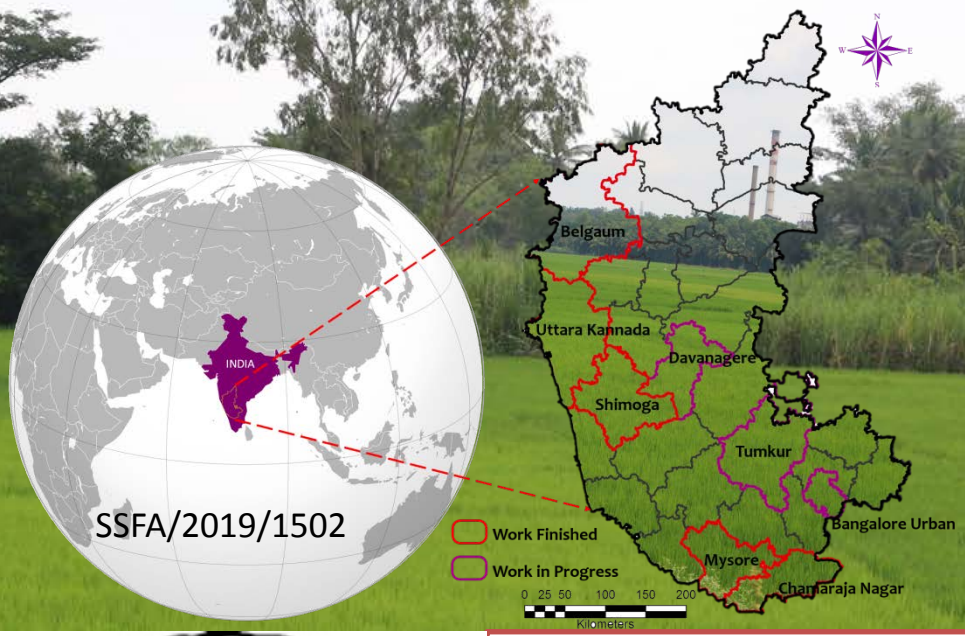
Natural Capital Accounting and Valuation of Ecosystem Services- Karnataka State, India

(Pilot study in select districts of Karnataka)



United Nations

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

T V Ramachandra

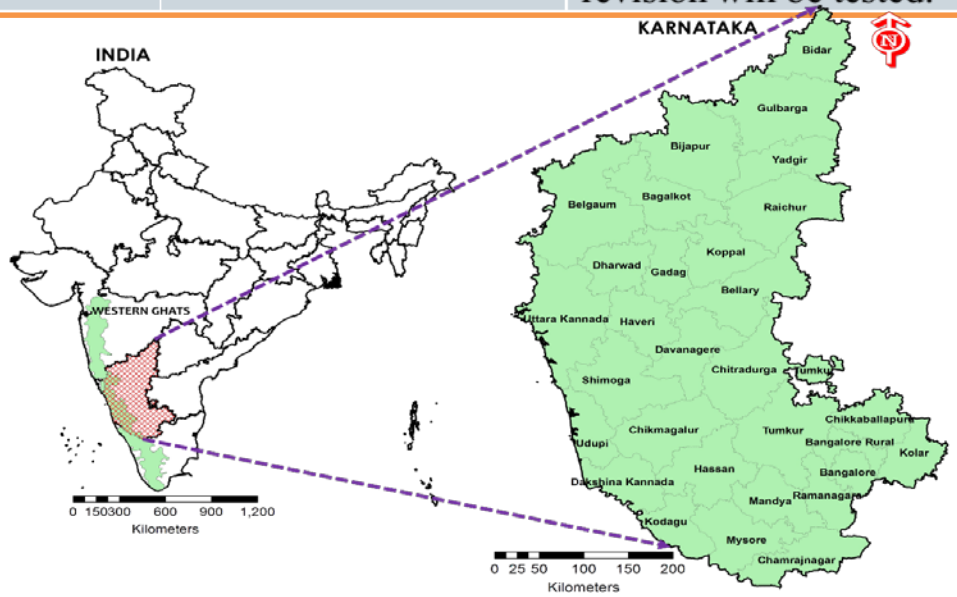
tvr@iisc.ac.in

Indian Institute of Science

Government of India

Ministry of Statistics and Programme Implementation

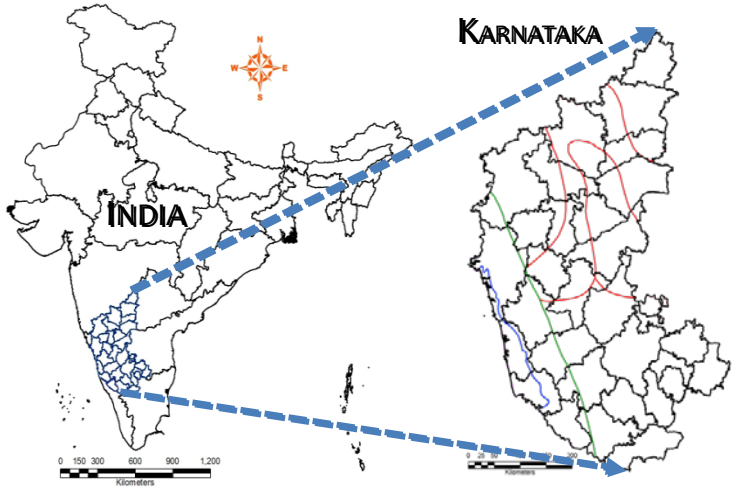
India	Extent; condition; services supply;	7 districts in Karnataka States;	The pilot in Karnataka state will cover a comprehensive set of ecosystem services, in physical and monetary units for various years. Land cover maps are used for the extent account. The condition indicators typology developed during SEEA EEA revision will be tested.



- (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
- (iv) Scenario-based assessment of policy interventions

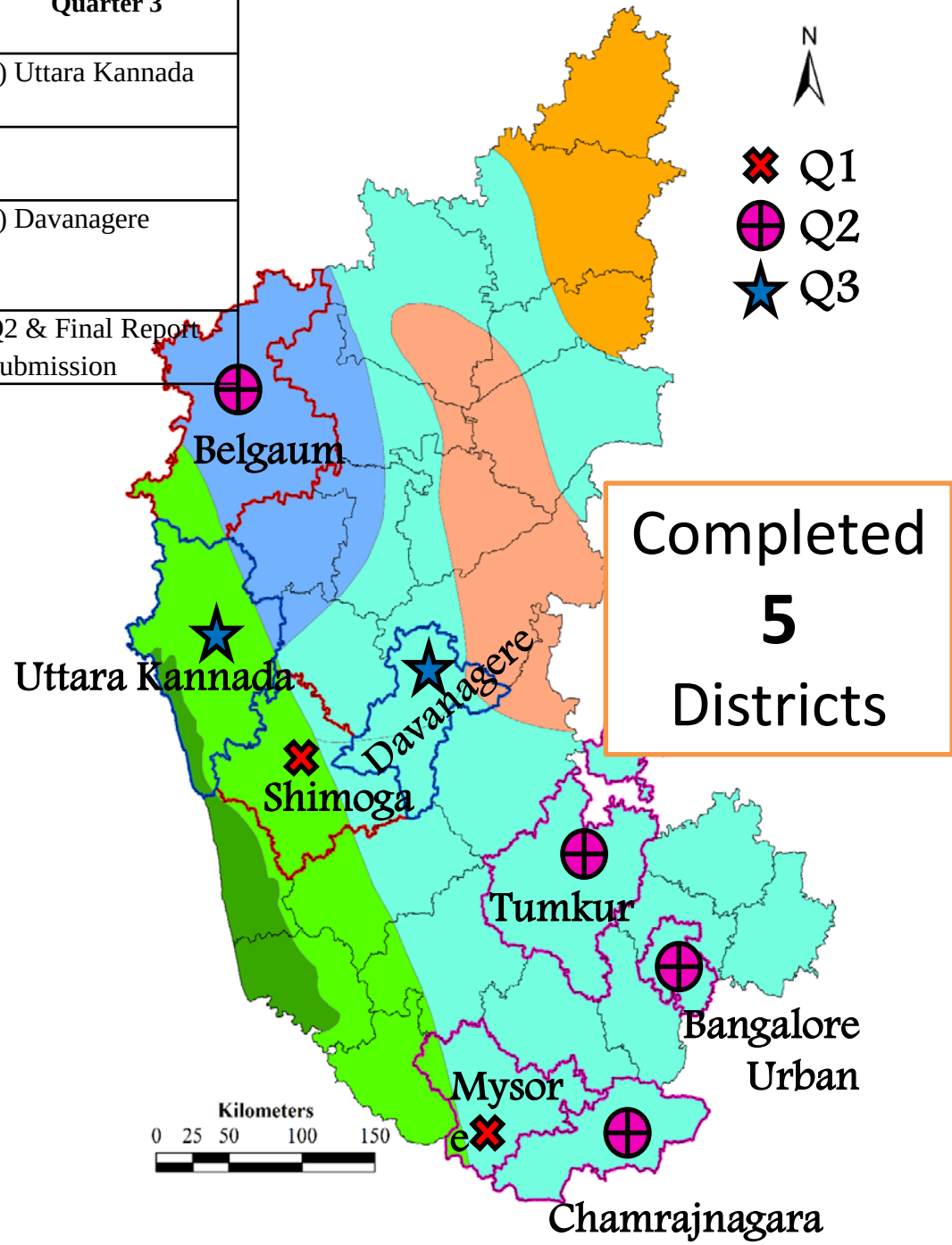
Year 2019-2020

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

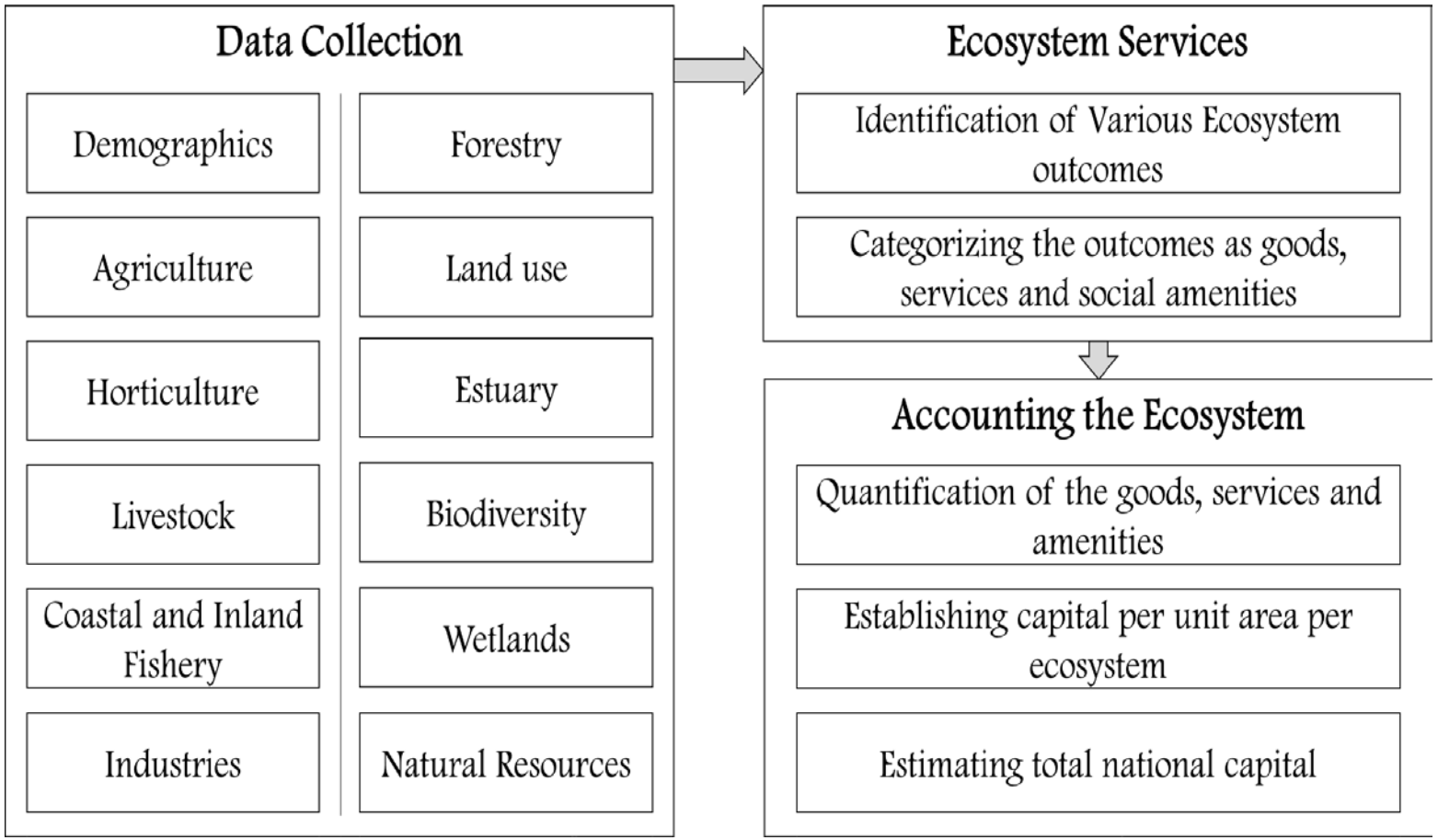


Agro Climatic Zones

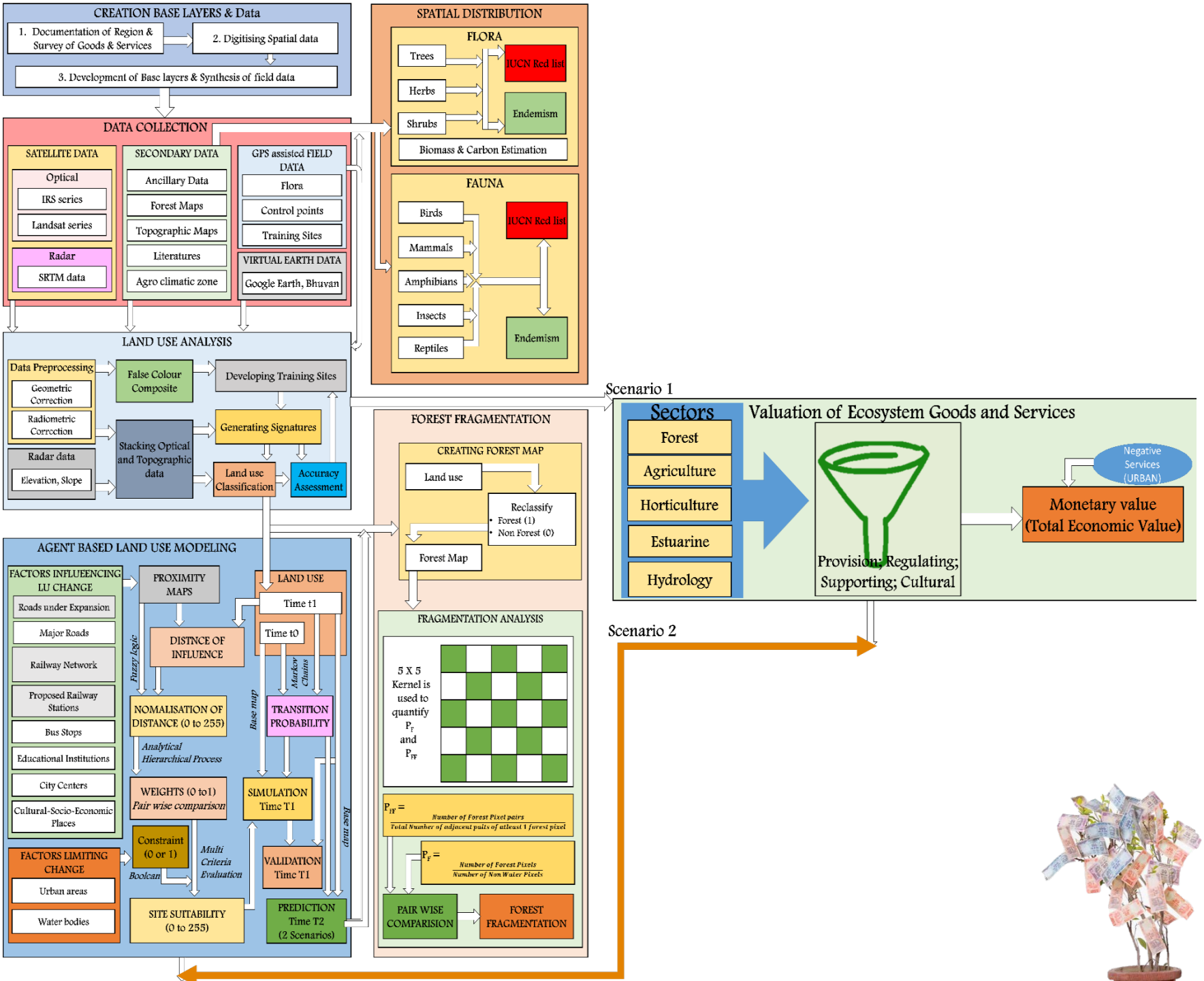
Karnataka Plateau	Hot Dry Arid
	Hot Dry Semi Arid
	Arid
	Hot Dry Sub Humid
Western Ghats	Hot Moist Sub Humid
Western Coast Plain	Hot Humid



Data Compilation & Analyses



METHOD

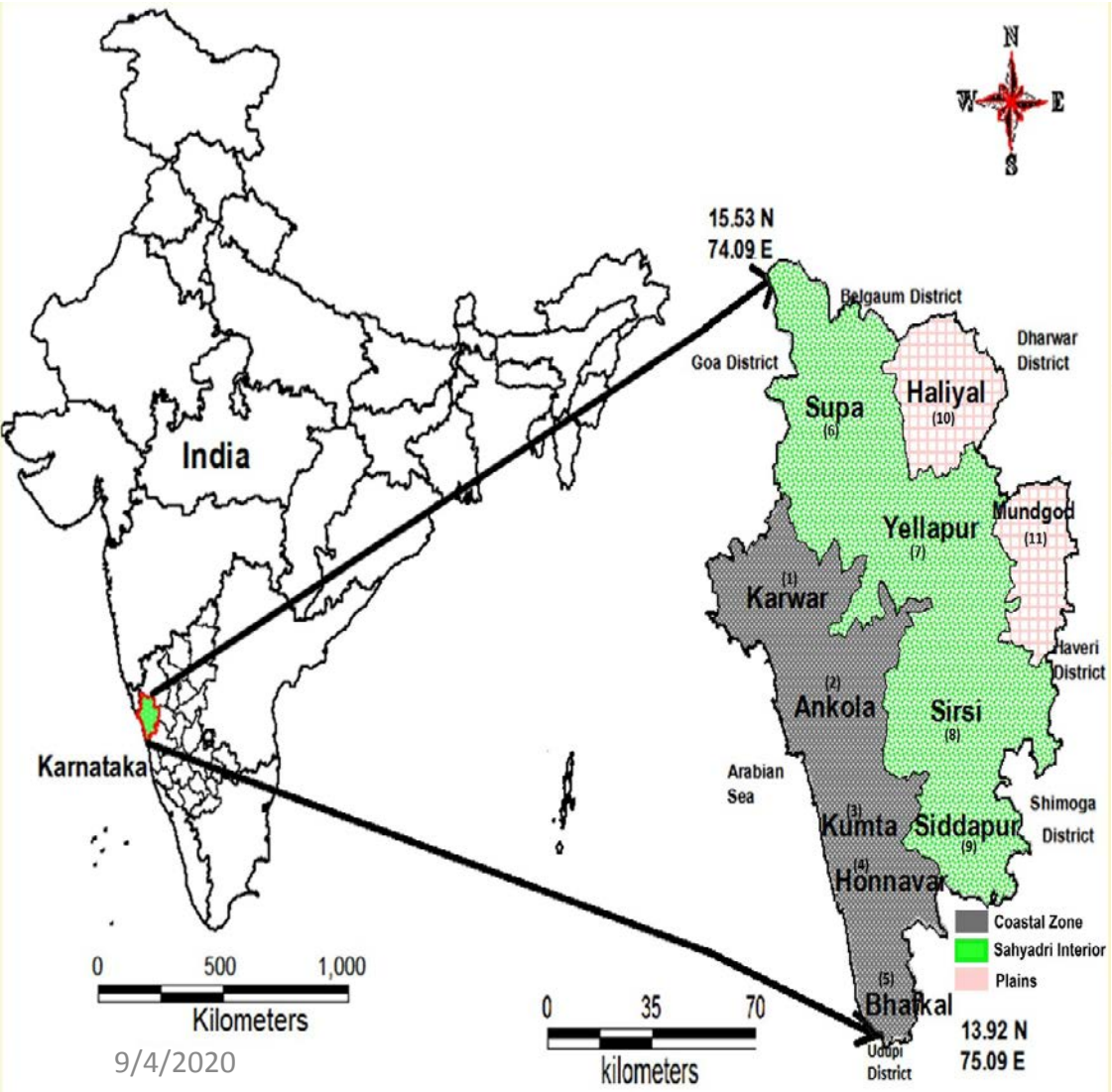

CREATION BASE LAYERS & Data
1. Documentation of Region & Survey of Goods & Services
2. Digitising Spatial data
3. Development of Basc layers & Synthesis of field data
SPATIAL DISTRIBUTION
FLORA
Trees
Herbs
Shrubs
IUCN Red list
Endemism
Biomass & Carbon Estimation
FAUNA
Birds
Mammals
Amphibians
Insects
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
TRANSITION PROBABILITY
Markov Chains
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

