (m^2)	$(DBH)^2/4\pi$	To estimate basal area from DBH values	All
Biomass (T/Ha)	$(2.81 + 6.78 \times BA)$	Effective for semi evergreen, moist deciduous forest cover types and having moderate rainfall	Coastal
Biomass (T/Ha)	$(21.297 - 6.953(DBH)) + 0.740(DBH^2)$	Effective for wet evergreen, semi evergreen forest cover types and having higher rainfall)	Sahyadri interior
Biomass (T/Ha)	$exp\{-1.996 + 2.32 \times \ln(DBH)\}$	Effective for deciduous forest cover types and having lower rainfall	Plains
Carbon stored (T/Ha)	(Estimated biomass) × 0.5	Sequestered carbon content in the region by forests	All
Annual increment in biomass (T/Ha)	(Forest cover) × 6.5	Incremental growth in biomass [49, 50]	Coastal
	(Forest cover) × 13.41		Sahyadri
	(Forest cover) × 7.5		Plains
Annual increment in carbon (T/Ha)	(Annual increment in biomass) × 0.5	Incremental growth in carbon storage	All
Net annual biomass productivity (T/Ha)	(Forest cover) × 3.95	Used to compute the annual availability of woody biomass in the region [49, 50]	Coastal
	(Forest cover) × 5.3		Sahyadri
	(Forest cover) × 3.5		Plains
Carbon sequestration of forest soil (T/Ha)	(Forest cover) × 152.9	Carbon stored in soil [57]	Coastal
	(Forest cover) × 171.75		Sahyadri
	(Forest cover) × 57.99		Plains
Annual increment of soil carbon	(Forest cover) × 2.5	Annual increment of carbon stored in the soil	All

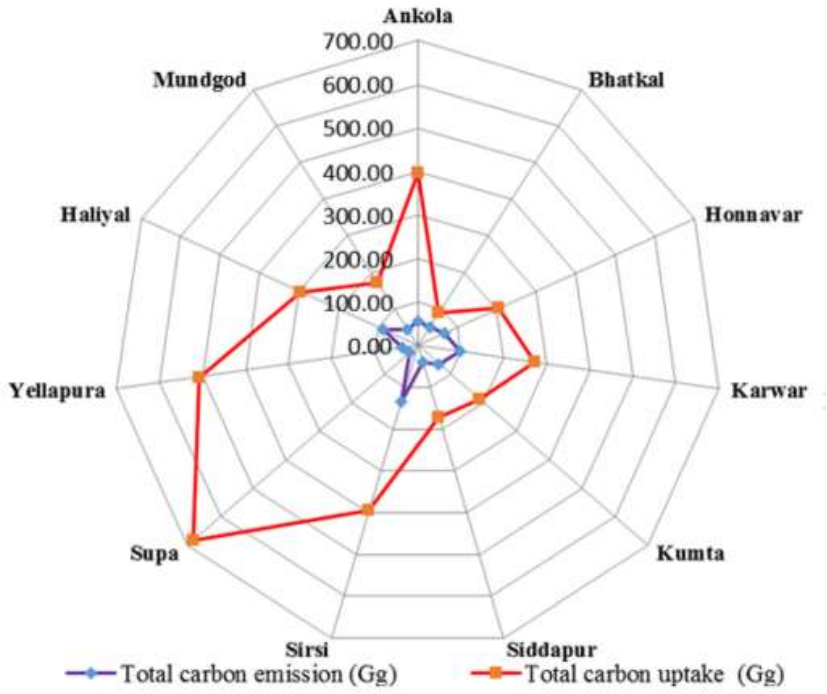



(a)
N
W
E
S
Biomass
(Tons/Ha)
< 150
150 - 200
200 - 250
250 - 300
> 300
0 5 10 20 30 40
Kilometers
(b)
Carbon
(Tons/Ha)
0 - 50
51 - 100
100 - 150
150 - 200
> 200
0 5 10 20 30 40
Kilometers
Soil Carbon (Gg)
<100
100-200
200-300
300-400
>400
0 5 10 20 30 40
Kilometers
(b)
N
W
E
S
Annual Increment
in Soil Carbon (Gg)
< 2.5
2.5 - 5.0
5.0 - 7.5
7.5 - 10.0
> 10.0

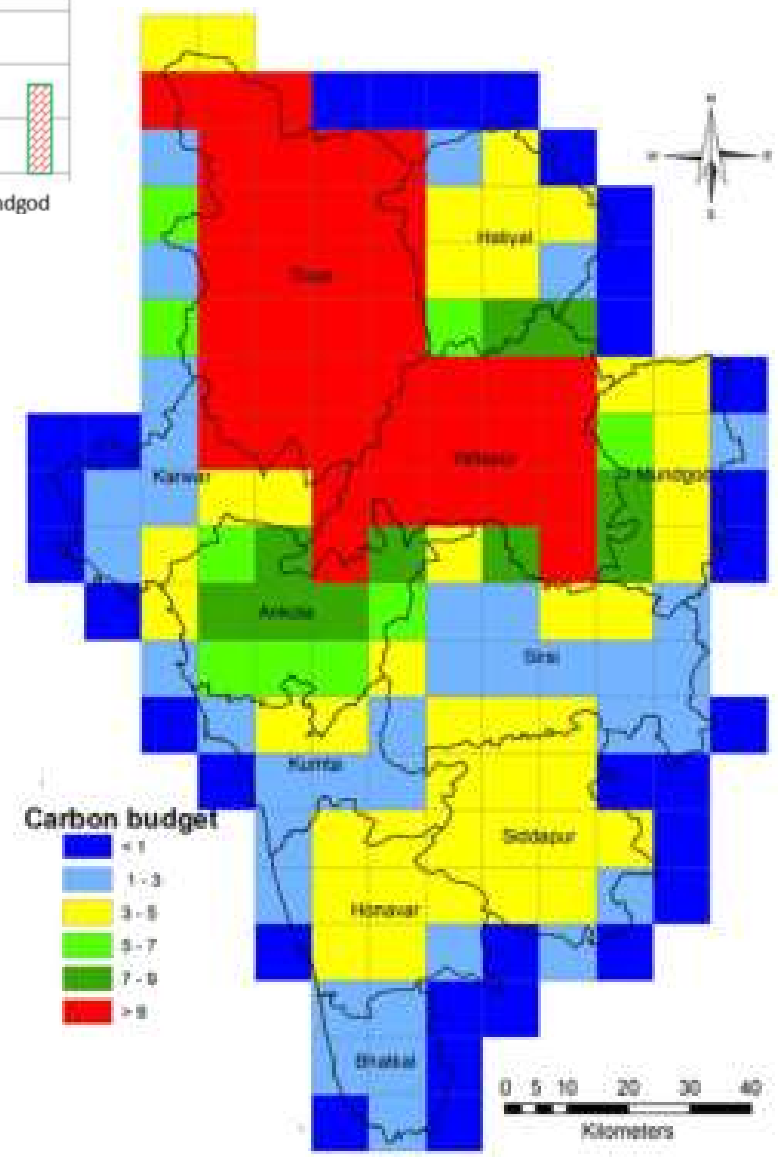
Carbon Emission from transport



Carbon Uptake Vs Emission



Carbon Budget



The Progress: July-August 2019

Ecosystem condition indicators

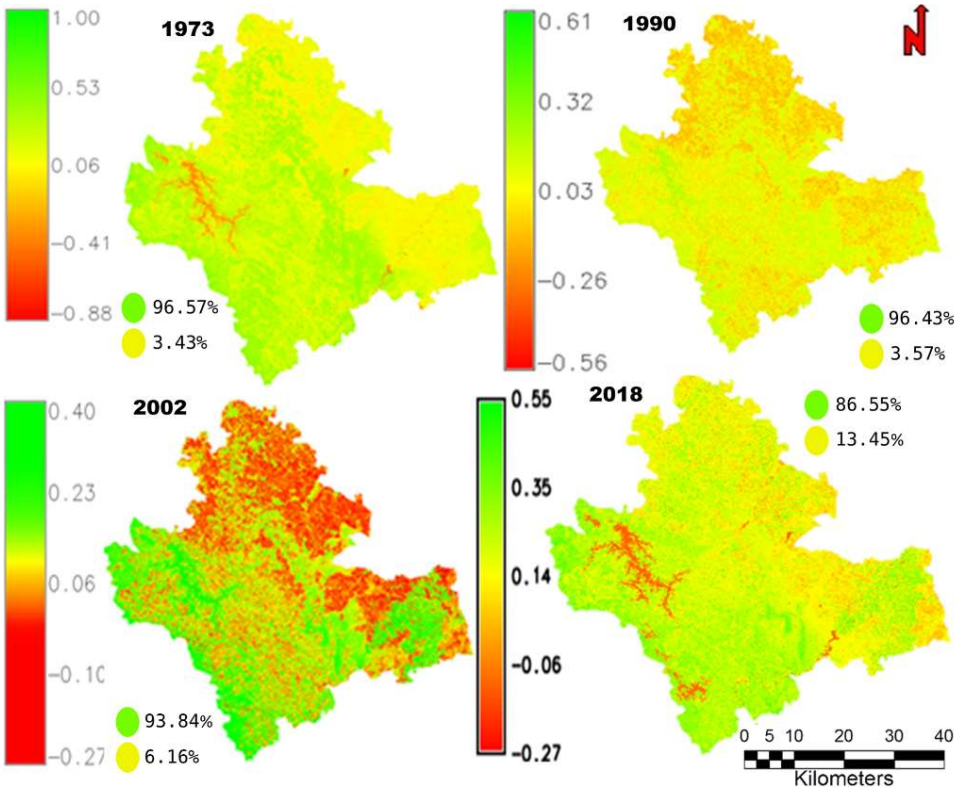
ECI class and subclasses
I. Species-based indicators (compositional characteristics) • birds • trees • fish • *…other relevant species groups*
II. Vegetation and biomass (structural characteristics) • tree cover (density / biomass) • shrub cover • litter • pelagic (chlorophyll, phytoplankton etc) • *…other relevant vegetation layers*
III. Ecosystem processes (functional characteristics) • disturbance intensity (fire, flood…) • *… other relevant ecosystem processes*
IV. Physical and chemical state (abiotic characteristics) • air • soil • water • *…other relevant (abiotic) ecosystem compartments*
V. Landscape pattern (landscape-level characteristics)

Ecosystem Indicators	Approach
Natural - Terrestrial	
Landscape level spatial patterns	• Land use land cover analyses using temporal remote sensing data [Geographical Resource Analysis Support System (GRASS); Quantum (Q) GIS] • Landscape metrics (# of Patches, edge density, normalized landscape shape index, Aggregation index, etc.) • Forest Fragmentation • Visualisation of land cover in 2025 – using AHP, Markov CA • Land surface temperature (during 2008-2019)
Species based indicators	• Distribution of flora and fauna, • Species – estuarine ecosystem • IUCN status • Local hotspots of biodiversity • Protected areas and national parks • Sacred groves and heritage area / site

Vegetation	• **Density and cover,** • **Standing biomass,** • **biomass productivity** • **Carbon sequestration – potential** • **Annual increment of carbon**
Ecosystem processes	• Eco-hydrologic indices • Soil erosion
Physical and Chemical State	• Soil carbon • Pollution • Energy (Renewable energy potential) • Grazing intensity • Eco-sensitive regions (@5’ x 5’ grids corresponding to a panchayath)
Social	• Population density • Livestock density
Geo-climatic	• Spatial patterns and trend of precipitation (@ 25 km interval) • Number of Rainy days • Spatial patterns and trend of temperature

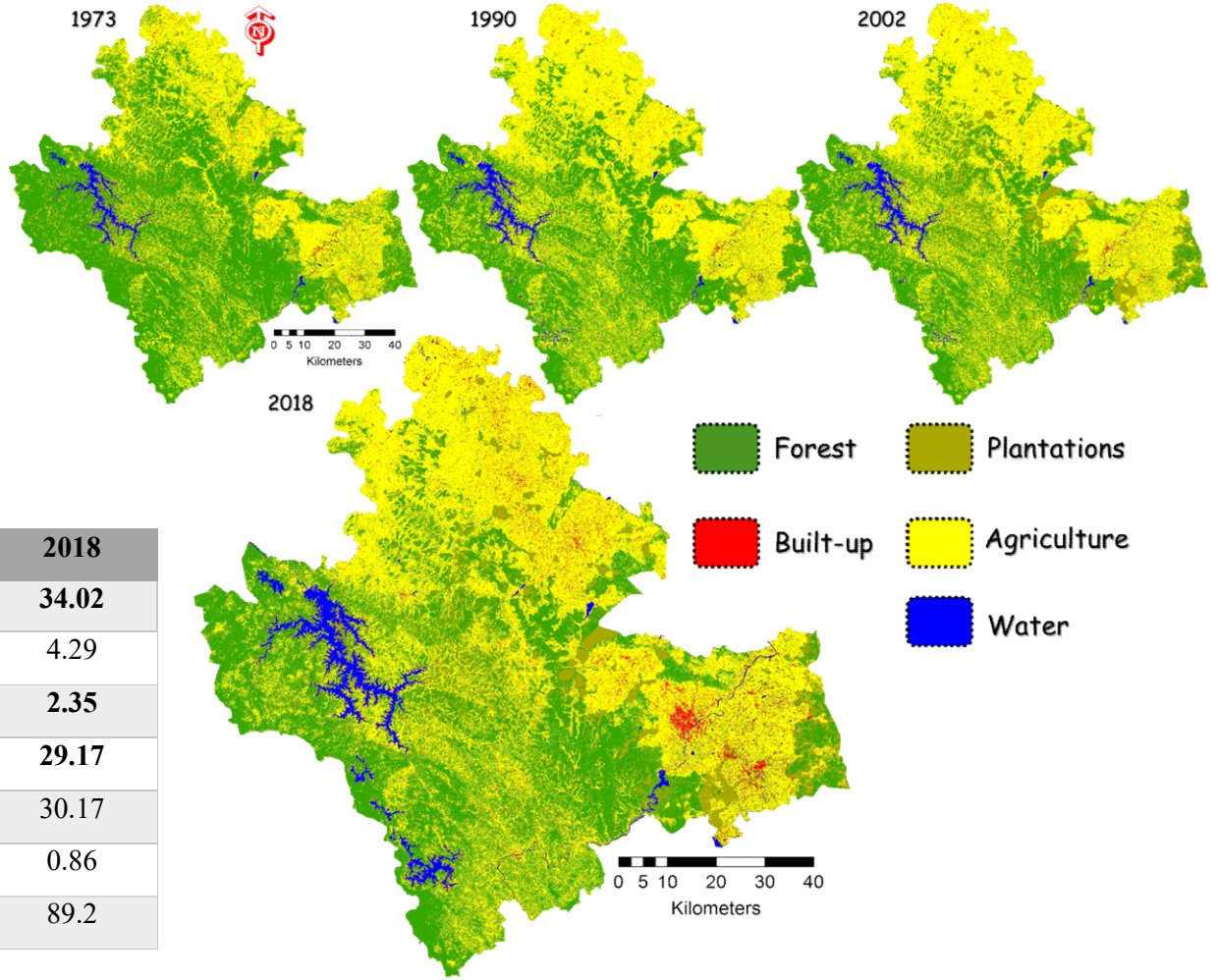
Natural - Aquatic Ecosystem	**Catchment yield** **Fuel wood and fodder** **Species diversity** **Productivity (estuarine system)**
Anthropogenic Systems • **Agriculture** • **Horticulture** • **Aquaculture**	 Crop type, production, yield Crop type, production, yield Yield