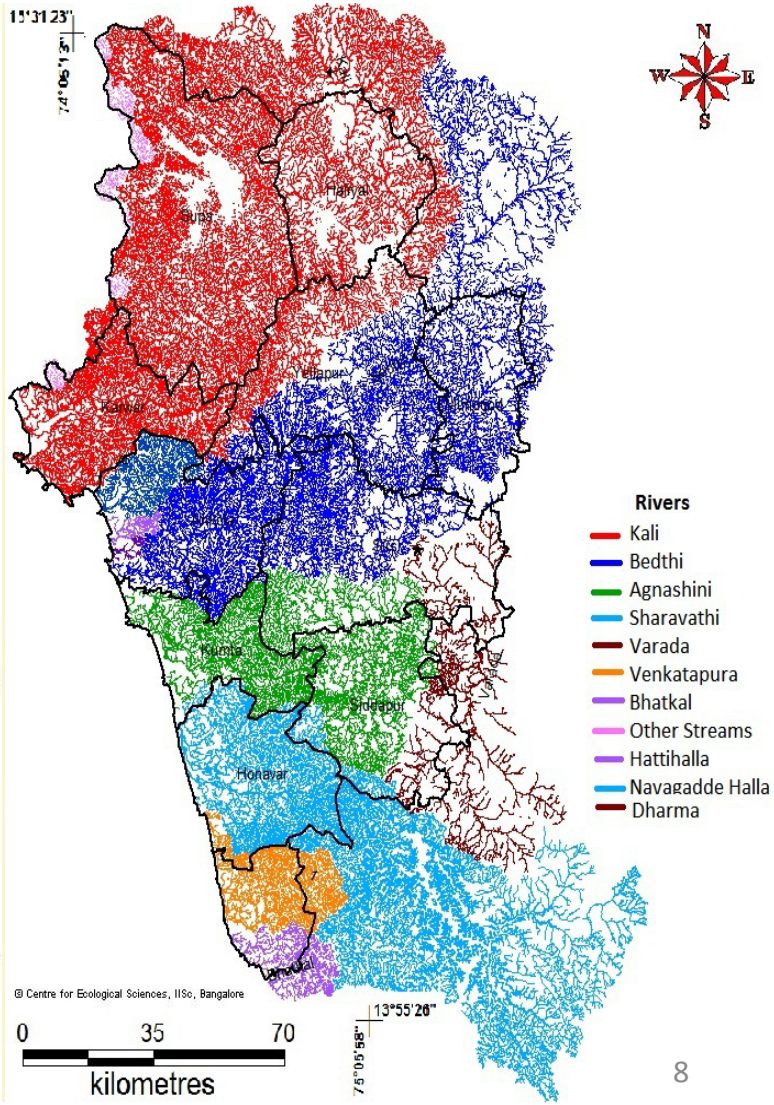
Task 1

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

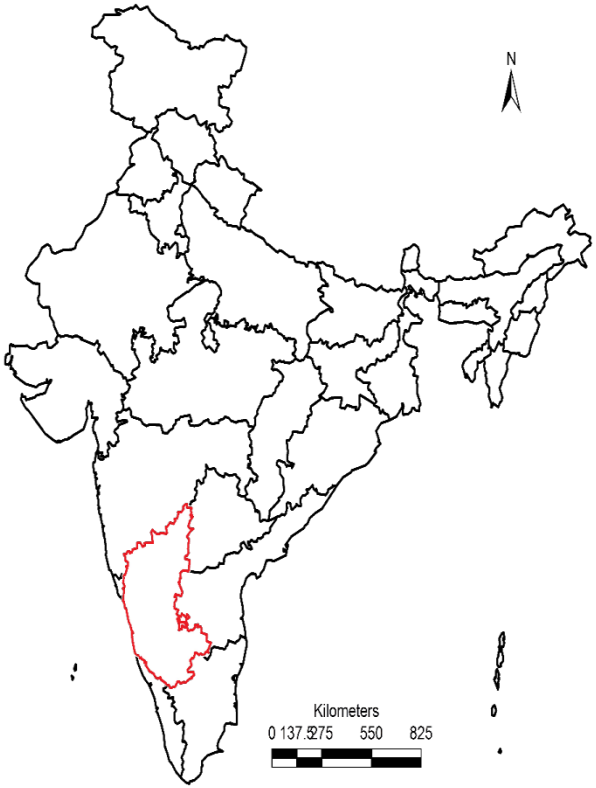
- 7 Districts

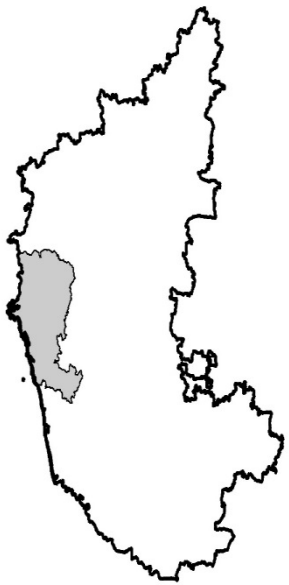
Uttara Kannada district, Karnataka, India





West flowing rivers- Uttara Kannada





Kali

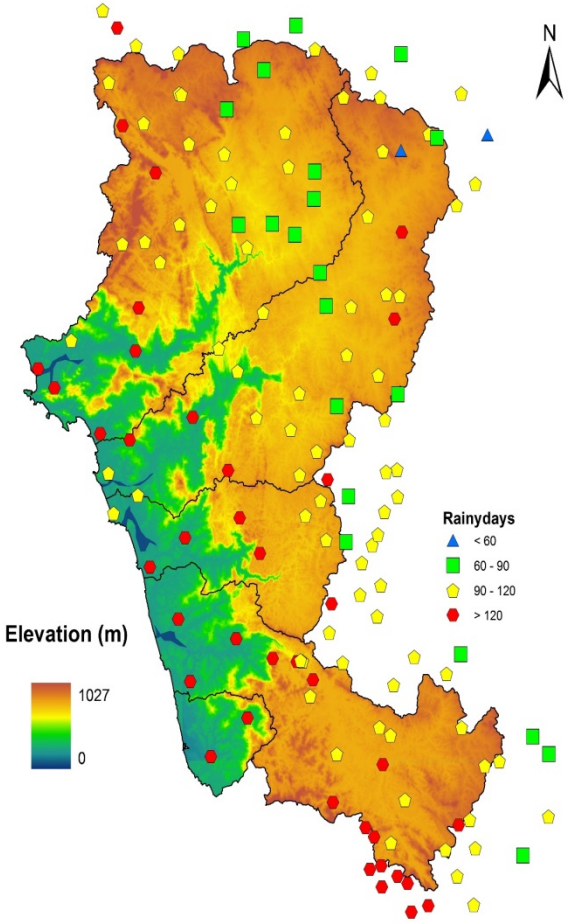
Gangavali

Aghanashini

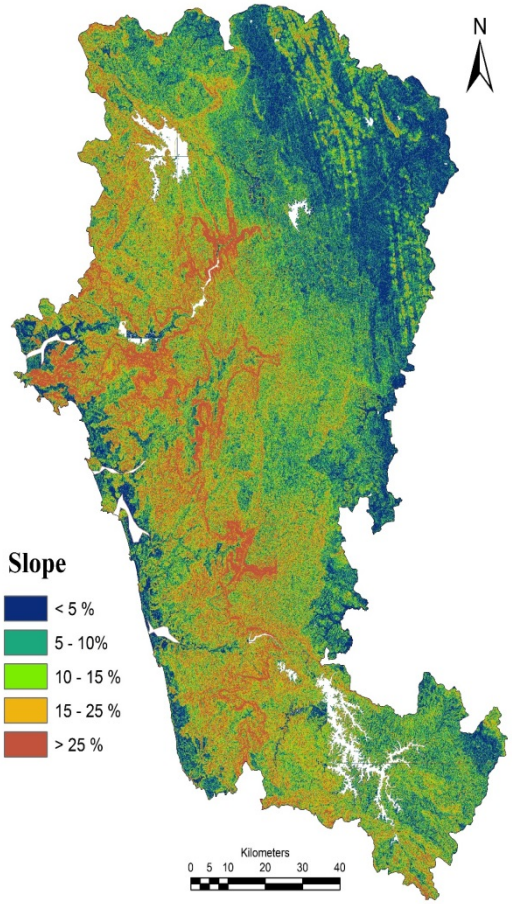
Sharavathi

Venkatapura

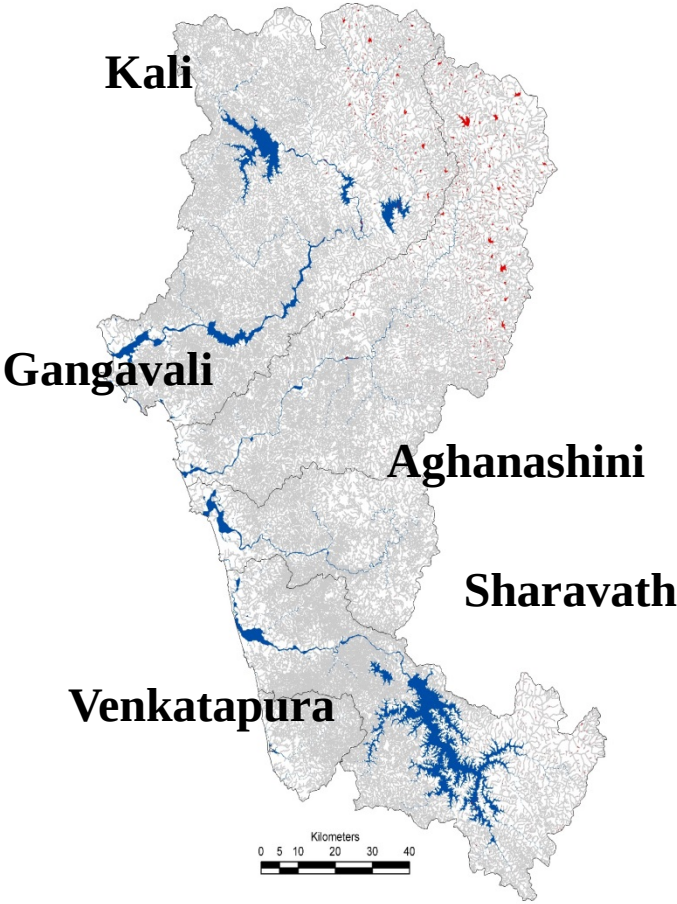
Topography



SRTM 90m DEM



Slope Map (%)



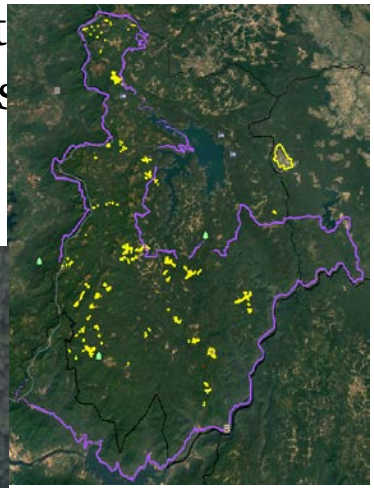
Drainage Network

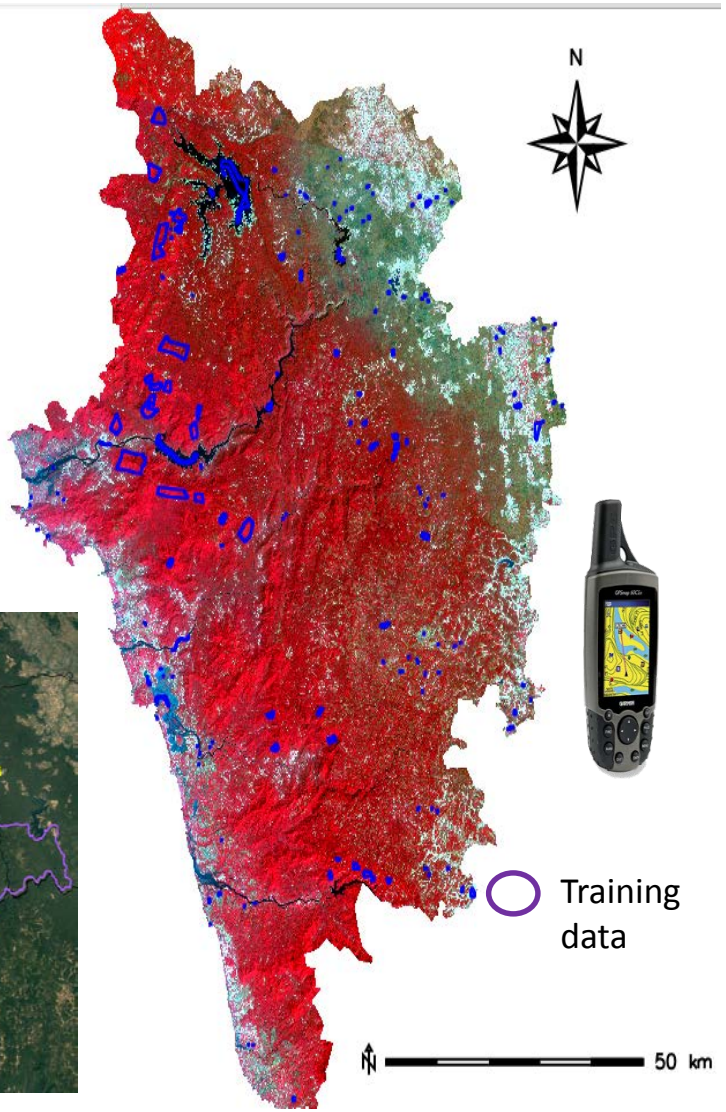
Land use dynamics- Remote sensing data

- The land use analysis from 1973-2016 was done using maximum likelihood algorithm.

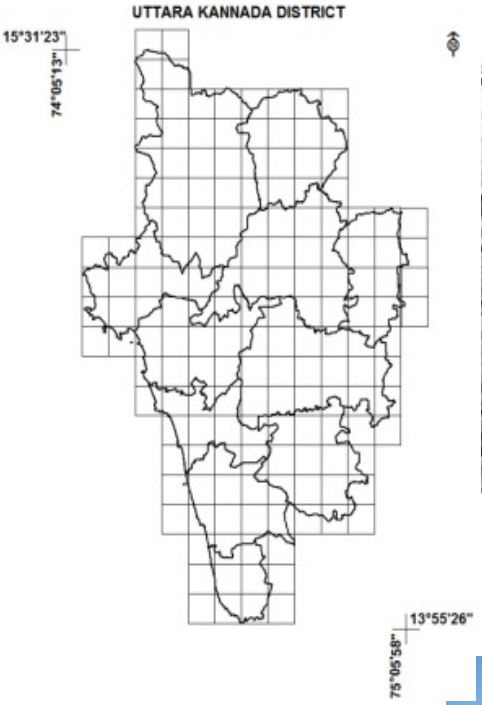
- Temporal remote sensing data of Landsat and IRS data were classified into eleven land use categories:

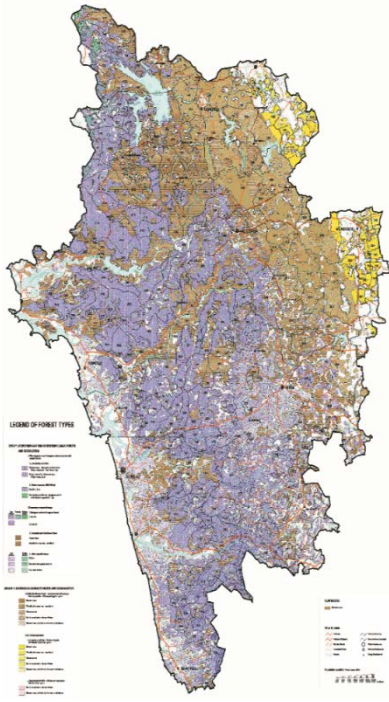
Evergreen forest to semi evergreen forest,
moist deciduous forest,
Shrub lands/grass lands,
Dry deciduous forest,
Acacia/Eucalyptus/ other hardwood plant
Teak/Bamboo/ other softwood plantations
Coconut/Areca nut plantations,
Built-up,
Water,
Crop lands,
Open fields.

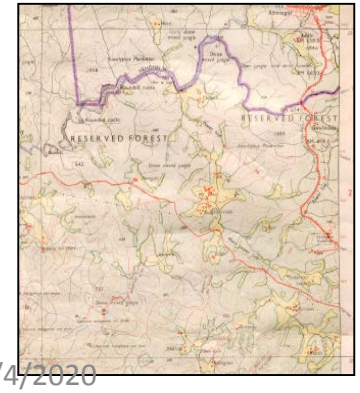


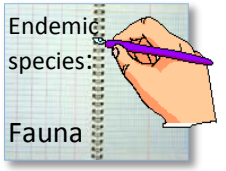


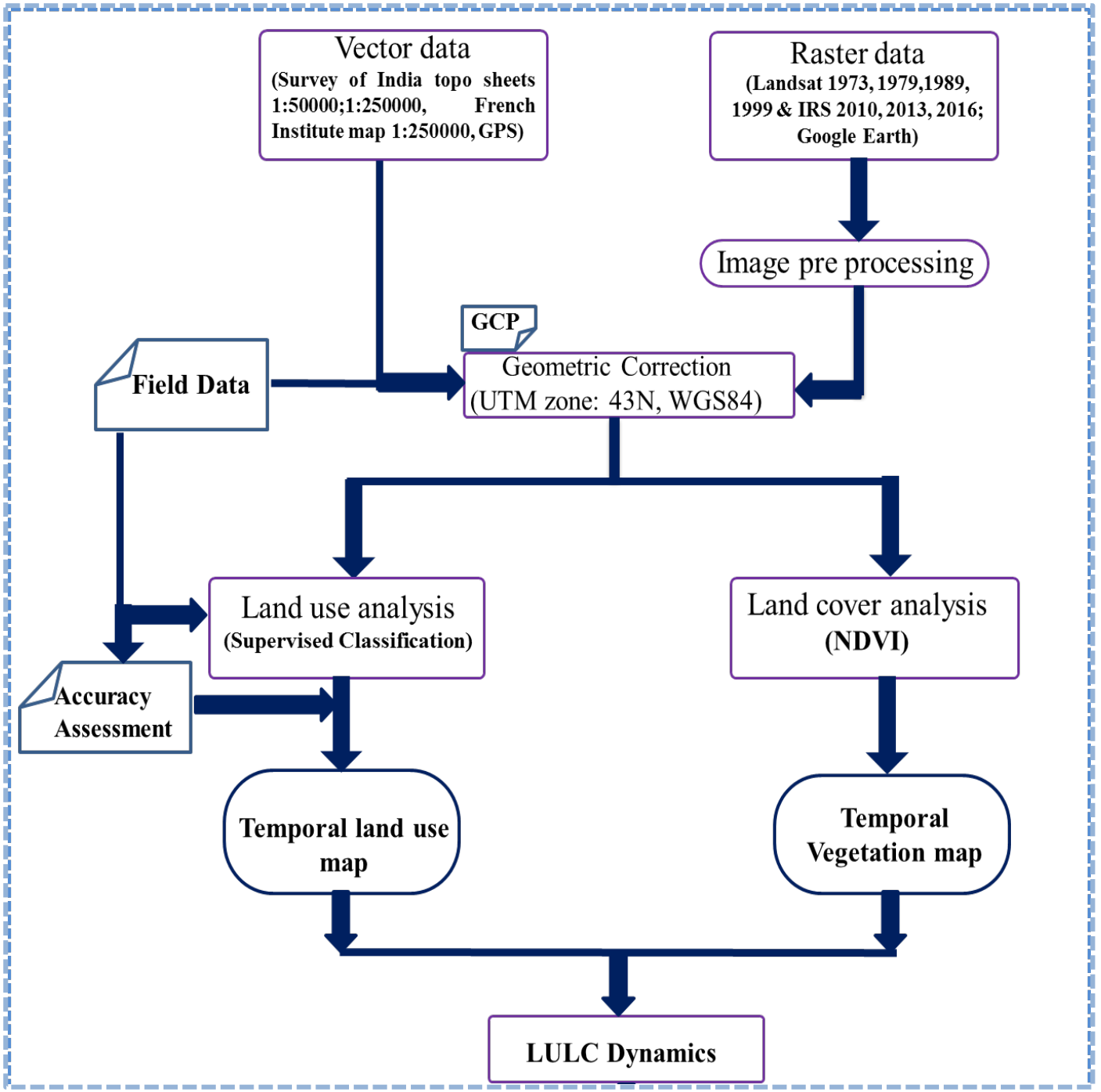
Field data collection



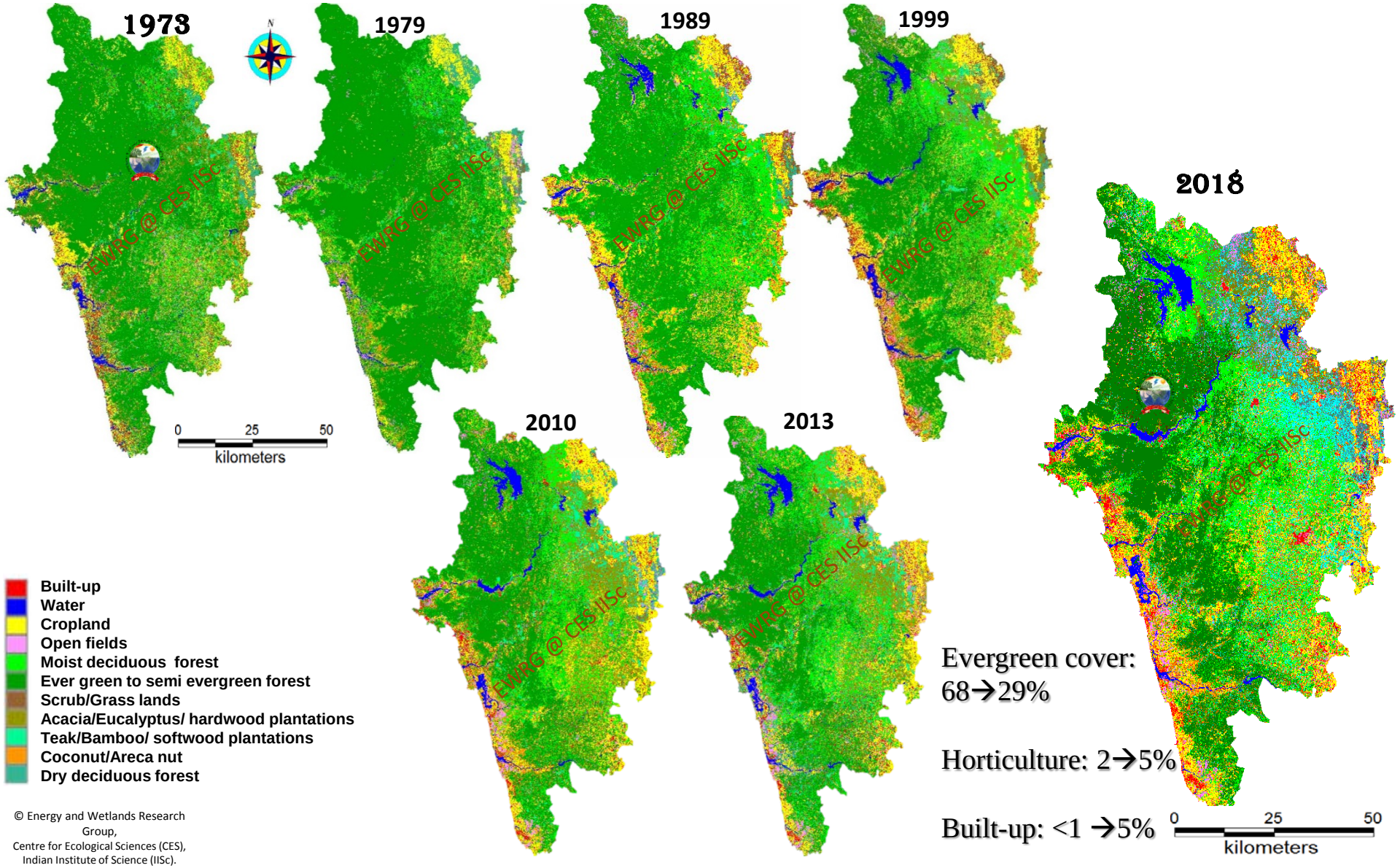







Vector data
(Survey of India topo sheets 1:50000;1:250000, French Institute map 1:250000, GPS)
Raster data
(Landsat 1973, 1979,1989, 1999 & IRS 2010, 2013, 2016; Google Earth)
Image pre processing
GCP
Field Data
Geometric Correction
(UTM zone: 43N, WGS84)
Land use analysis
(Supervised Classification)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

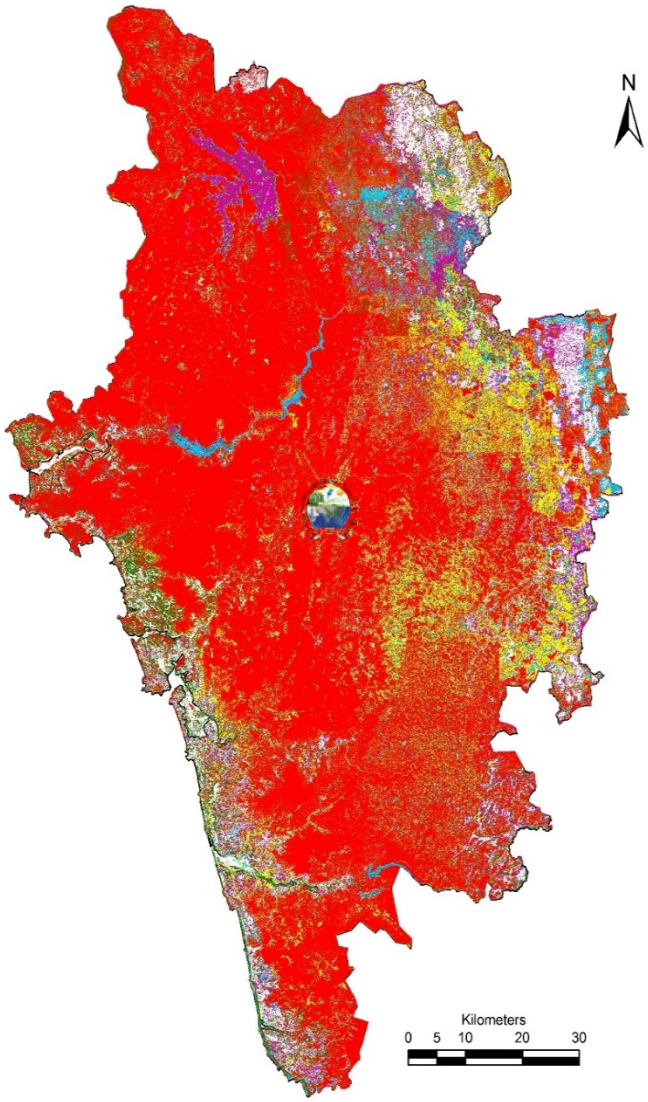
1989 71.3%

1999 63.93%

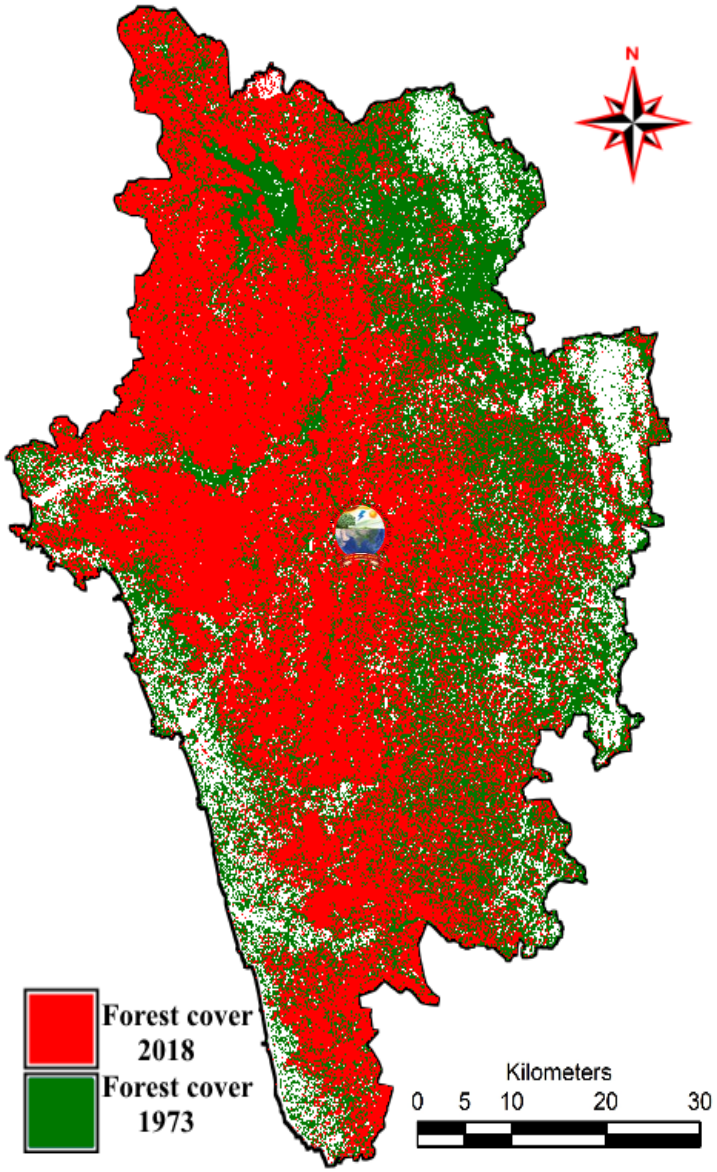
2010 56.12%

2013 52.71%

2018 50.22%



Forest cover loss→
32.9% (1973 to 2018)



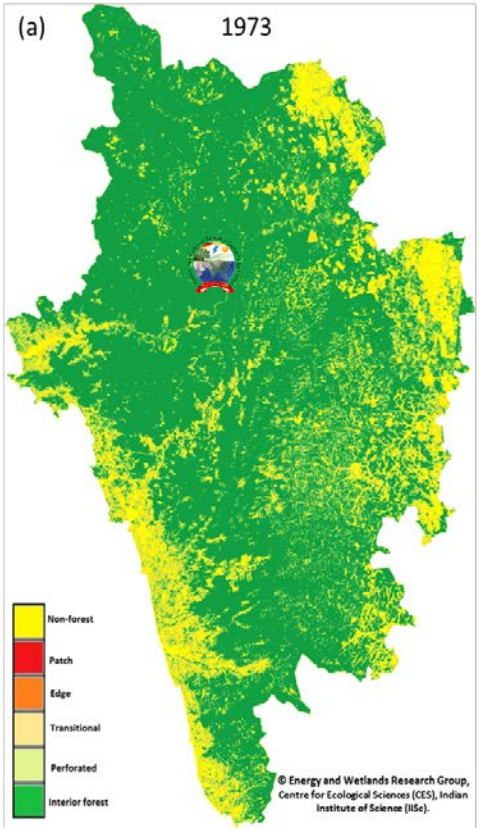
Forest Fragmentation

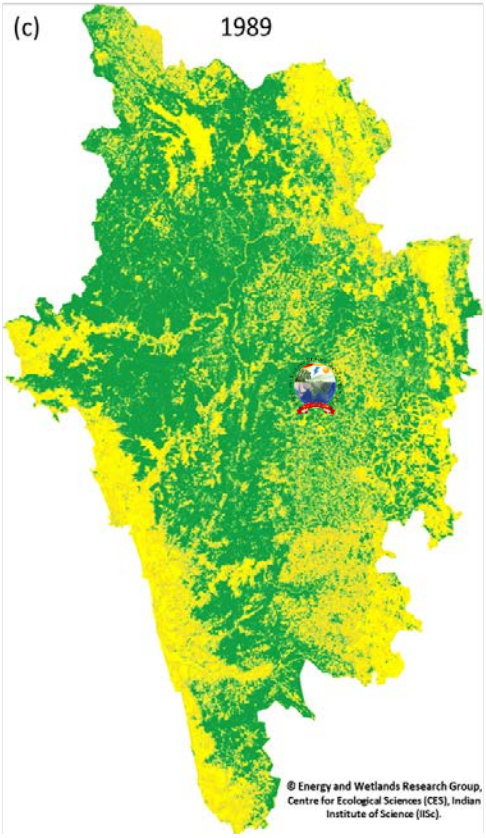
$$P_f = \frac{\text{Proportion of number of forest pixels}}{\text{Total number of non} - \text{ Water pixels in window}} \quad (1)$$

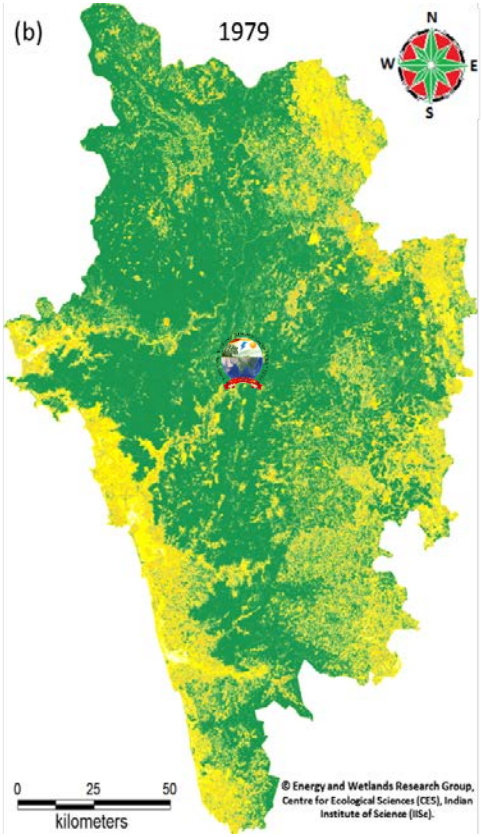
$$P_{ff} = \frac{\text{Proportion of number of forest pixel pairs}}{\text{Total number of adjacent pairs of at least one forest pixel}} \quad (2)$$

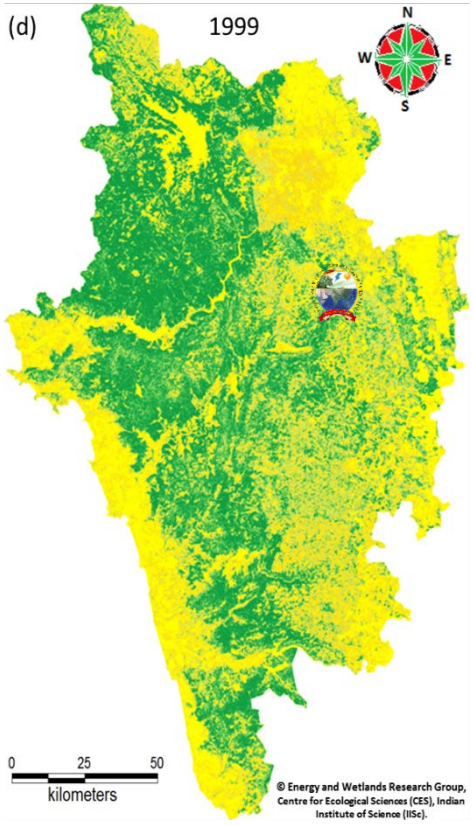
Interior	**(P_f = 1), All of the pixels surrounding the center pixel are forest**
Patch	(P_f < 0.4), Pixel is part of a forest patch on a non-forest background, such as a small wooded lot within a built-up region.
Perforated	(P_f > 0.6 and P_f - P_{ff} > 0), Most of the pixels in the surrounding area are forested, but the center pixel appears to be part of the inside edge of a forest patch, such as would occur if a small clearing was made within a patch of forest.

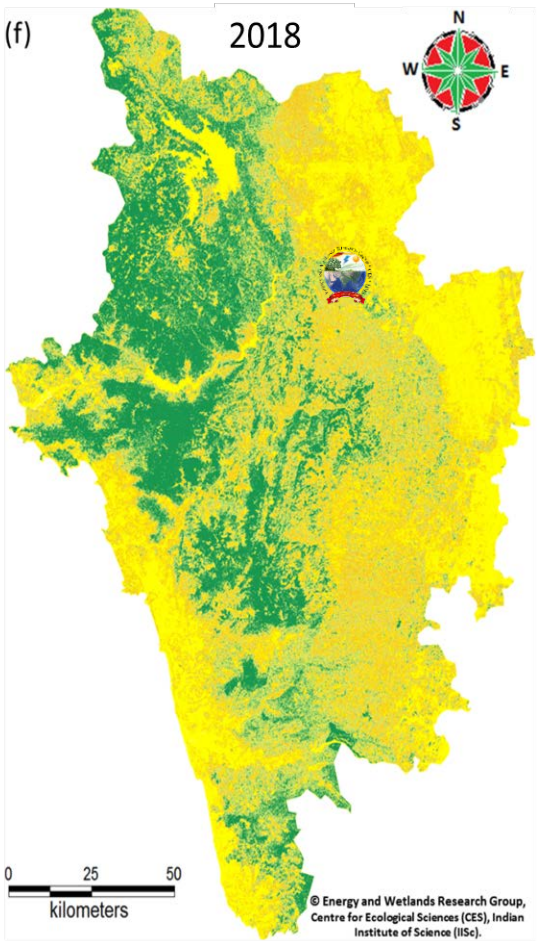
Temporal forest Fragmentation

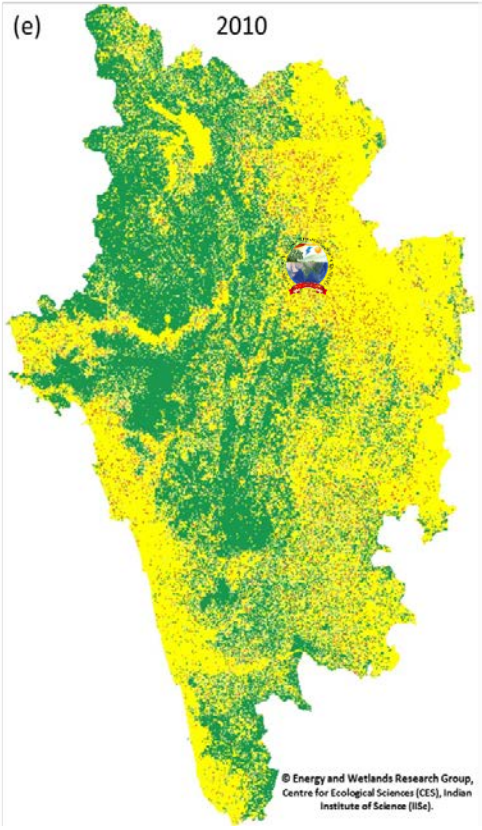


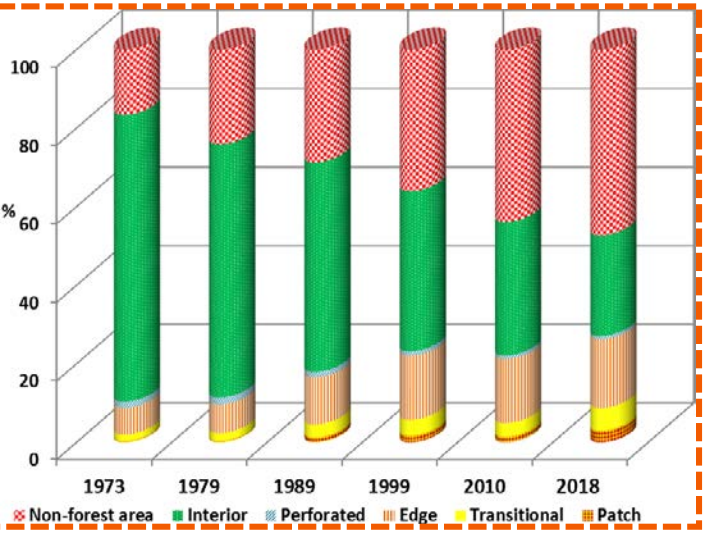






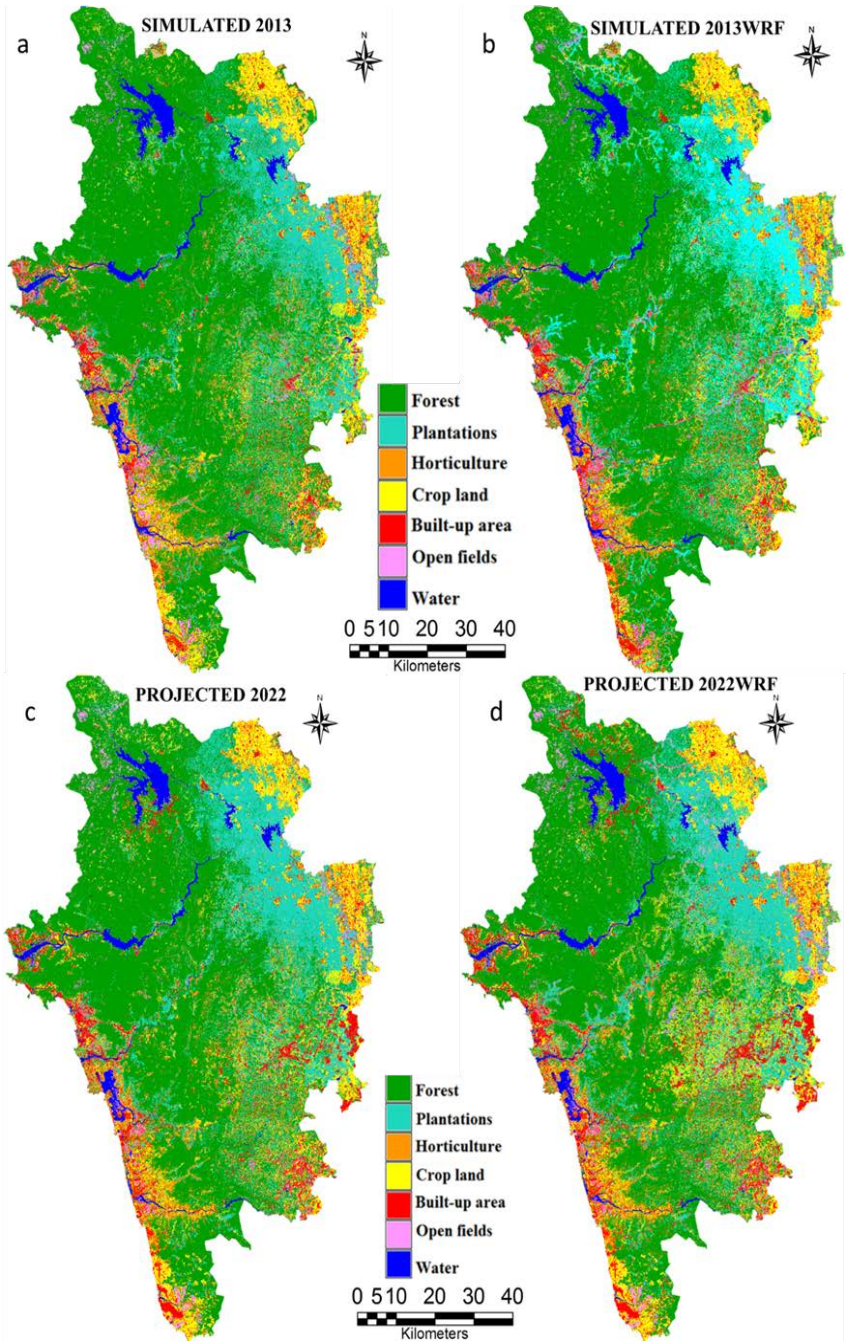






Interior forest cover lost from 73 to 23% (1973-2018)