Landscape Dynamics - Shimoga



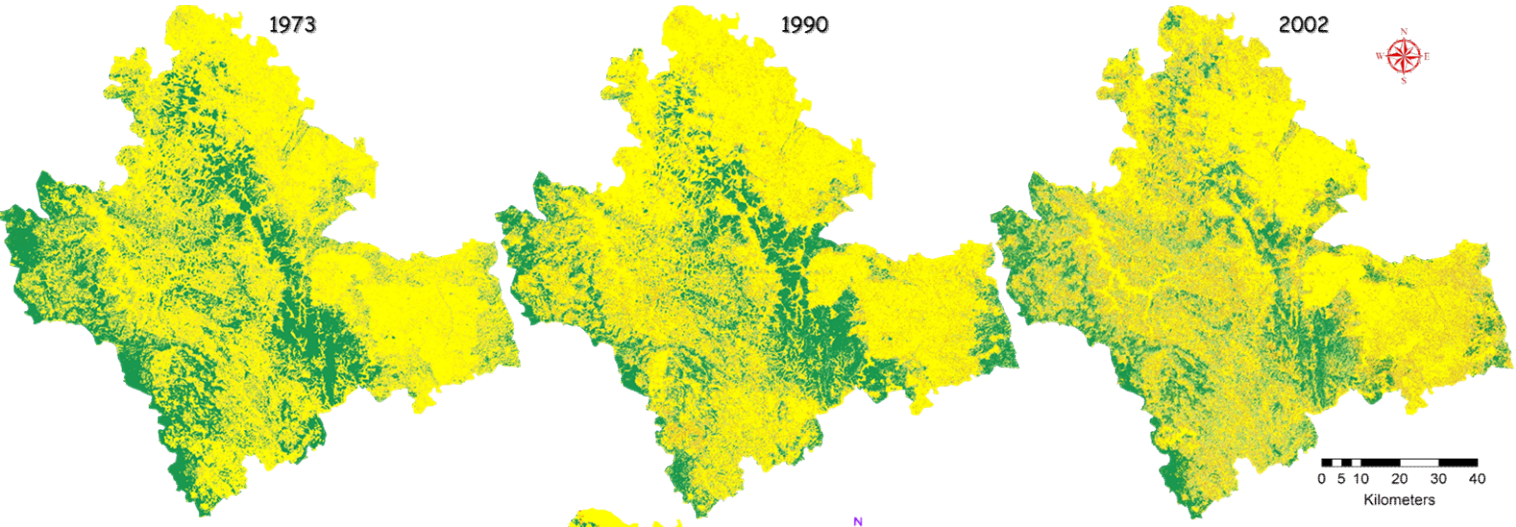
Loss of forest cover from **44 to 34 %** (1973-2018)

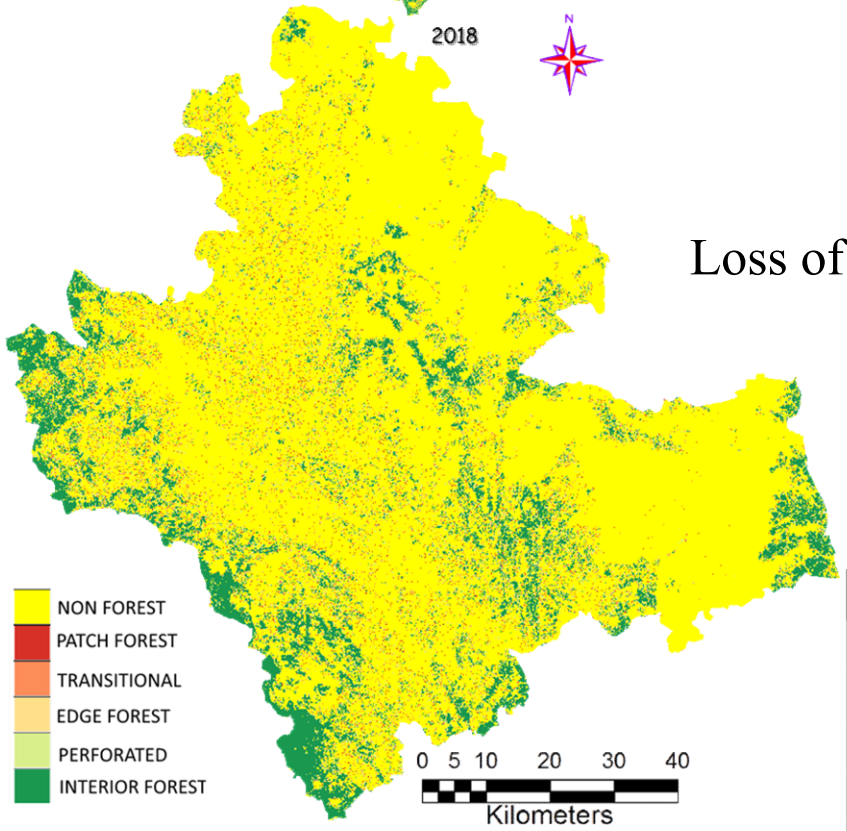
Increase in Plantation from **9 to 29%**