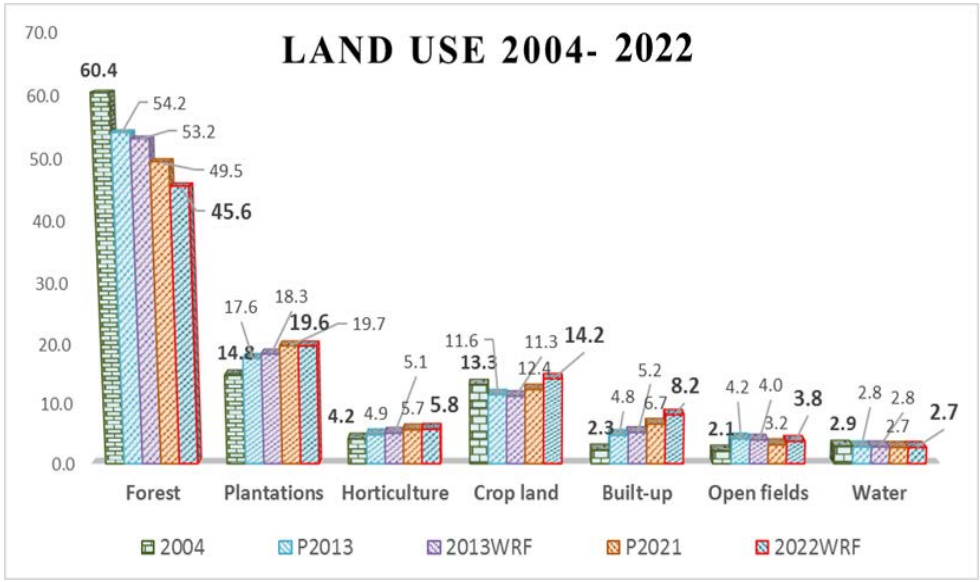
Modelling Landscape dynamics



Modelled LU change under two scenarios

1→ With Reserve Forest Protection

2→ Without Reserve Forest Protection



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

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):

Energy and Wetlands Research Group, Centre for Ecological Sciences,
Indian Institute of Science, Bangalore 560 012
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

Valuation of Ecosystems Goods & Services

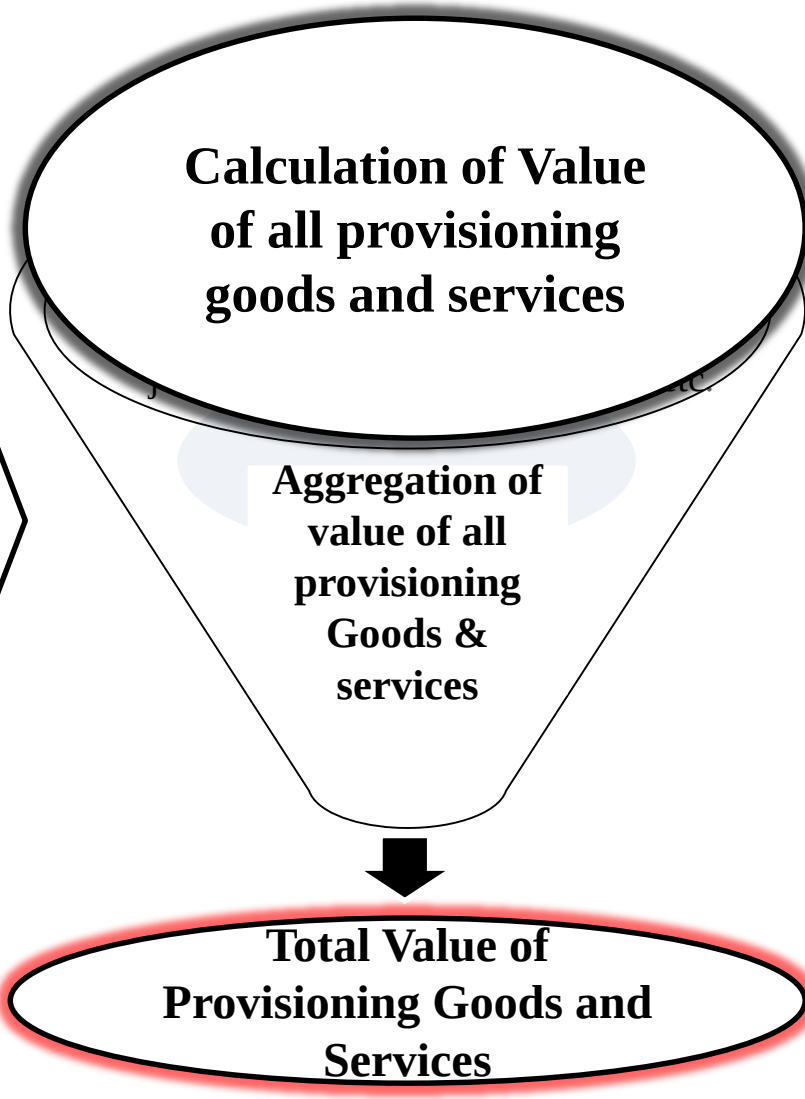
- Forests

- Estuarine Ecosystem

Quantification

Timber
NTFP
Medicinal plants
Food
Bee-keeping
Bamboo, Cane,
Fuelwood (domestic & commercial)
Fodder
Litter
Mulching leaves
Inland fishing
Domestic water use
Industrial water use
Water for power generation
Irrigation Services
Wild fruits
Oxygen provision

Valuation



TEV

PROVISIONING SERVICES

Regulating Services

Supporting Services

Information Services

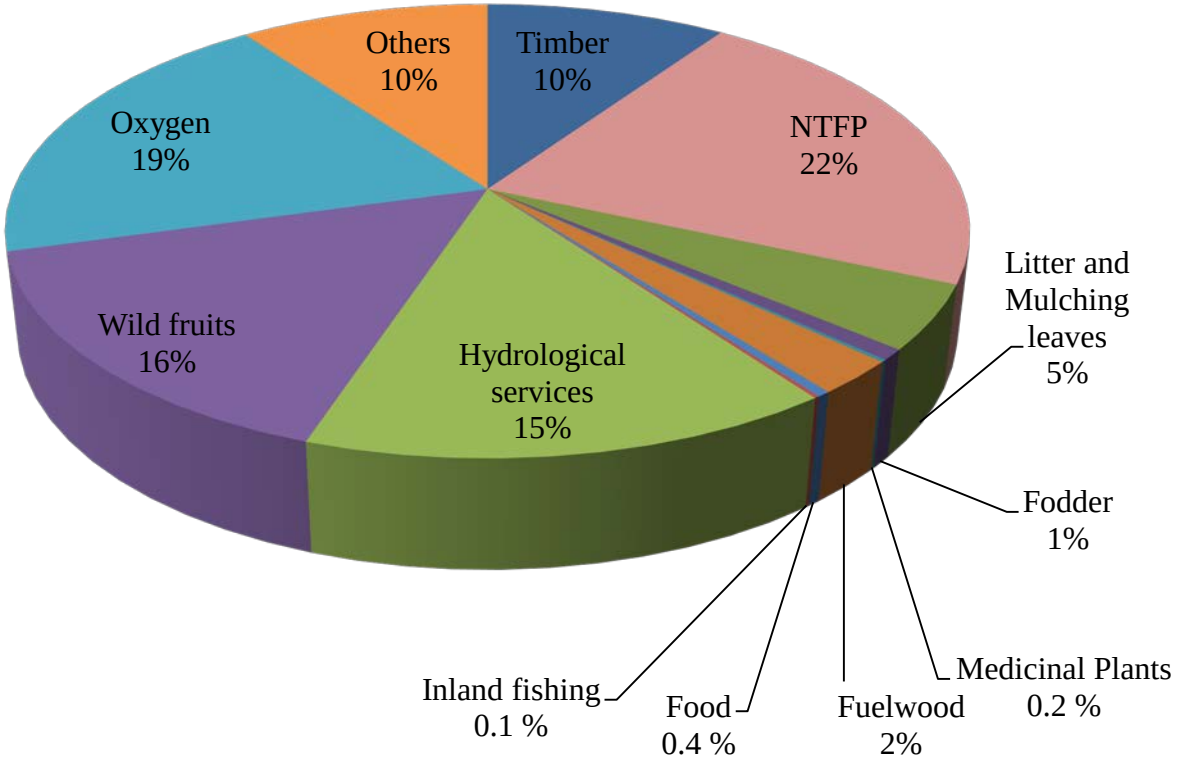
Results

Total value of Provisioning goods and Services

Scenario	Value of Provisioning goods and services (in Rs. Crores per year)
Scenario I	9,282
Scenario II	11,898
Scenario III	15,159

Share of various goods and Services

Scenario - III



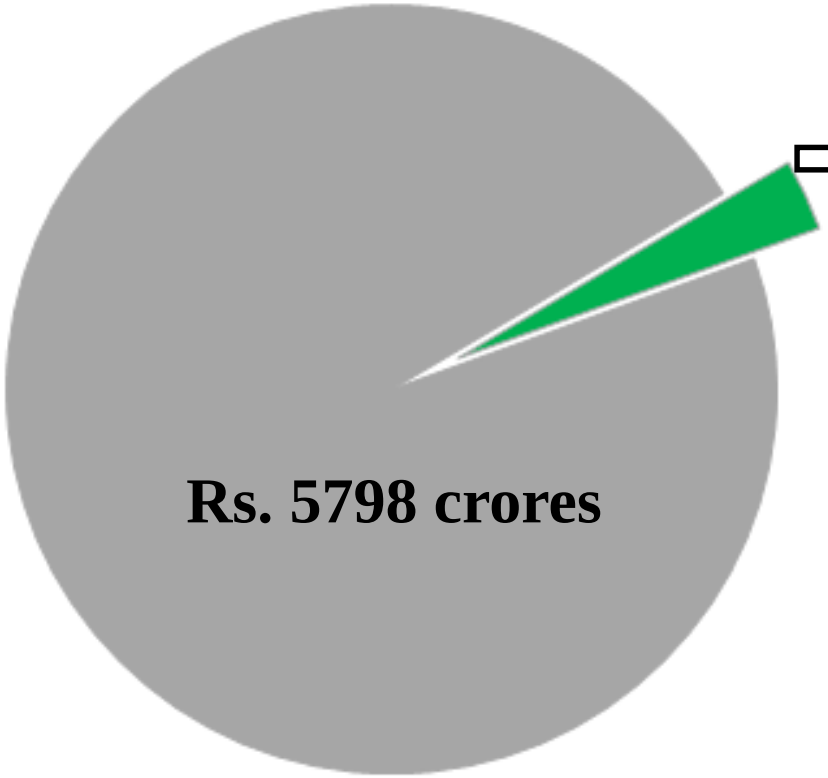
Results

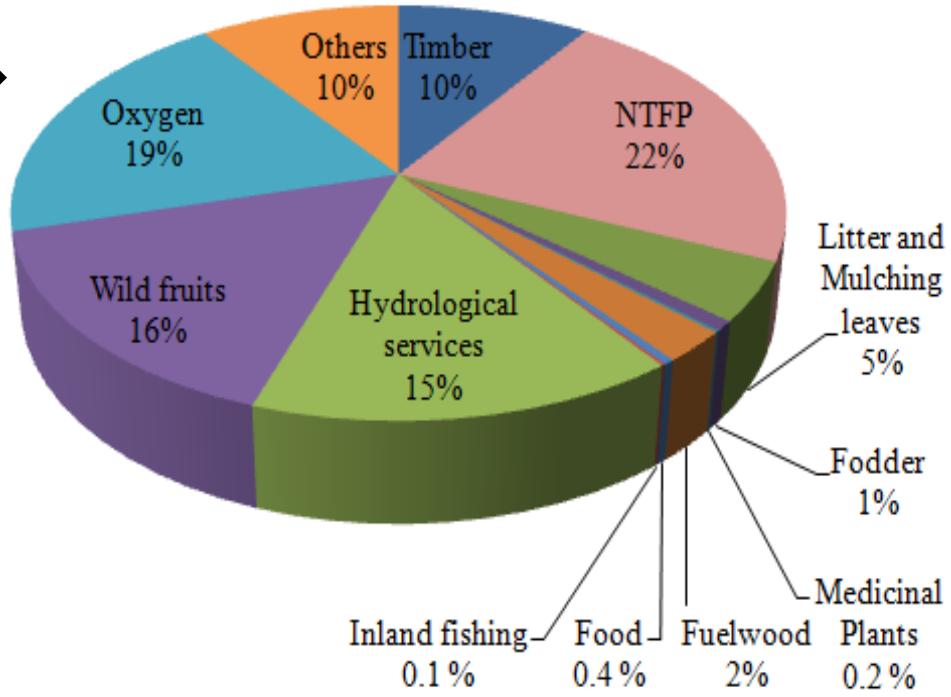
- Total Economic Value (TEV) of goods and services from forest ecosystem

Services from forest Ecosystem	District Value per year (in Rs. crores)	Per cent share	Value of services per hectare per year (in Rs.)
Provisioning services	15,159	19	2,05,388
Regulating services	42,091	53	5,70,266
Cultural services	13,754	17	1,86,349
Supporting services	9,039	11	1,22,464
Total Value	80,043	100	10,84,466

Results

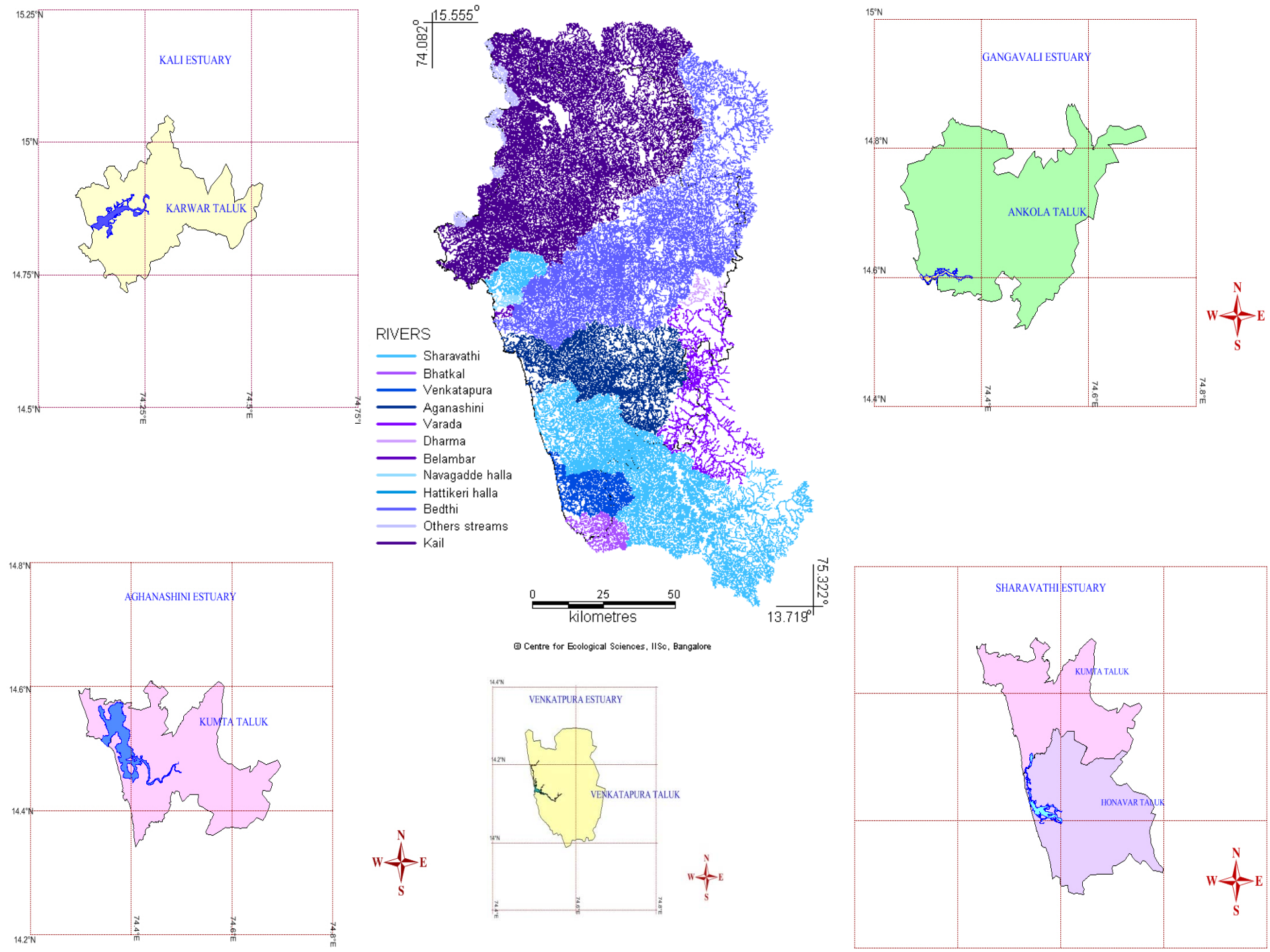
GDDP of Uttara Kannada: Rs. 5978 crores	Estimated value of Provisioning goods and services: Rs, 15,159 crores





Source: DES, Karnataka, 2009-10

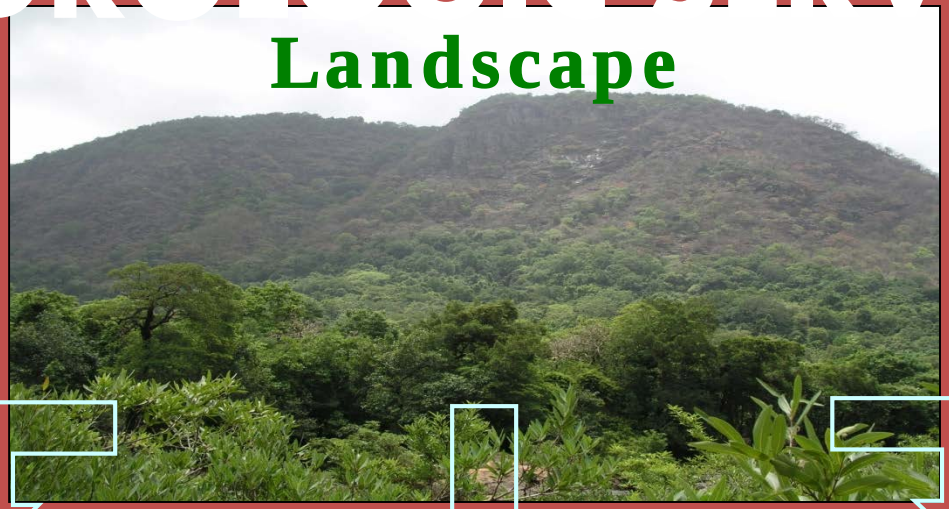
ECOSYSTEM GOODS AND SERVICES FROM ESTUARIES OF UTTARA KANNADA


KALI ESTUARY
KARWAR TALUK
15.25°N
15°N
14.75°N
14.5°N
74.25°E
74.5°E
74.75°E
15.555°
74.082°
RIVERS
Sharavathi
Bhatkal
Venkatapura
Aganashini
Varada
Dharma
Belambar
Navagadde halla
Hattikeri halla
Bedthi
Others streams
Kail
0
25
50
kilometres
75.322°
13.719°
GANGAVALI ESTUARY
ANKOLA TALUK
15°N
14.8°N
14.6°N
14.4°N
74.4°E
74.6°E
74.8°E
N
W
E
S
AGHANASHINI ESTUARY
KUMTA TALUK
14.8°N
14.6°N
14.4°N
14.2°N
74.4°E
74.6°E
74.8°E
© Centre for Ecological Sciences, IISc, Bangalore
VENKATPURA ESTUARY
VENKATAPURA TALUK
14.4°N
14.2°N
14°N
74.4°E
74.6°E
74.8°E
SHARAVATHI ESTUARY
KUMTA TALUK
HONAVAR TALUK

VALUE (Rs/Ha/Yr) OF THE GOODS AND SERVICES OBTAINED FROM THE ESTUARIES IN UTTARA KANNADA

ESTUARY	PROVISIONING SERVICES	REGULATING SERVICES	SUPPORTING SERVICES	INFORMATION SERVICES
Kali	240,395	1,839,037	369,435	122,531
Gangavali	219,545	2,055,250	348,256	53,210
Aghanashini	1,135,847	1,835,288	1,946,030	87,871
Sharavathi	286,964	1,828,300	267,706	70,541
Venkatpura	55,707	1,028,162	211,976	37,247

HYDROLOGIC SERVICES

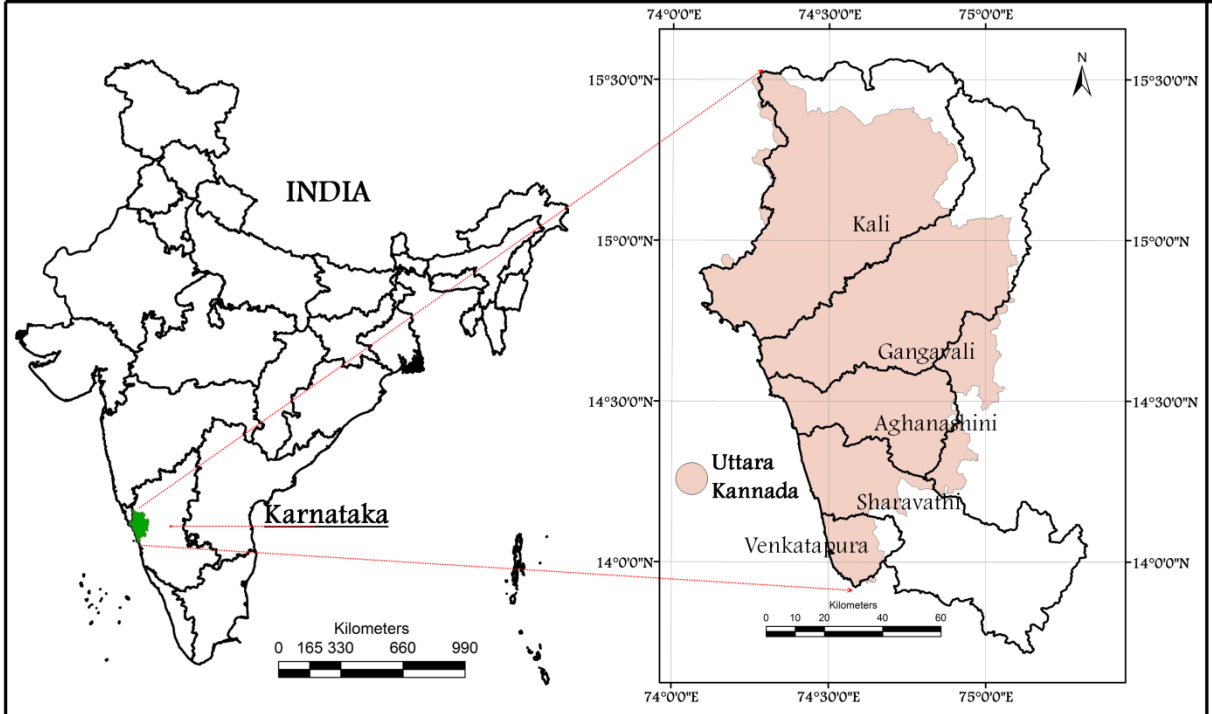


- Interaction
- Material flow
- Energy flow

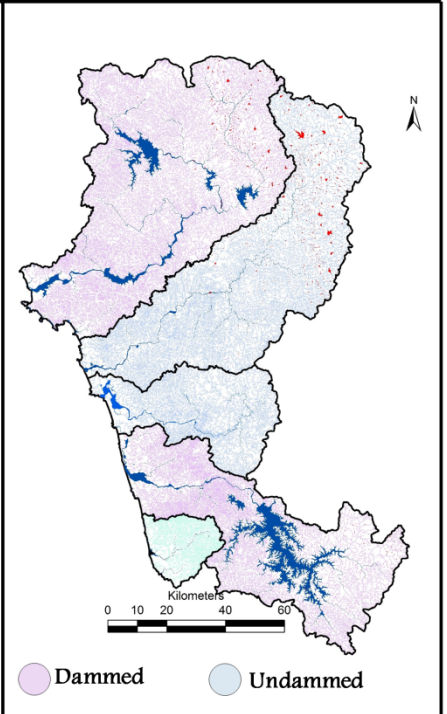
- Size
- Shape
- Number
- Types

Alteration in structure and function

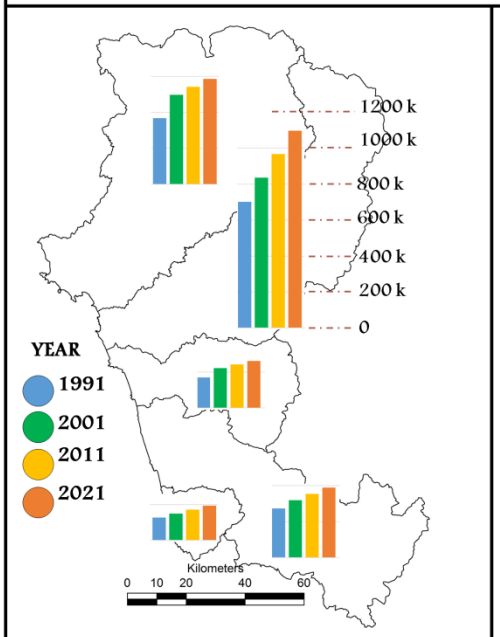
- ❖Hydrological
- ❖Ecological
- ❖Nutrient



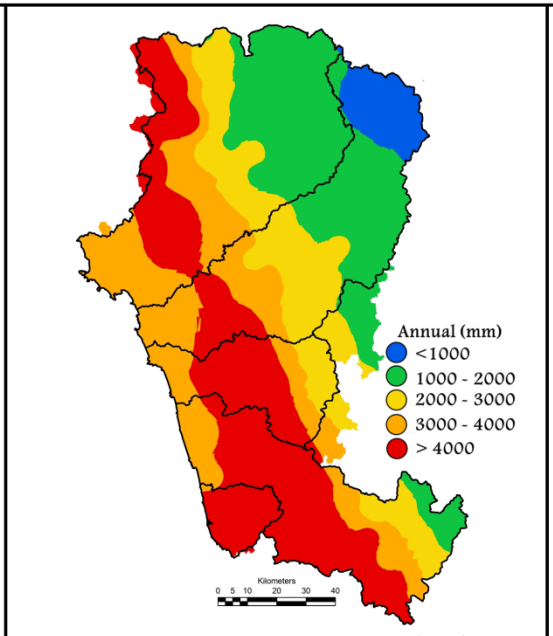
RIVERS OF UTTARA KANNADA



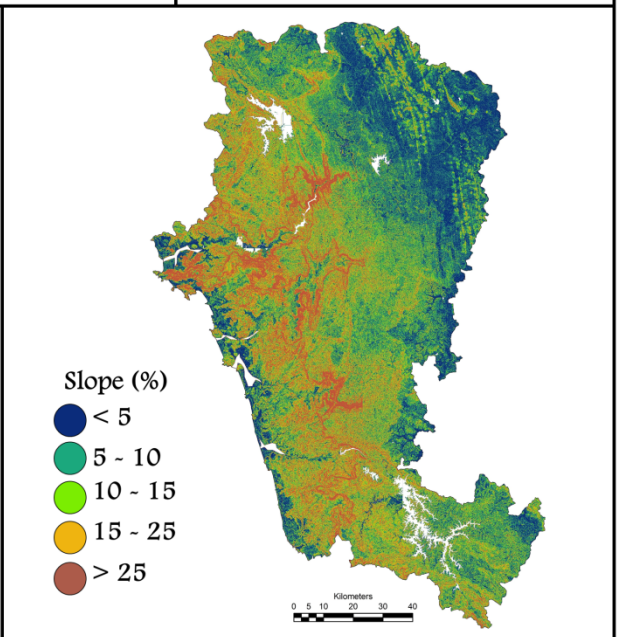
DRAINAGE PATTERN



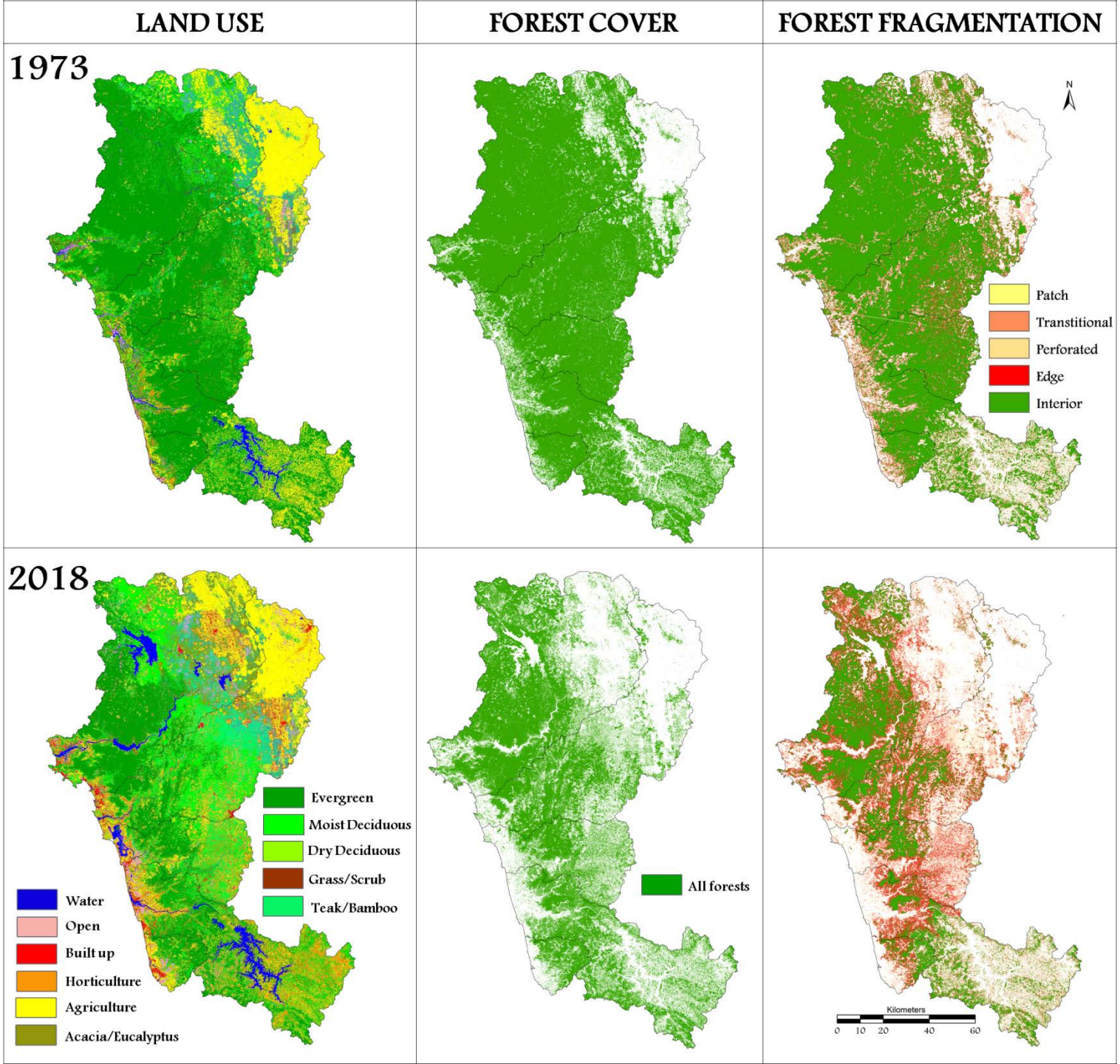
POPULATION DYNAMICS

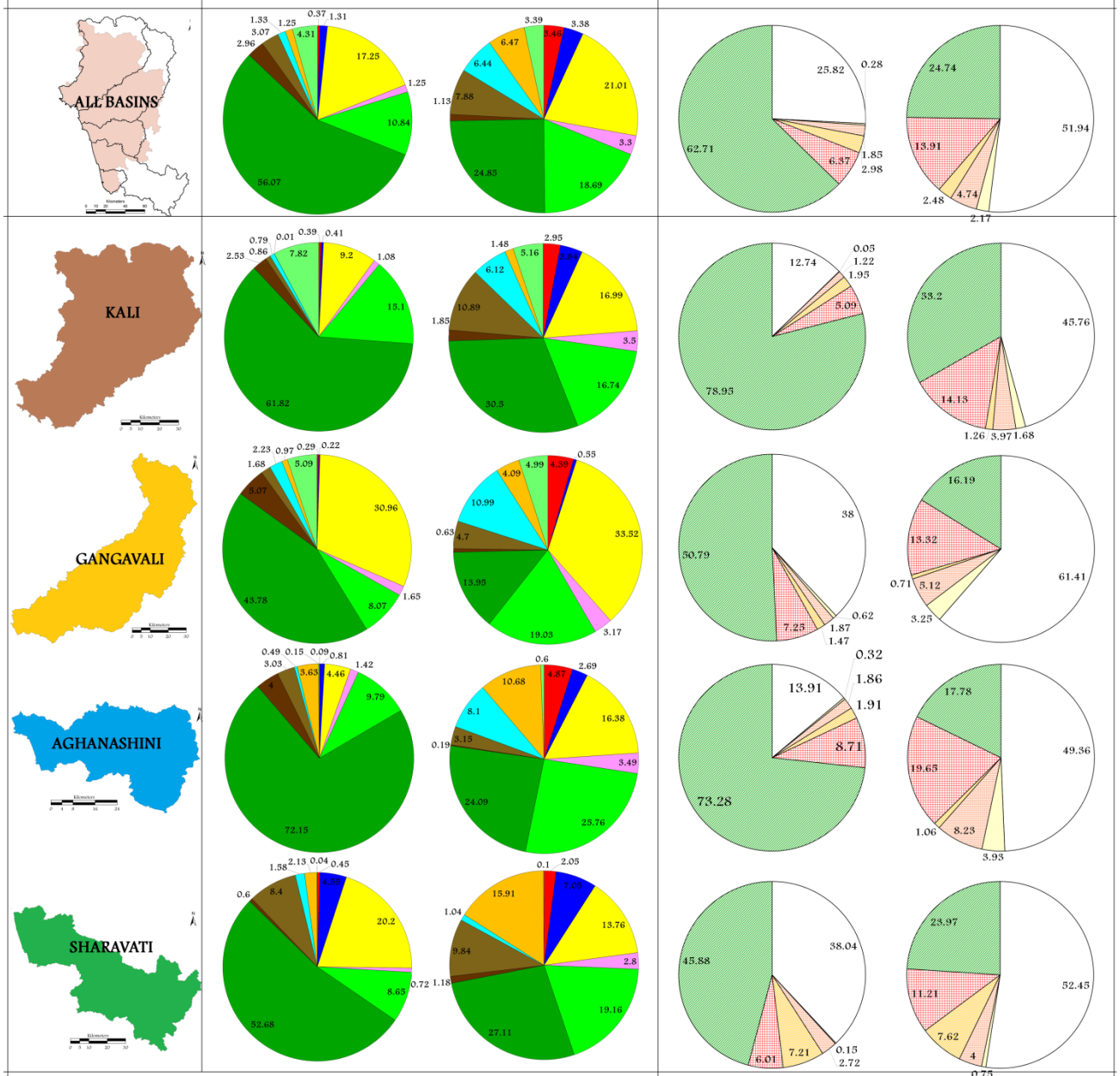


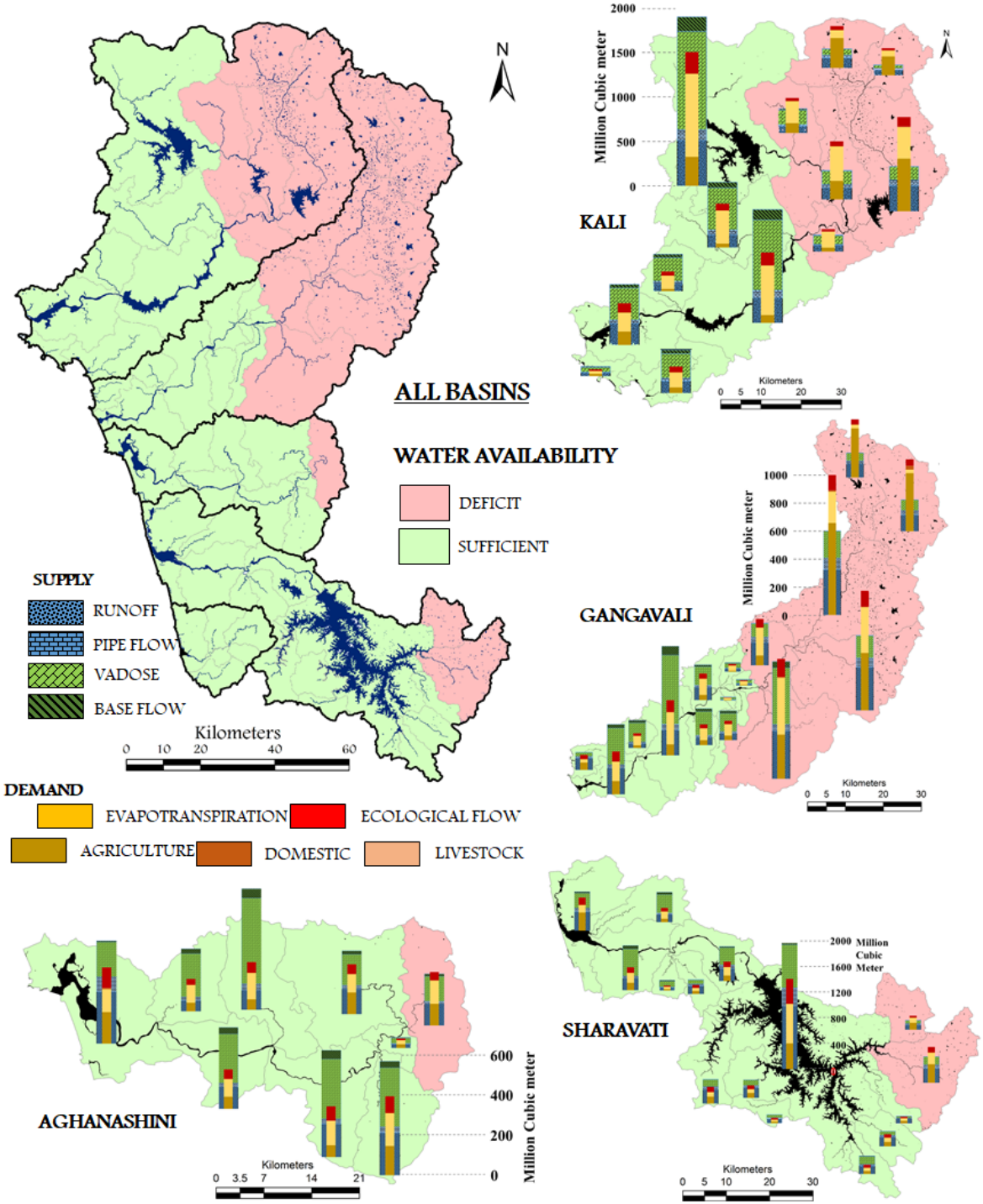
ANNUAL RAINFALL VARIATIONS (mm)

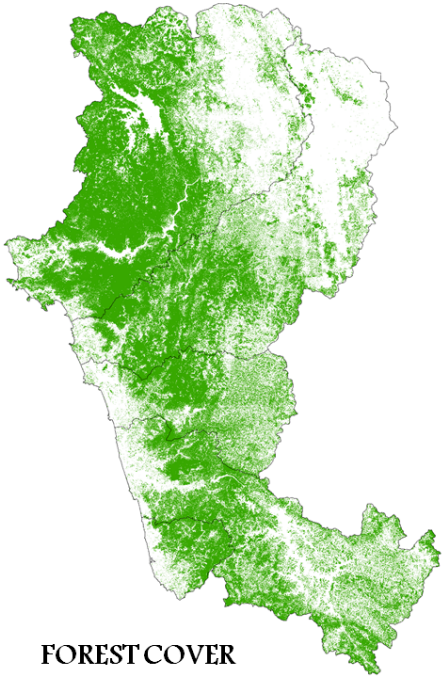


SLOPE

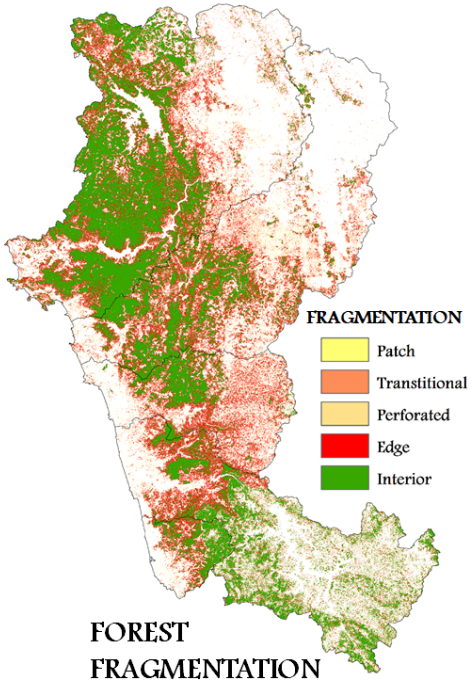

LAND USE
FOREST COVER
FOREST FRAGMENTATION
1973
2018
N
Patch
Transtitional
Perforated
Edge
Interior
Evergreen
Moist Deciduous
Dry Deciduous
Grass/Scrub
Teak/Bamboo
Water
Open
Built up
Horticulture
Agriculture
Acacia/Eucalyptus
All forests
Kilometers
0 10 20 40 60


LAND USE
1973
2018
FOREST FRAGMENTATION
1973
2018
ALL BASINS
KALI
GANGAVALI
AGHANASHINI
SHARAVATI
Evergreen
Moist Deciduous
Open
Dry Deciduous
Teak/Bamboo
Horticulture
Grass/Scrub
Acacia/Eucalyptus
Agriculture
Built up
Water
Interior
Perforated
Edge
Transitional
Patch