Year/ Category (%)	1973	1990	2002	2018
Forest	**43.83**	39.90	37.78	**34.02**
Water	1.91	4.53	4.57	4.29
Built-up	**0.63**	0.74	1.08	**2.35**
Plantation	9.46	25.15	26.36	**29.17**
Agriculture	44.14	29.68	30.21	30.17
Kappa coefficient	0.82	0.89	0.83	0.86
Overall Accuracy	74.68	86.31	92.23	89.2

Forest Fragmentation-Shimoga





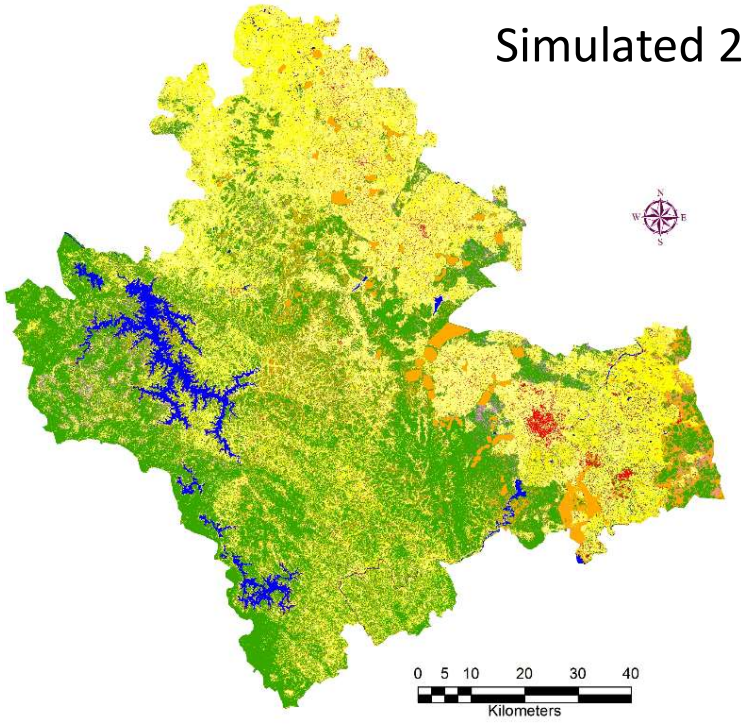
Loss of interior forest cover from **26 to 11 %** (1973-2018)

Increase in non-forest cover from **56 to 79%**

SNO	Category (%)	1973	1990	2002	2018
1	Interior Forest	**26.41**	21.04	17.02	**11.21**
2	Patch Forest	0.00	2.52	3.93	1.21
3	Transitional Forest	4.75	3.72	3.88	2.47
4	Edge Forest	5.27	1.21	0.86	2.02
5	Perforated Forest	7.61	9.33	11.00	4.19
6	Non-forest cover	**55.96**	62.17	63.31	**78.91**

Modelling Landscape dynamics

Simulated 2018



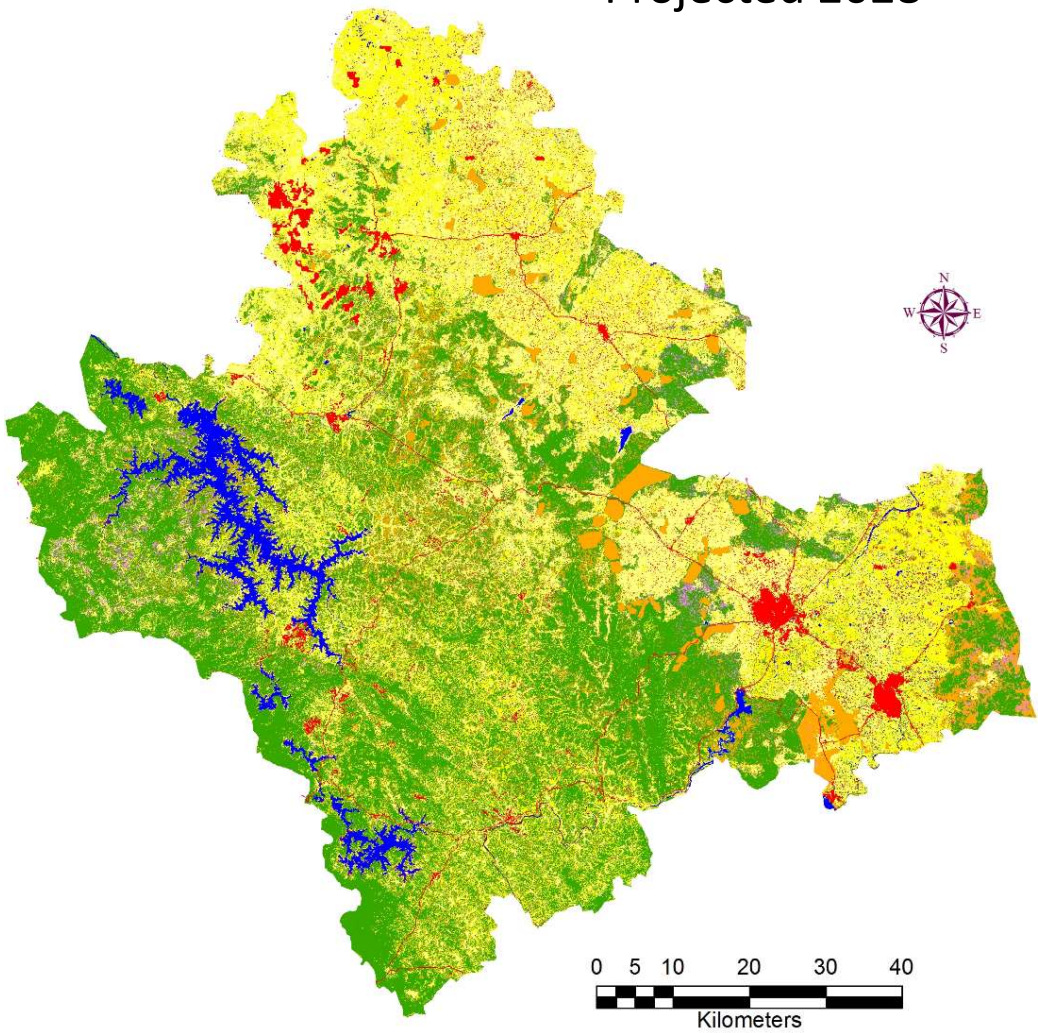
Accuracy→ 93 %

Loss of forest cover from **34 to 26 %**
(2018-2028)