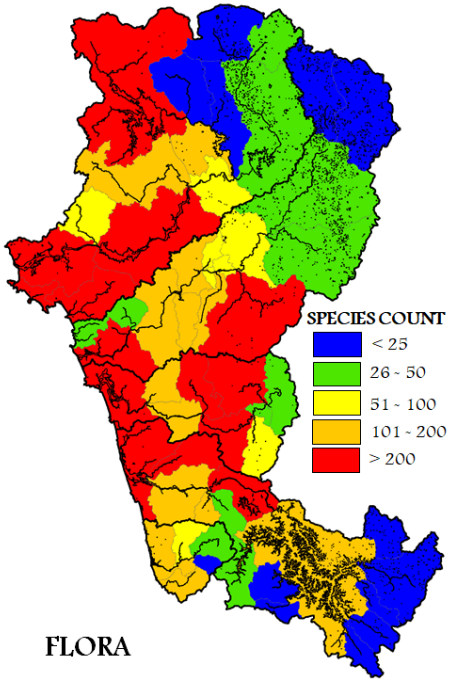

N
ALL BASINS
WATER AVAILABILITY
DEFICIT
SUFFICIENT
SUPPLY
RUNOFF
PIPE FLOW
VADOSE
BASE FLOW
Kilometers
0 10 20 40 60
DEMAND
EVAPOTRANSPIRATION
ECOLOGICAL FLOW
AGRICULTURE
DOMESTIC
LIVESTOCK
KALI
Million Cubic meter
2000
1500
1000
500
0
Kilometers
0 5 10 20 30
GANGAVALI
Million Cubic meter
1000
800
600
400
200
0
Kilometers
0 5 10 20 30
AGHANASHINI
600
400
200
0
Million Cubic meter
Kilometers
0 3.5 7 14 21
SHARAVATI
2000 Million Cubic Meter
1600
1200
800
400
Kilometers
0 5 10 20 30



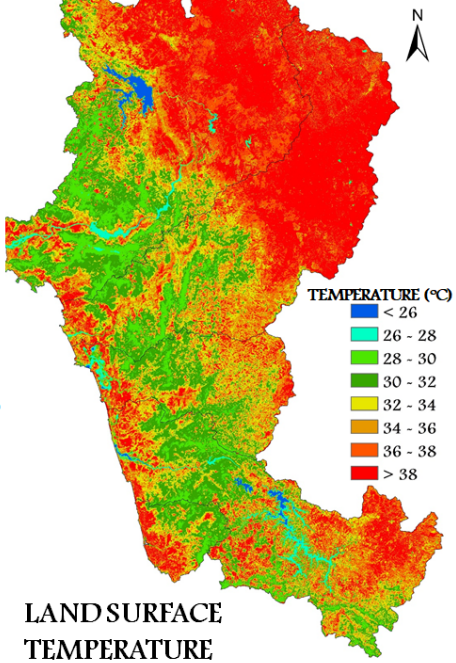
FOREST COVER



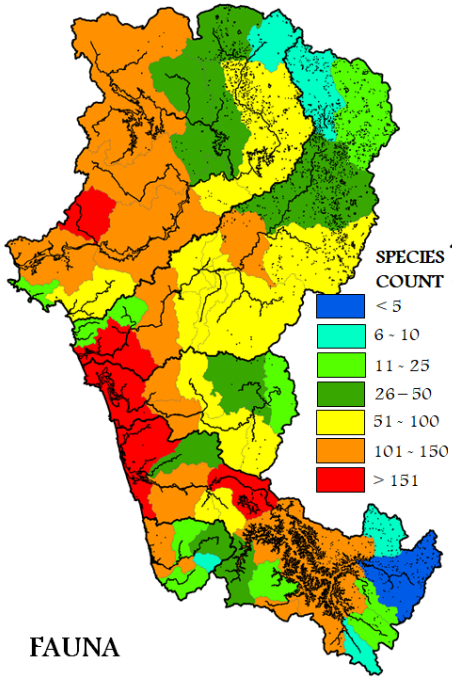
FOREST FRAGMENTATION



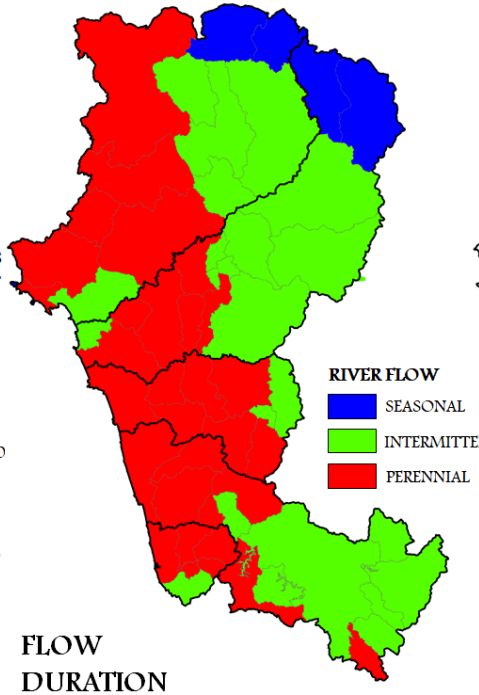
FLORA



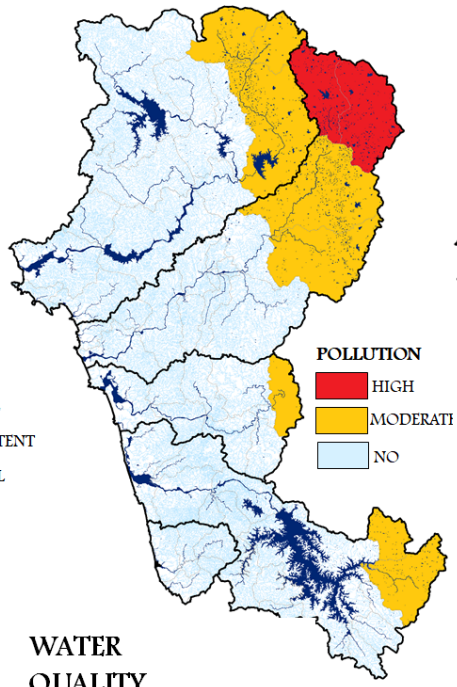
LAND SURFACE TEMPERATURE



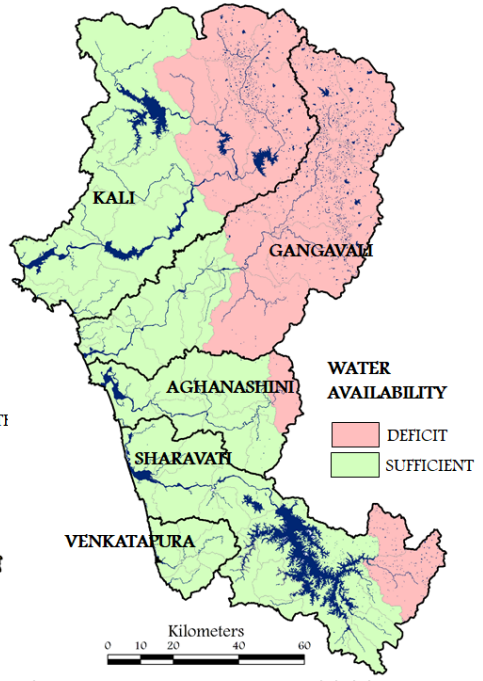
FAUNA



FLOW DURATION



WATER QUALITY



ECO HYDROLOGICAL STATUS

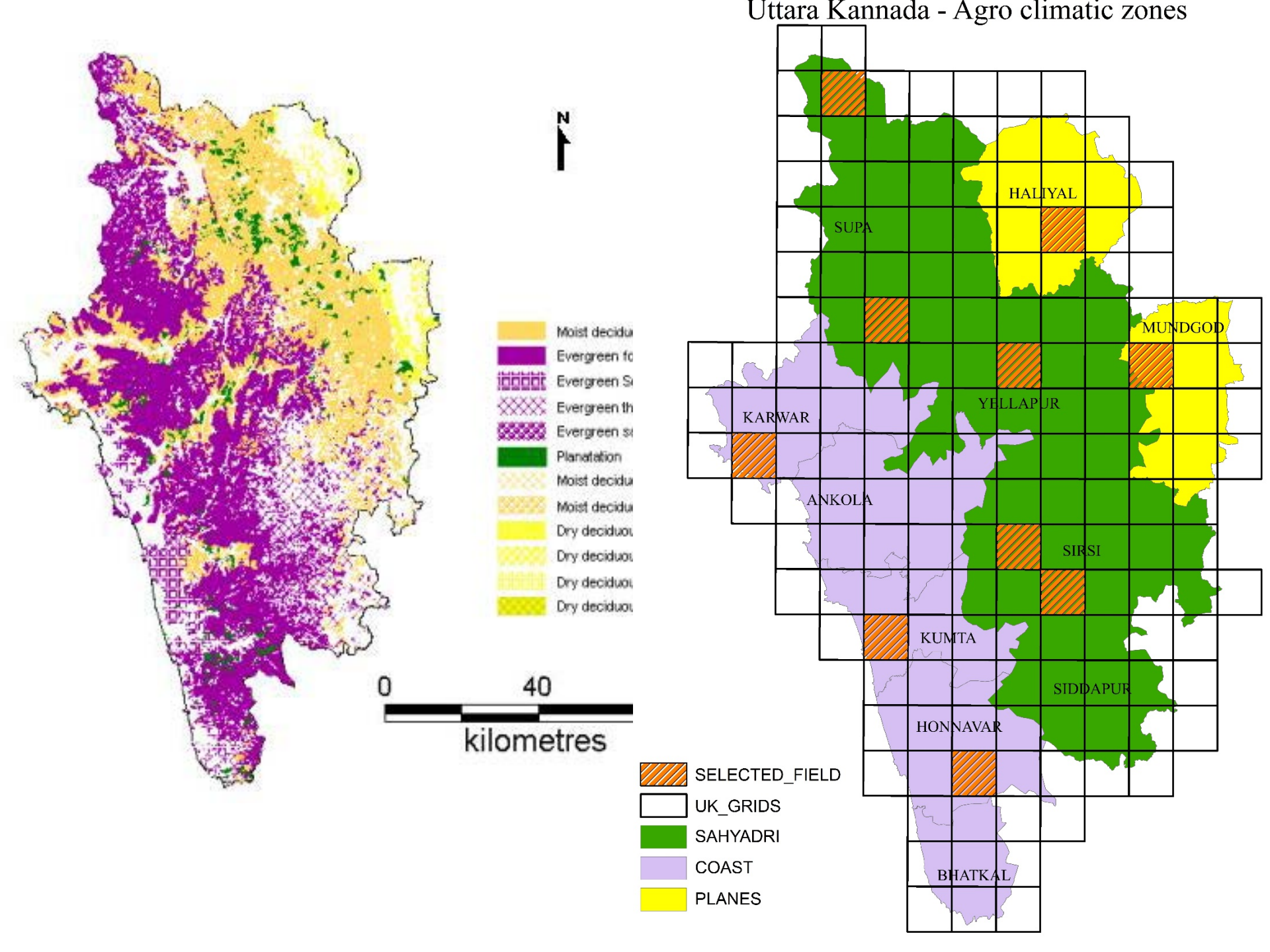
Ecosystem condition indicators

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


Uttara Kannada - Agro climatic zones
N
Moist decidu
Evergreen fo
Evergreen S
Evergreen th
Evergreen s
Planatation
Moist decidu
Moist decidu
Dry deciduou
Dry deciduou
Dry deciduou
Dry deciduou
0
40
kilometres
HALIYAL
SUPA
MUNDGOD
YELLAPUR
KARWAR
ANKOLA
SIRSI
KUMTA
SIDDAPUR
HONNAVAR
BHATKAL
SELECTED_FIELD
UK_GRIDS
SAHYADRI
COAST
PLANES

Biodiversity – inventory, mapping

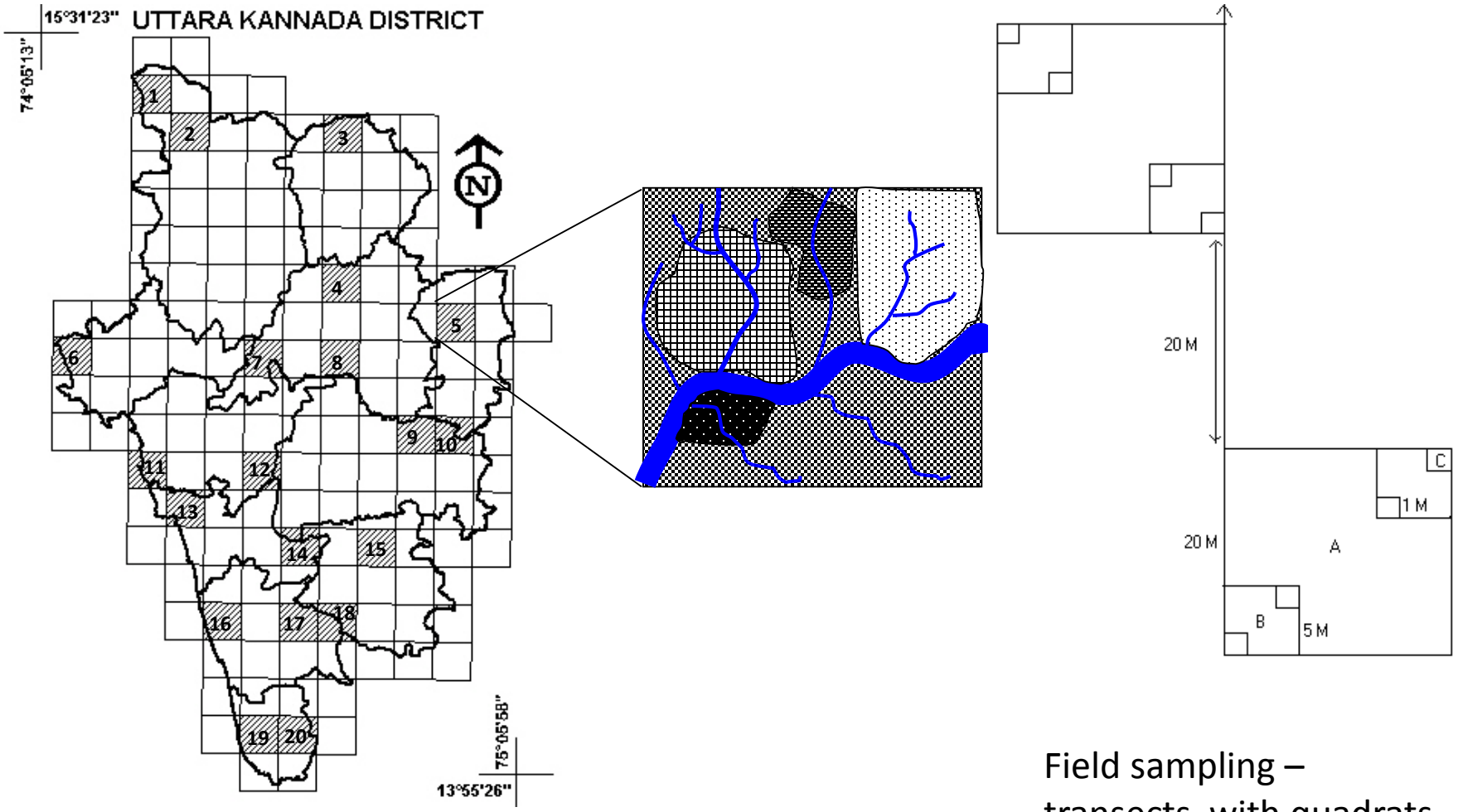
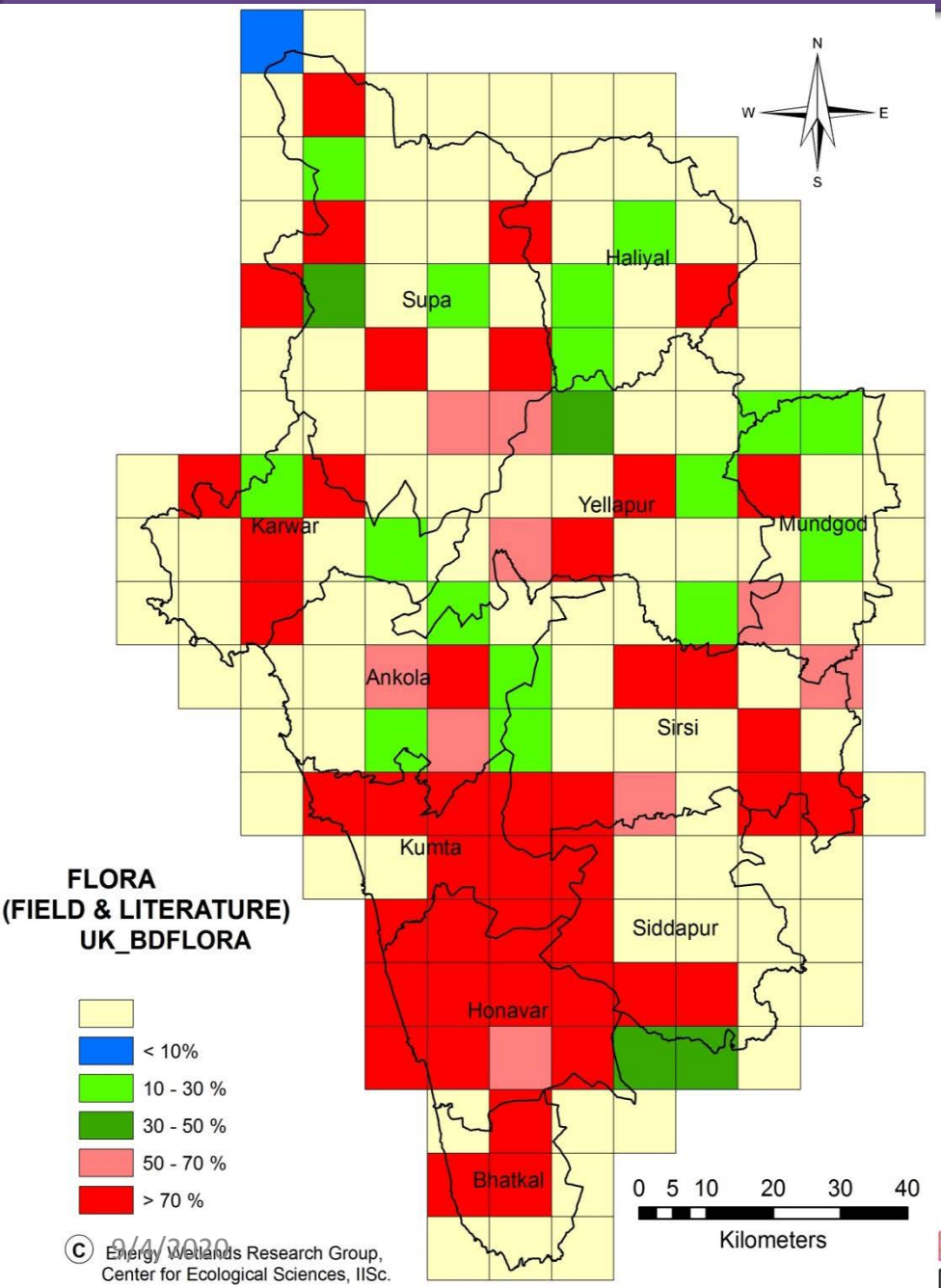
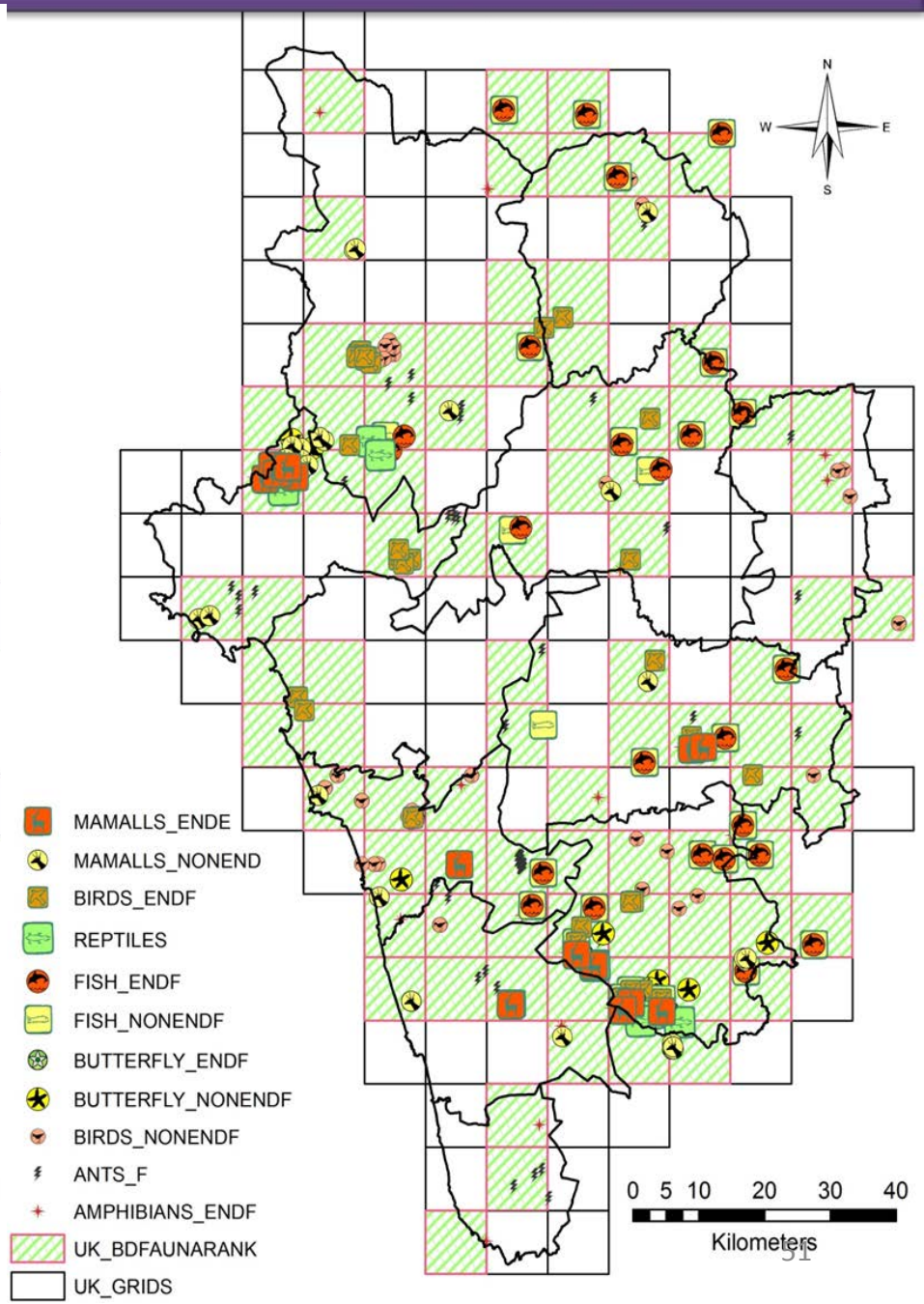


Figure 1. Uttara Kannada district map with study regions (darkened squares) and various landscape elements under consideration

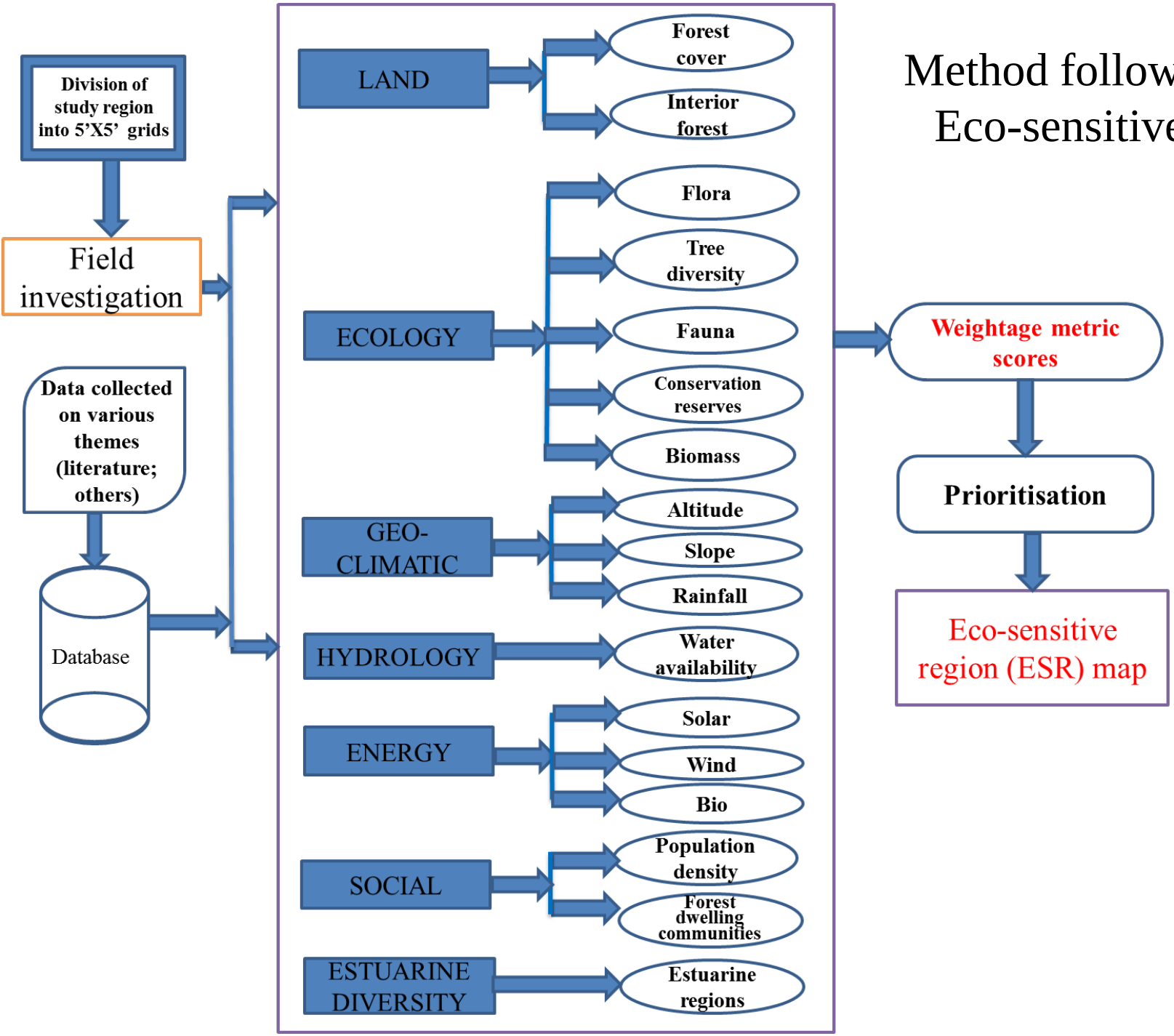
Field sampling –
transects with quadrats
- Species area curve

ENDEMIC FLORA AND FAUNA DATA COLLECTED FROM FIELD





Method followed to map Eco-sensitive regions



S.NO.	Themes	Weightages				
		1	3	5	7	10
1.	**LAND**					
	Land use	FC<20%	20<FC<40%	40<FC<60%	60<FC <80%	FC > 80%
	Interior forest	IF<20%	20<IF<40%	40<IF<60%	60<IF<80%	IF> 80%
2.	**ECOLOGY**					
	Flora	NEND	END<30%	30<END<50%	50<END<70%	END>70%
	Tree diversity	SHD<2	2<SHD<2.5	2.5 <SHD<2.7	2.7<SHD<3	SHD>3
	Fauna	-	NEND	-	-	END
	Conservation reserves (CR)	-	-	-	-	National parks, Wild life reserves, Myristica swamps, Sanctuaries
	Biomass (Gg)	BM<250	250<BM<500	500<BM<750	750<BM<1000	BM>1000
3	**GEO-CLIMATIC**					
	Altitude					
	Slope	-	-	-	Slope > 20%	Slope > 30%
	Precipitation	-	1000>RF> 2000 mm	2000>RF> 3000 mm	3000>RF> 2000 mm	RF> 4000 mm
4.	**HYDROLOGY**					
	Stream flow	WA<4	4<WA<6	6<WA<9	9<WA<12	WA=12
5.	**ENERGY**					
	Solar	-	-	<5 KWh/m^2/day	5-6 KWh/m^2/day	6-6.5 KWh/m^2/day
	Wind	-	-	2.4 to 2.55 m/s	2.5 to 2.6 m/s	2.6 to 2.7 m/s
	Bio	SD<1	SD>1	1>SD<2	2<SD<3	SD>3
6.	**SOCIAL**					
	Population density (PD)	PD>200	100<PD<200	100<PD<150	50<PD<100	PD<50
	Forest dwelling communities (Tribes)		-		Tribes are present then assigned 10; if no tribal population exists, then assigned as 0	
7.	**ESTUARINE DIVERSITY**					
	Estuarine regions	-	low	moderate	high	very high

FC-forest cover; IF-interior forest cover; END-endemic; NEND-non-endemic; BM-biomass; SD-supply to demand ratio; WA-Water availability; RF- rainfall

The weightage is defined as shown equation

$$Weighatge = \sum_{i=1}^{n} W_i V_i$$

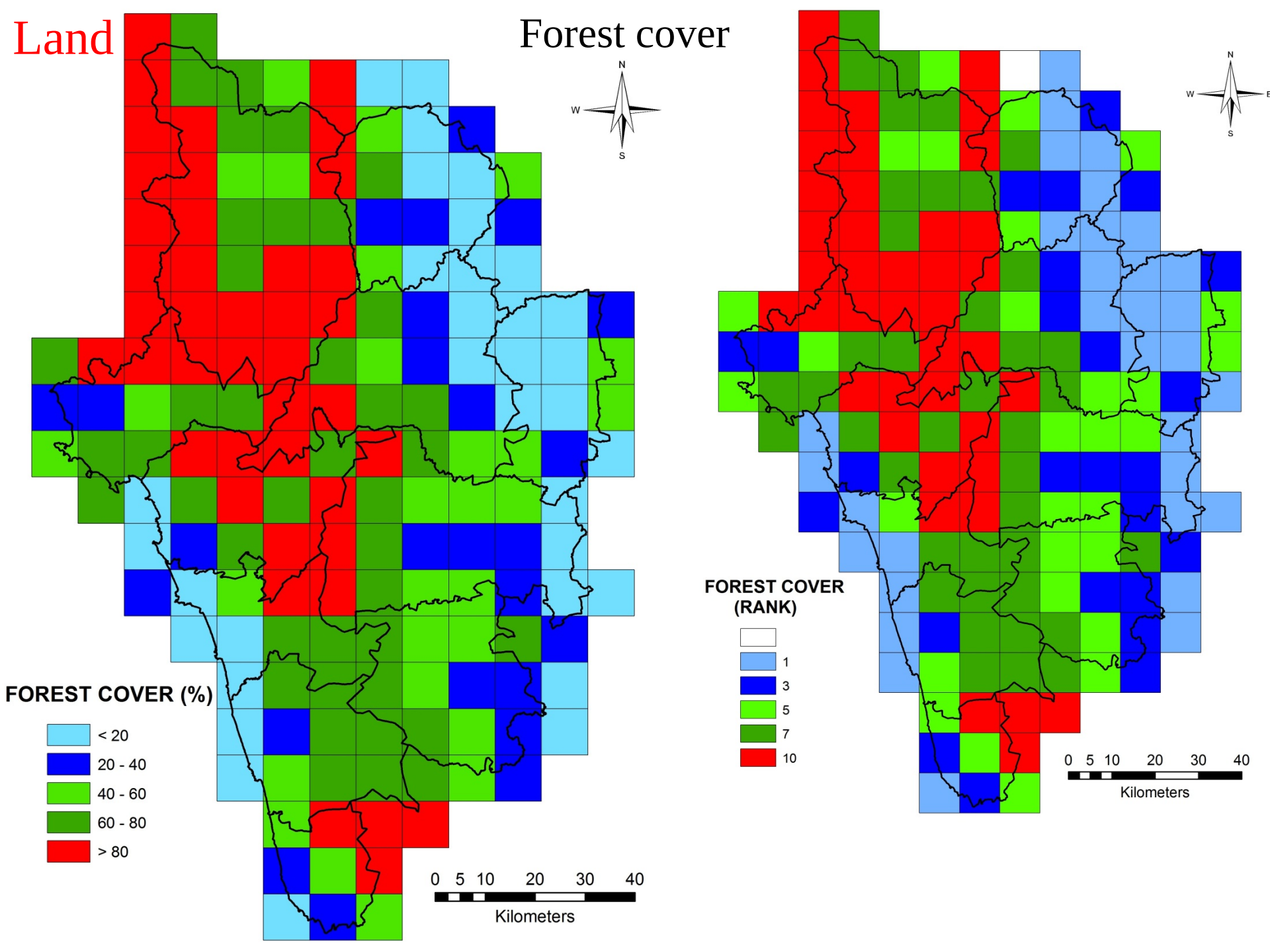
- Where n is the number of data sets, V_i is the value associated with criterion i, and wi is the weight associated to that criterion.

- The table expresses the theme wise decision variable considered and their significance. Each criterion is described by an indicator mapped to a value normalised between 10 to 1.

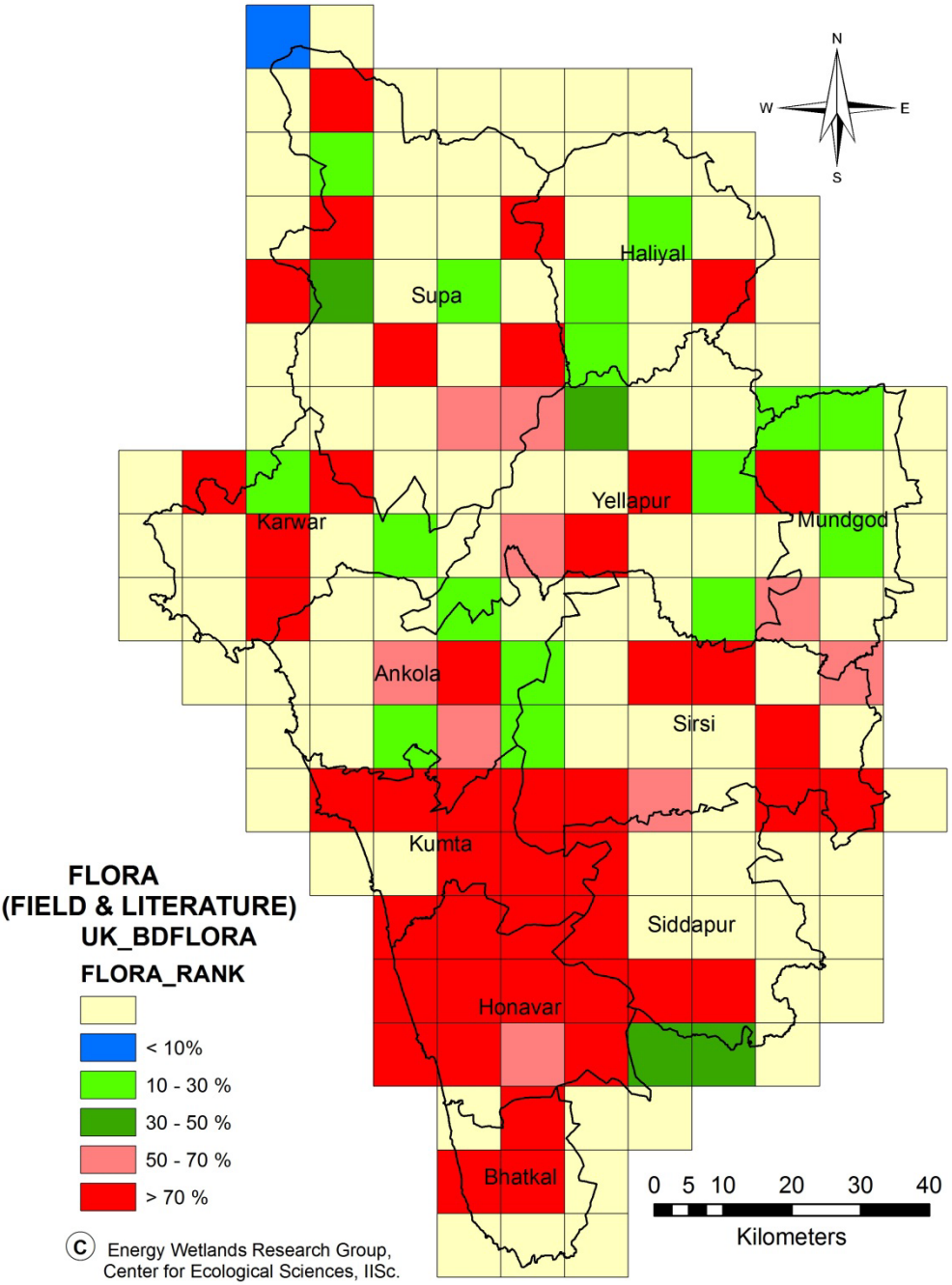
- The value 10 corresponds to very higher priority for conservation whereas 1 is converse to above. The value 7, 5 and 3 corresponds to high, moderate levels of conservation.