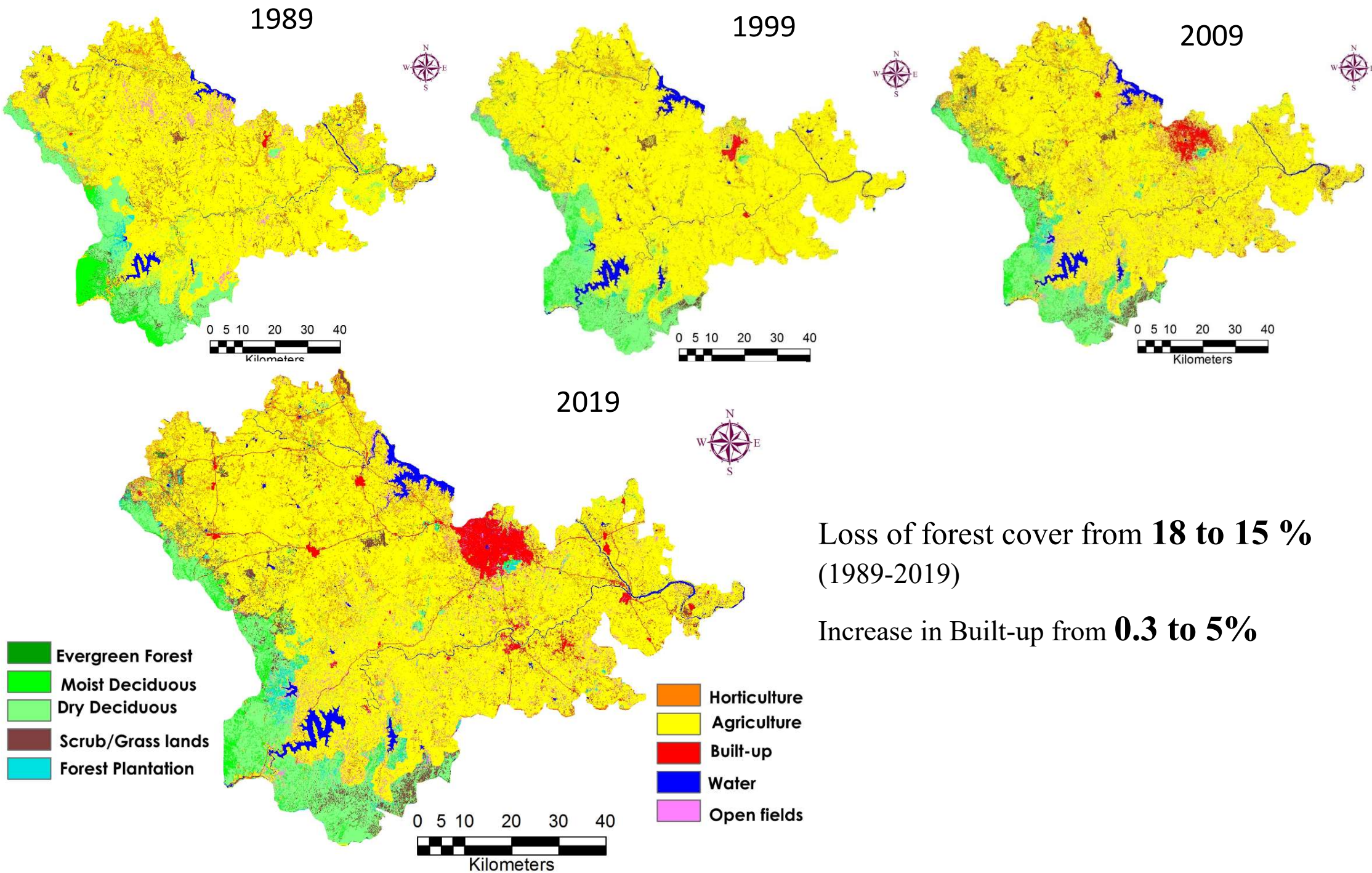
Increase in Built-up from **3 to 8%**

Modelled LU change using transition from 2002-2012; 2012-2018

Projected 2028



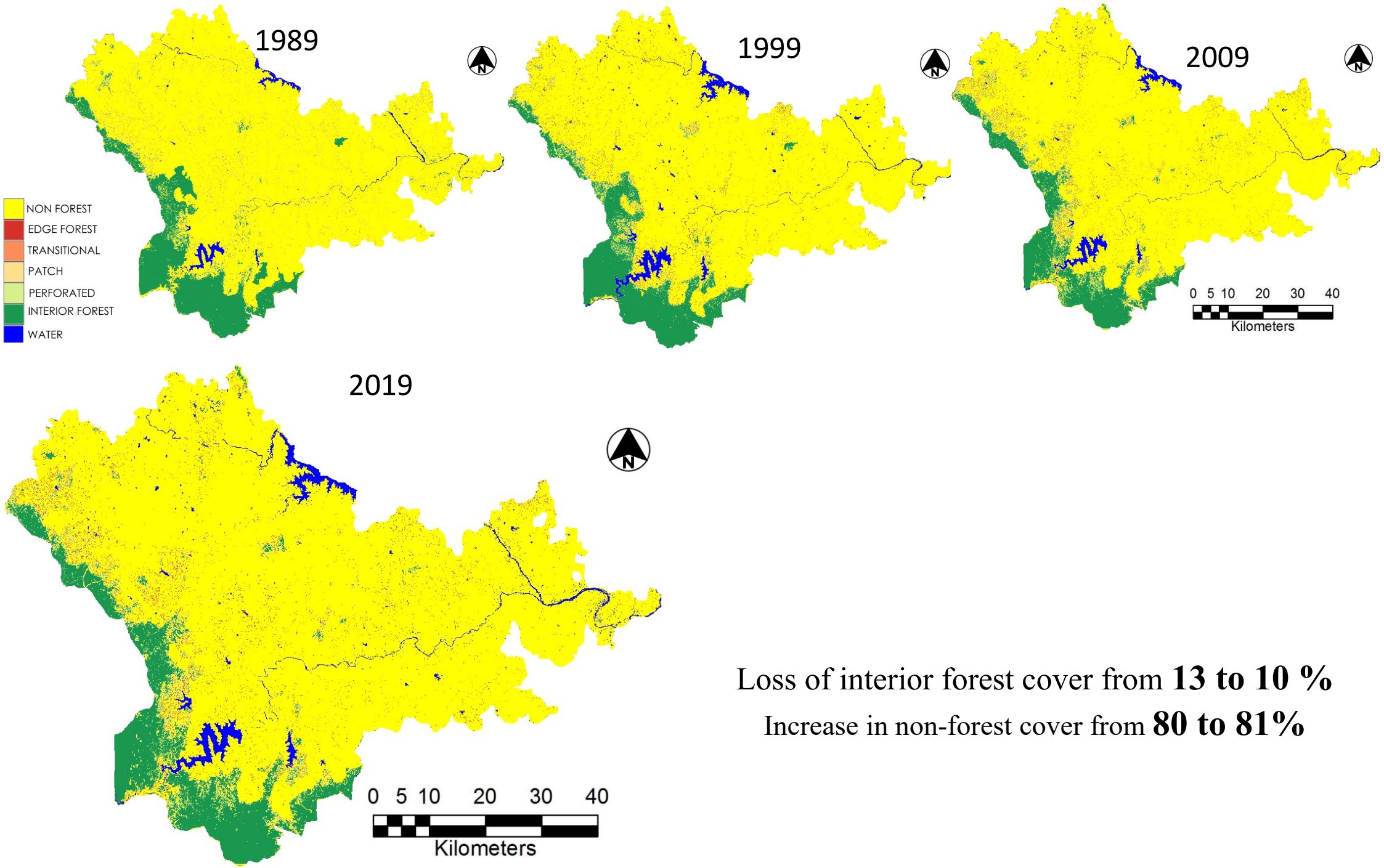
Landscape Dynamics - MYSORE



Loss of forest cover from **18 to 15 %** (1989-2019)

Increase in Built-up from **0.3 to 5%**

Forest Fragmentation-Mysore

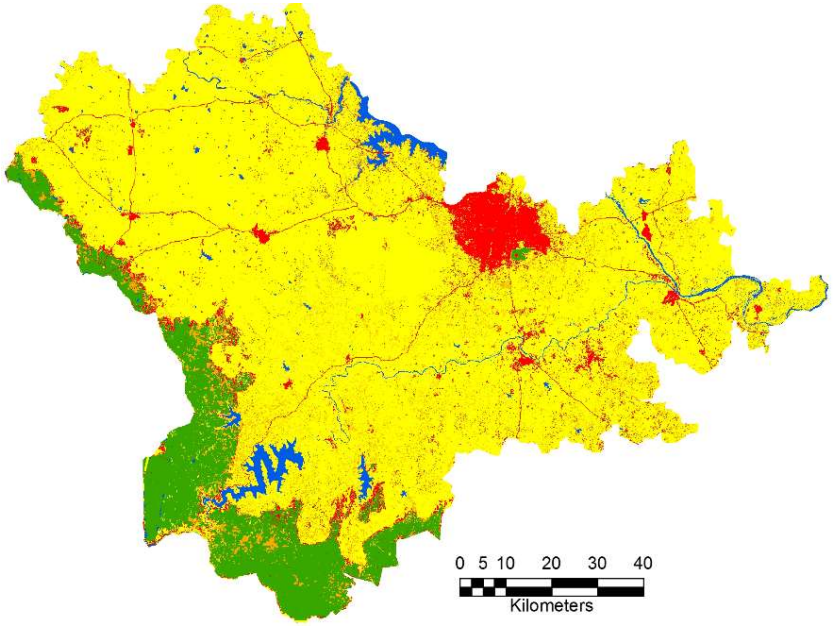


Loss of interior forest cover from **13 to 10 %**

Increase in non-forest cover from **80 to 81%**

Modelling Landscape dynamics

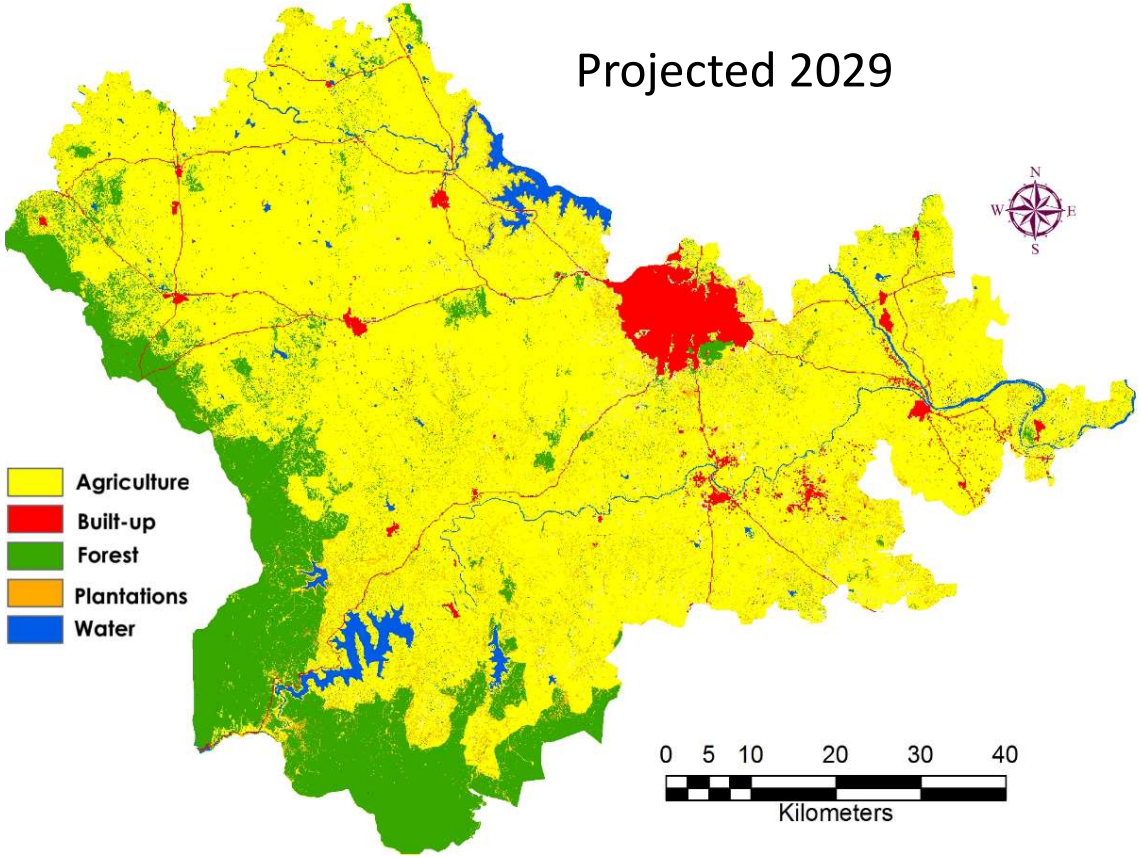
Simulated 2019



Accuracy→ 92.5 %

Modelled LU change using transition from 1999-2009; 2009-2019

Projected 2029



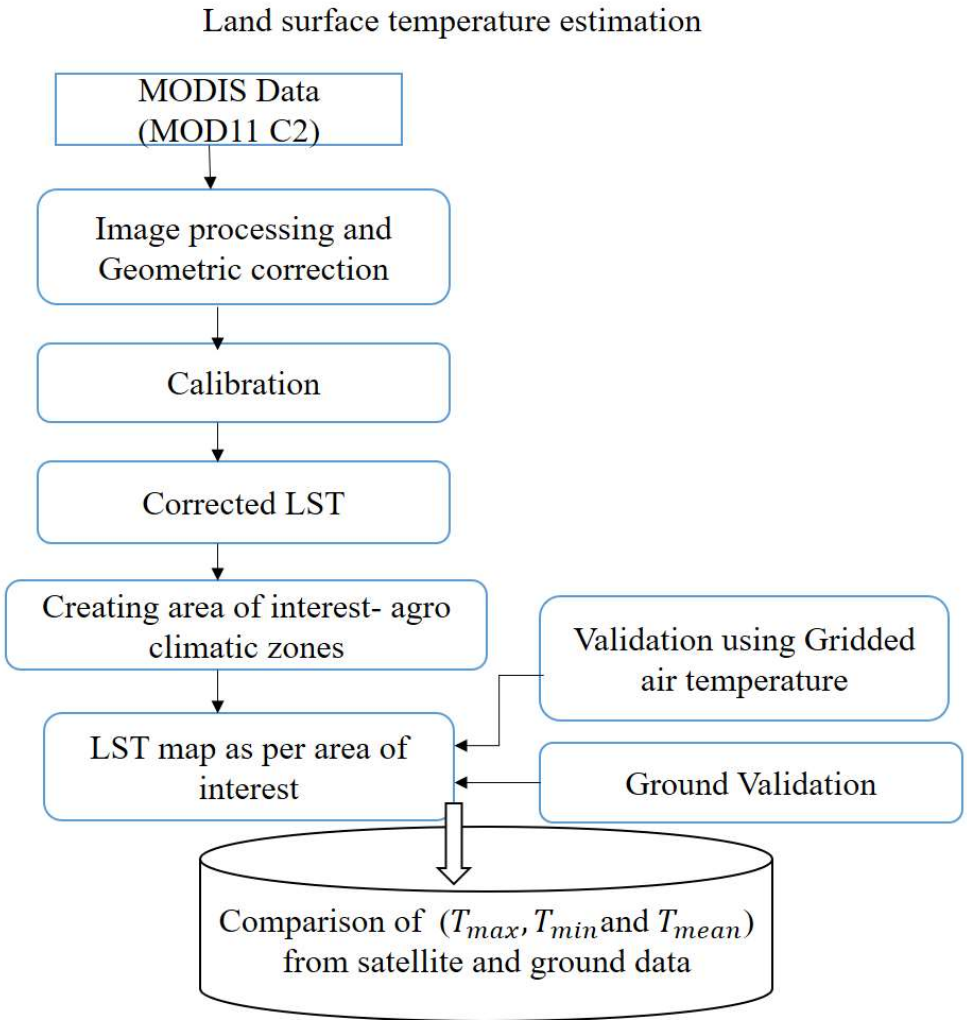
Loss of forest cover from **15 to 12 %** (2019-2029)

Increase in Built-up from **5 to 11%**

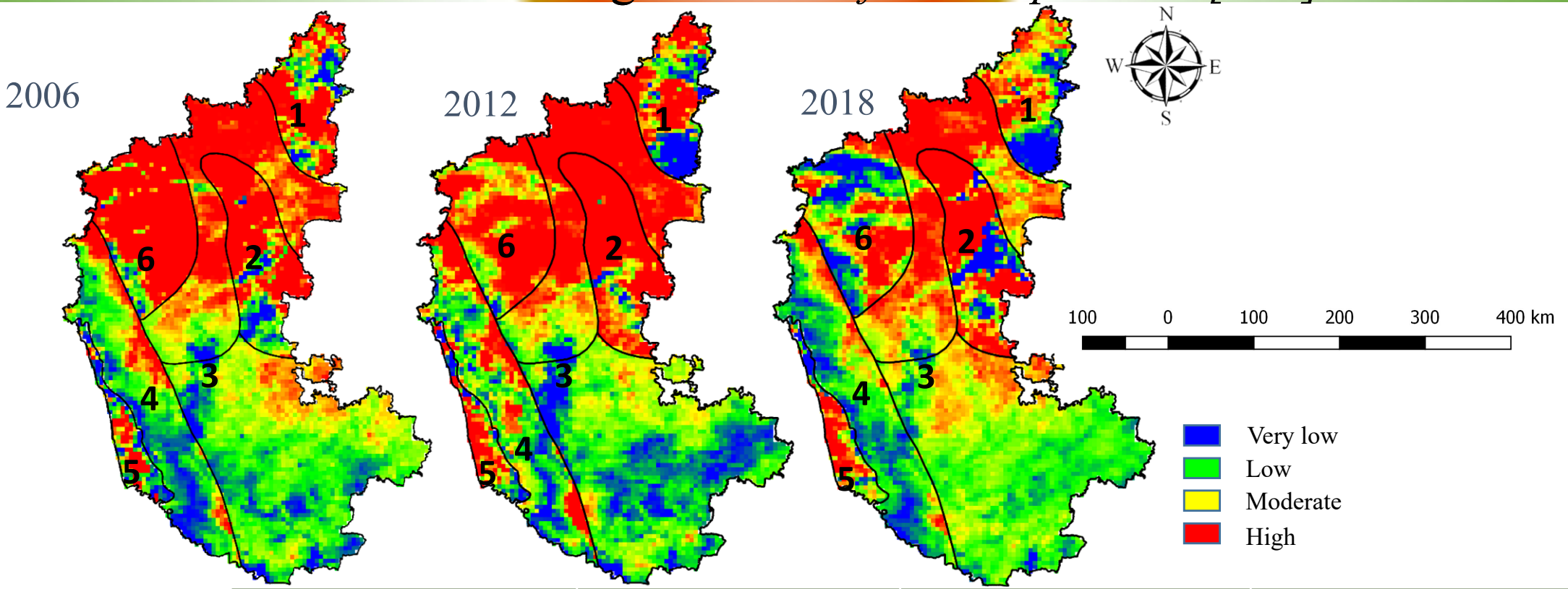
Regulating Services:
Local Climate through *Land Surface Temperature [LST]:*

Land surface temperature (LST) is the measure of the heat emission from land surface due to various activities associated with the land surface.

Land surface and atmospheric temperatures rise is enhanced by various anthropogenic activities, decreases in vegetation and water surfaces.



Regulating Services:
Local Climate through *Land Surface Temperature [LST]:*



Agro-climatic regions	2006			2012			2018		
	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max	**Mean**
Hot dry semi arid (1)	38.55	41.92	**40.24**	40.35	43.5	**41.925**	43.27	48.46	**45.865**
Arid (2)	33.57	38.08	**35.825**	29.39	33.88	**31.635**	37.21	41.25	**39.23**
Hot moist semi arid (3)	26.91	41.58	**34.245**	26.49	38.7	**32.595**	28.78	44.57	**36.675**
Hot moist sub humid (4)	22.85	32.38	**27.615**	21.53	27.3	**24.415**	27.11	38.31	**32.71**
Hot humid (5)	26.83	29.9	**28.365**	25.77	28.9	**27.335**	29.89	32.46	**31.175**
Hot dry sub humid (6)	32.49	35.92	**34.205**	29.33	39.08	**34.205**	38.11	45.68	**41.895**

II. Services supply accounts for Karnataka as per the SEEA-EEA technical guide

- Assess and compile available data for the biophysical modeling of a suite of ecosystem services (forest, agriculture, livestock, etc.); on the basis of the data availability and limitations, refine the list of services and method for the analysis;
- Biophysical modeling of the selected ecosystem services, using either existing modeling platforms based on our in house constructed models; extrapolation of existing studies; the modeling will result in maps of individual ecosystem services
- Integrate the resulting maps with the extent accounts (based on LULC dynamics analyses) in order to compile a set of ecosystem service supply accounts that detail the amount of services supplied by main ecosystem types;
- Documentation of the protocol with the significant outcome of the study.

III. Valuation of the modeled ecosystem services and ecosystems

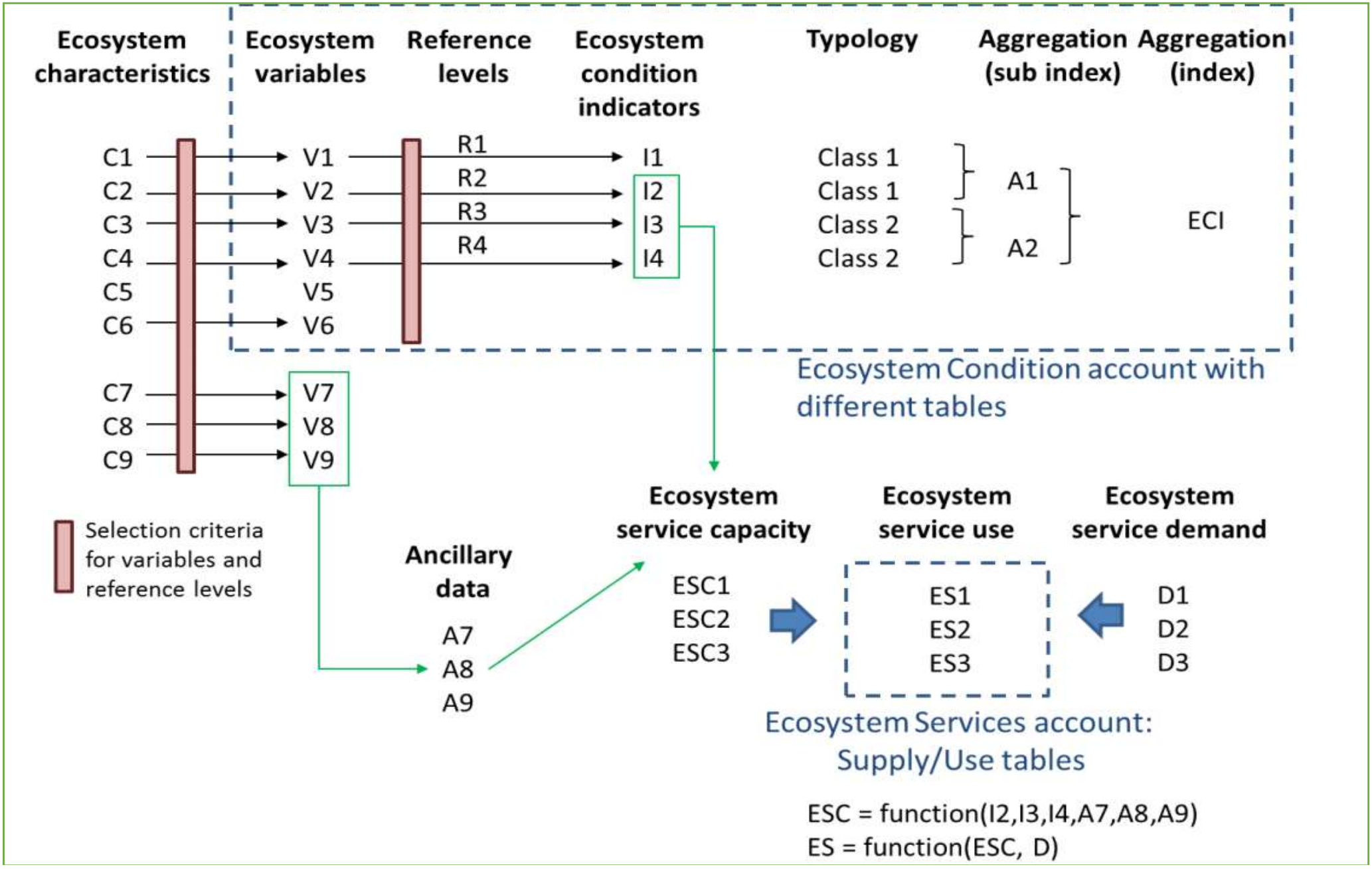
- Compilation of available data (secondary data from the government agencies, published literatures – peer reviewed journals, reports, etc.) for the valuation of the chosen ecosystem services;
- For the assessed ecosystem services, the focus would lie on further testing / experimenting with exchange value methods (as more experience is needed here); whenever possible undertake both an exchange value valuation and a welfare-based valuation, as to obtain a better understanding of their difference; this would result in thematic layers (spatial maps with values of the assessed ecosystem services) for different time periods;
- Prices will be expressed in current and constant prices, base year;
- Estimate values of the ecosystem assets;
- Documentation with reports and database of the accounts.

IV. Scenario-based assessment of policy interventions

- scenario-based assessment to demonstrate the applications of the developed accounts to a policy intervention (such as implications of improved land use planning and/or management for the supply and value of ecosystem services.)
- Scenarios include plausible and realistic alternative management and policy options vis a vis business as usual scenario;
- Modify and/or apply the models developed for the valuation to estimate the implications of the scenarios for the supply and value of ecosystem services.
- Estimate the implications of the scenarios for relevant sectoral outputs and the economic and employment implications on the basis of existing regional multipliers.
- Documentation of the modeled ecosystem services.

Ecosystem	Service	Approach & Tools to be used	Comment
Forest; Hydrology; Coast; Agriculture	Provisional	Spatial analyses of land uses, Statistical analysis; Market based approach;	Field data collection; Data from govt. agencies (forest department), gate market price (at taluk)
		Land use land cover [LULC] scenario- Multi Criteria Evaluation, Analytical Hierarchical Process (AHP); Geographical Resource Analysis Support System (GRASS); Quantum (Q) GIS	
	Regulating	InVEST; GRASS; QGIS; Revised Universal Soil Loss Equation (RUSLE); Natural Resource Conservation Series (SCS-curve number); Field estimates-statistical analysis	Analysis of high resolution land use land cover data;
	Cultural	InVEST recreation model; Cellular Automata-MARKOV chains; Travel cost method; Multi Criteria Evaluation, Analytical Hierarchical Process (AHP)	LULC; Data from Government of Karnataka Tourism Department

Components of an ecosystem condition account and relation with the ecosystem service account –SEEA Rev



Limitations of Invest

- **Absence of Land use types**: Carbon model does not consider ecosystem specific values as it considers whole land use map (which can lead to bias and lower values)

- **Coarse Resolution**: The resolution of land use map is the major constraint → as it cannot allow high resolution data for input due to space constraints in evaluation of model

- **Soil erosion module** cannot distinguish between various soil types and erosion factors associated due to the resolution of raster input (coarse resolution data), may provide approximate values as compared to actuals.

Thank you…!