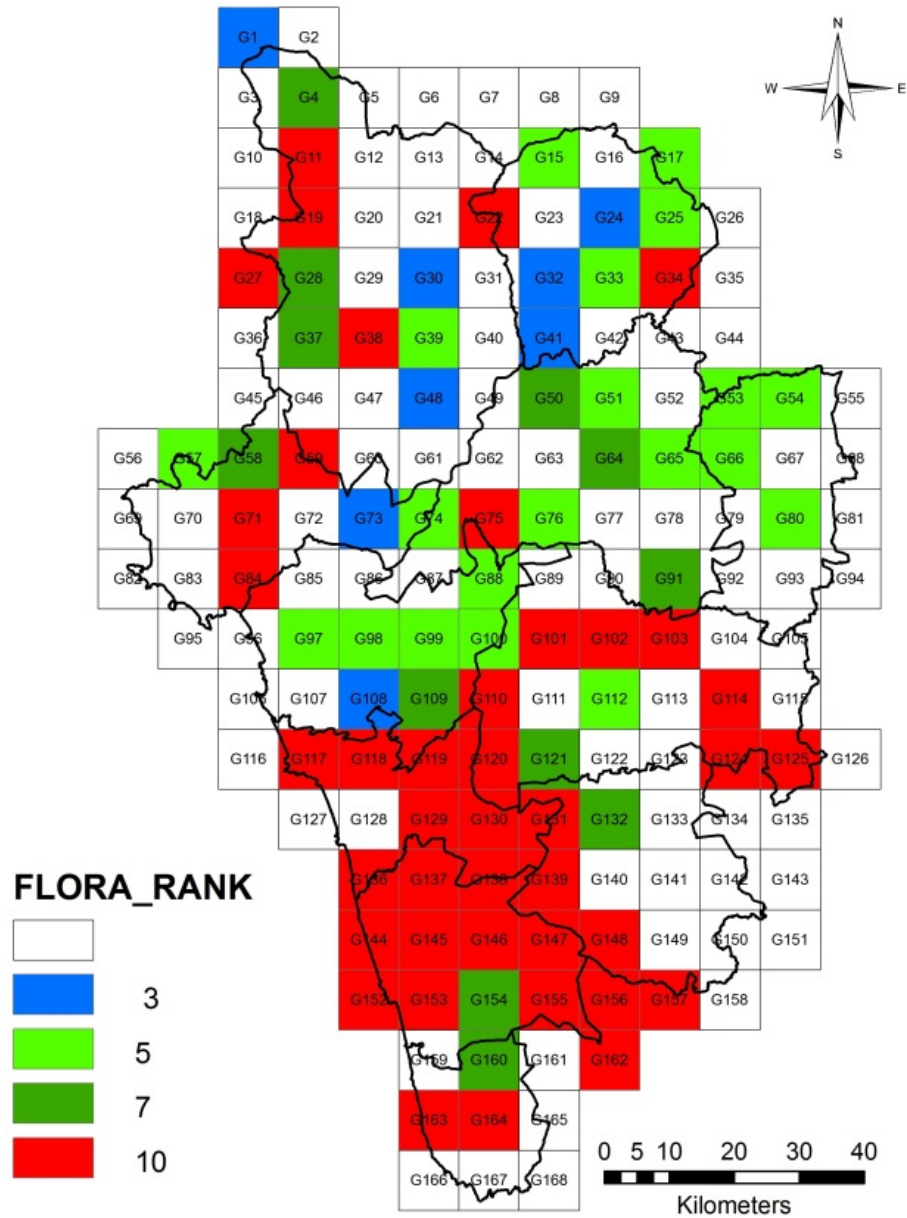
Land

Forest cover

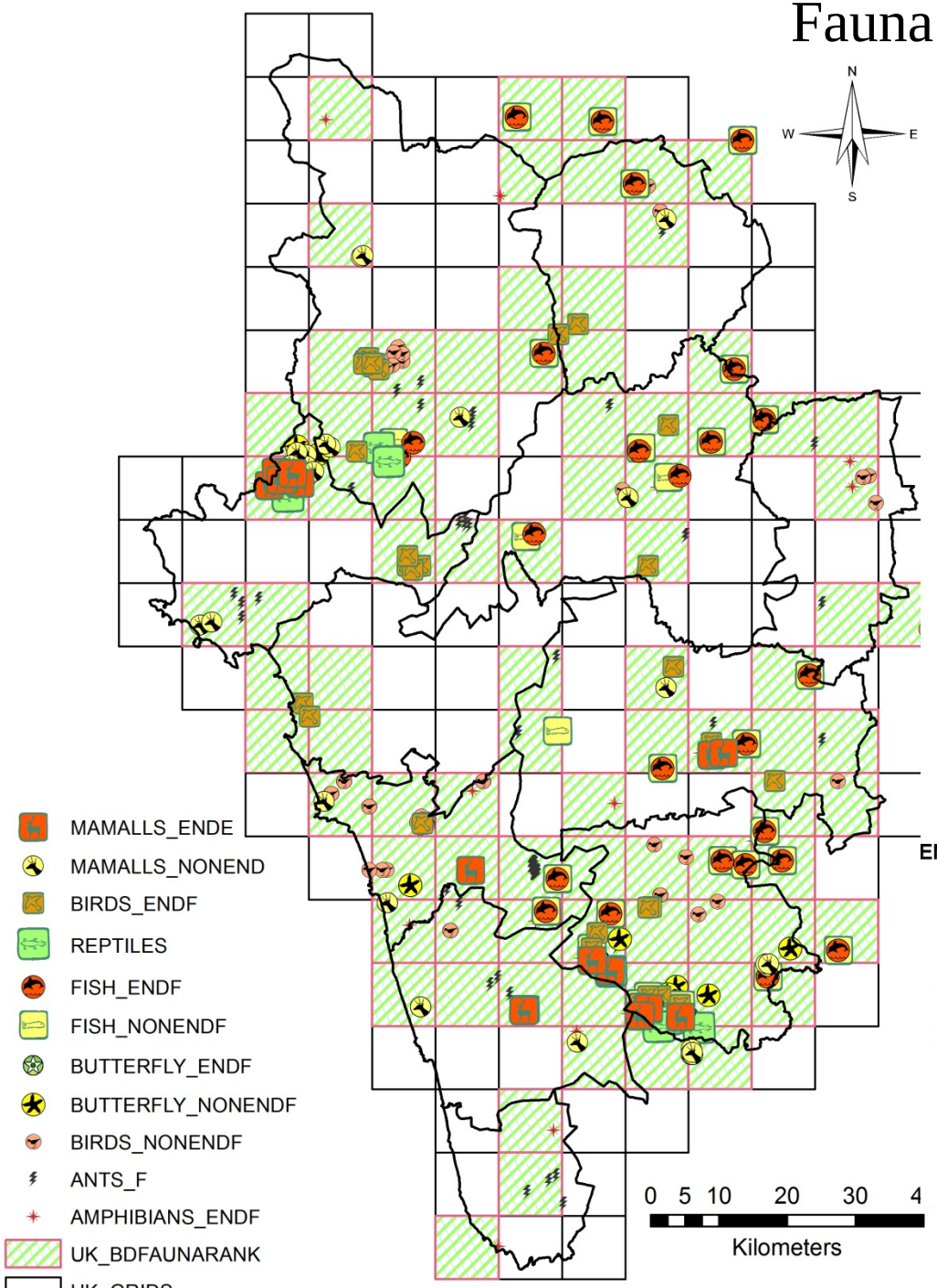


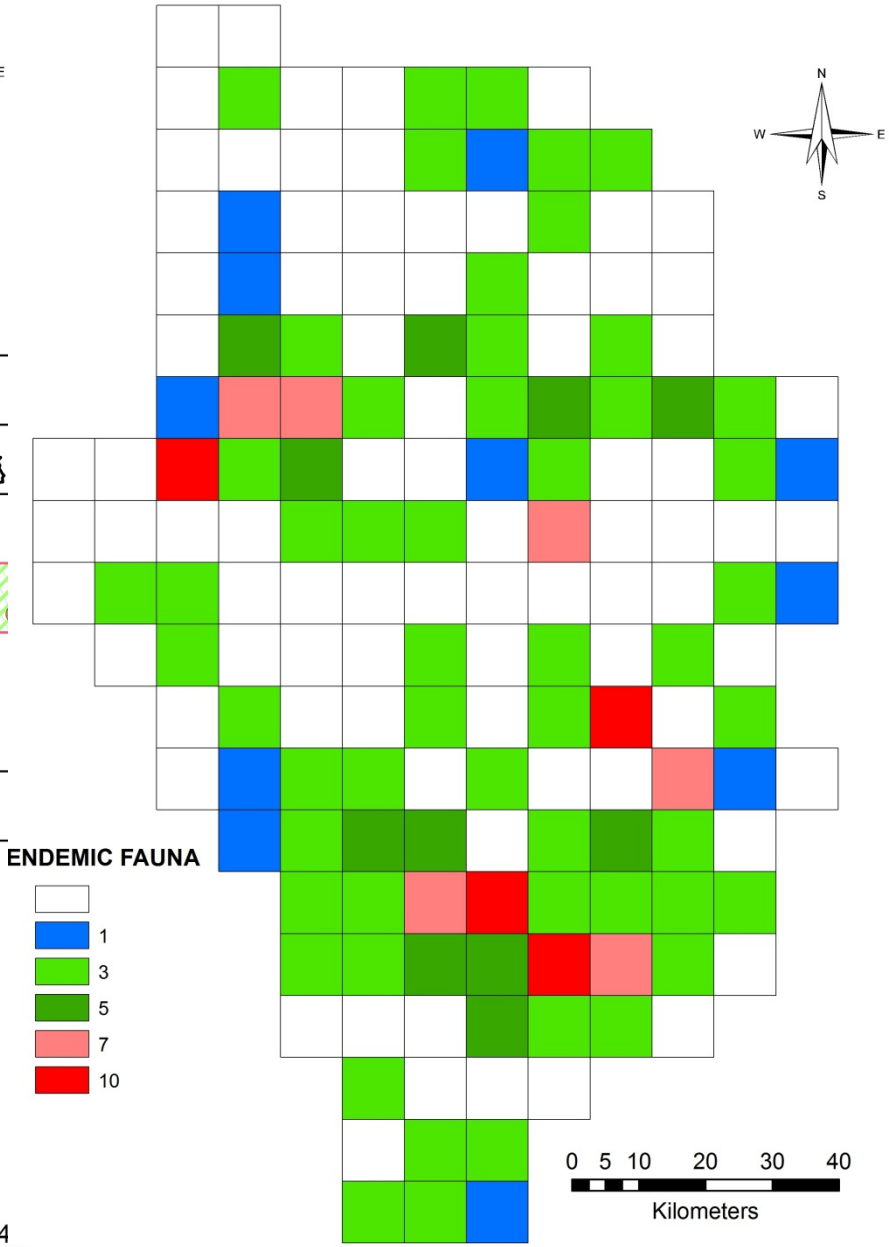
Flora


N
W
E
S
Haliyal
Supa
Karwar
Yellapur
Mundgod
Ankola
Sirsi
Kumta
Siddapur
Honavar
Bhatkal
0 5 10 20 30 40
Kilometers
FLORA
(FIELD & LITERATURE)
UK_BDFLORA
FLORA_RANK
< 10%
10 - 30 %
30 - 50 %
50 - 70 %
> 70 %
© Energy Wetlands Research Group,
Center for Ecological Sciences, IISc.

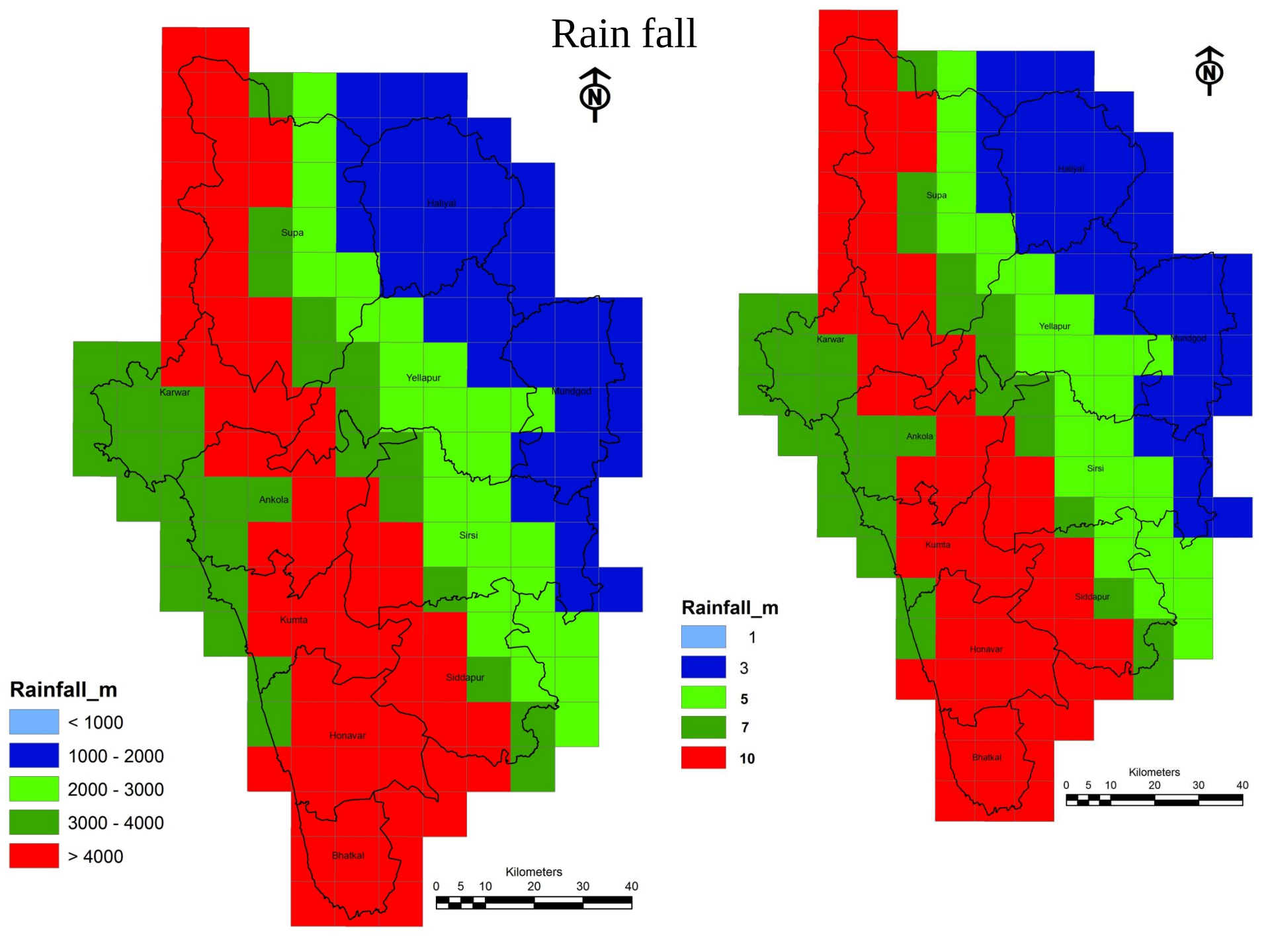

N
W
E
S
FLORA_RANK
3
5
7
10
0 5 10 20 30 40
Kilometers

Fauna

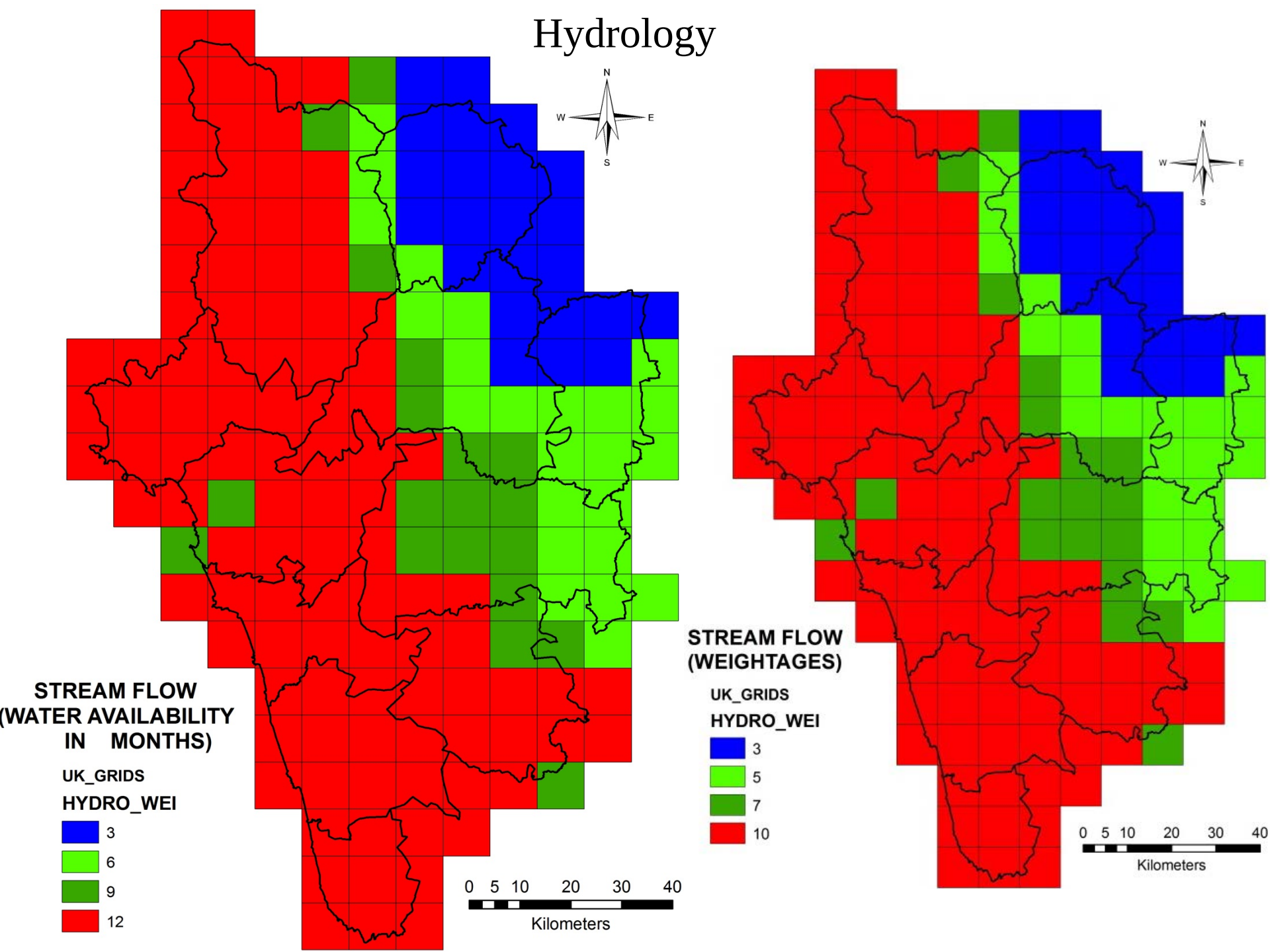

N
W
E
S
MAMALLS_ENDE
MAMALLS_NONEND
BIRDS_ENDF
REPTILES
FISH_ENDF
FISH_NONENDF
BUTTERFLY_ENDF
BUTTERFLY_NONENDF
BIRDS_NONENDF
ANTS_F
AMPHIBIANS_ENDF
UK_BDFAUNARANK
UK_GRIDS
0 5 10 20 30 4
Kilometers

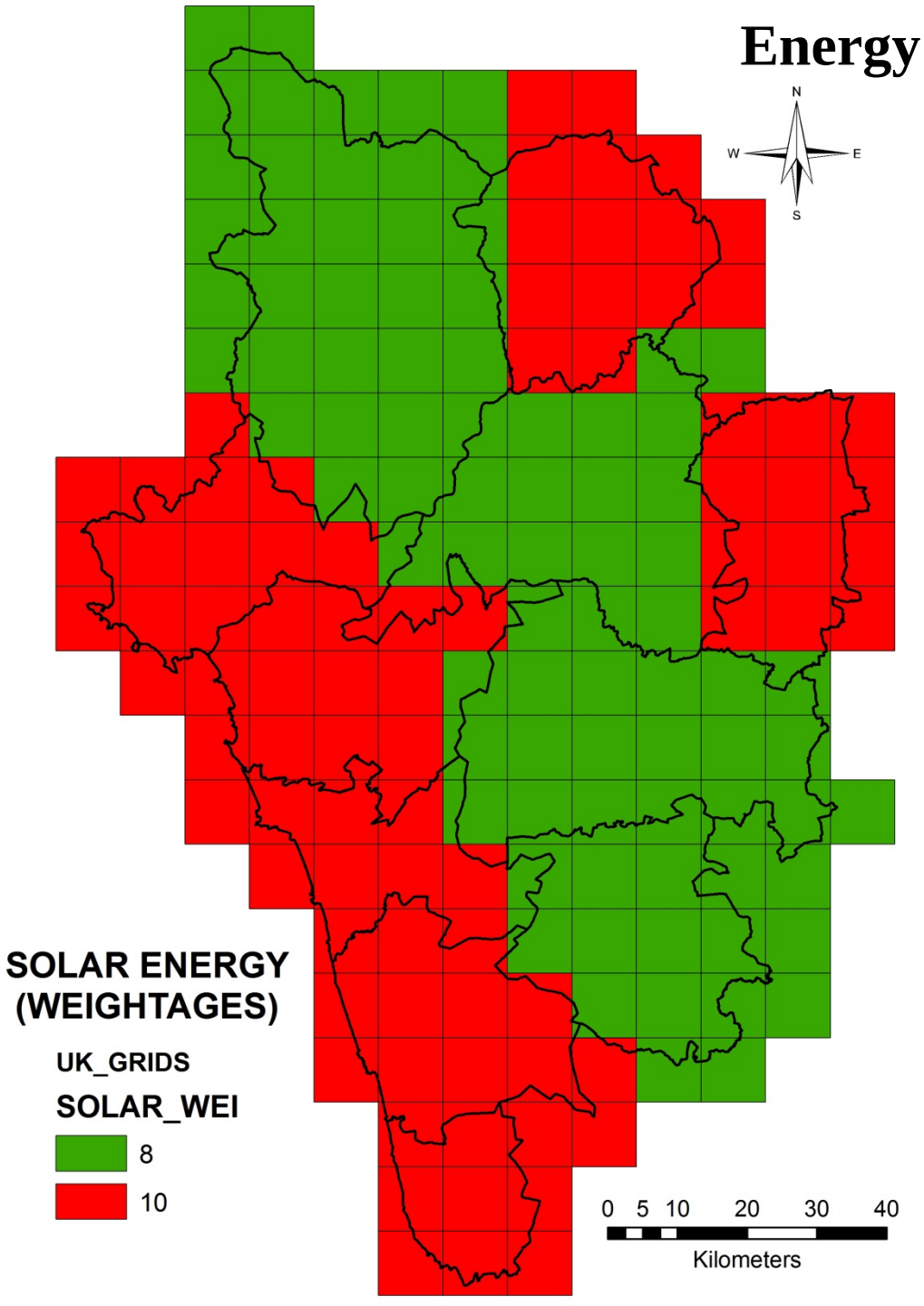

N
W
E
S
ENDEMIC FAUNA
1
3
5
7
10
0 5 10 20 30 40
Kilometers

Rain fall


Haliyal
Supa
Karwar
Yellapur
Mundgod
Ankola
Sirsi
Kumta
Siddapur
Honavar
Bhatkal
Rainfall_m
< 1000
1000 - 2000
2000 - 3000
3000 - 4000
> 4000
Kilometers
0 5 10 20 30 40
Rainfall_m
1
3
5
7
10
Kilometers
0 5 10 20 30 40

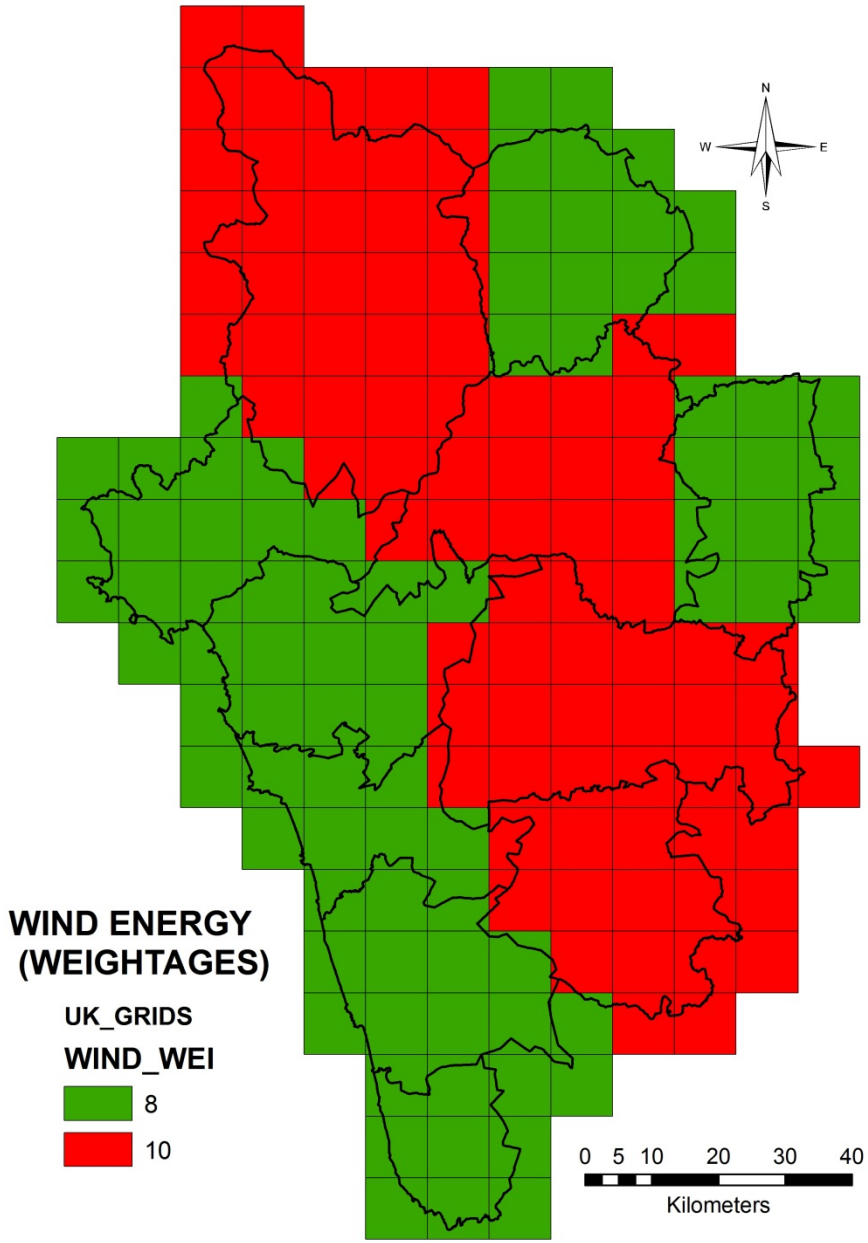
Hydrology


N
W
E
S
STREAM FLOW
(WATER AVAILABILITY
IN MONTHS)
UK_GRIDS
HYDRO_WEI
3
6
9
12
0 5 10 20 30 40
Kilometers
STREAM FLOW
(WEIGHTAGES)
UK_GRIDS
HYDRO_WEI
3
5
7
10
0 5 10 20 30 40
Kilometers

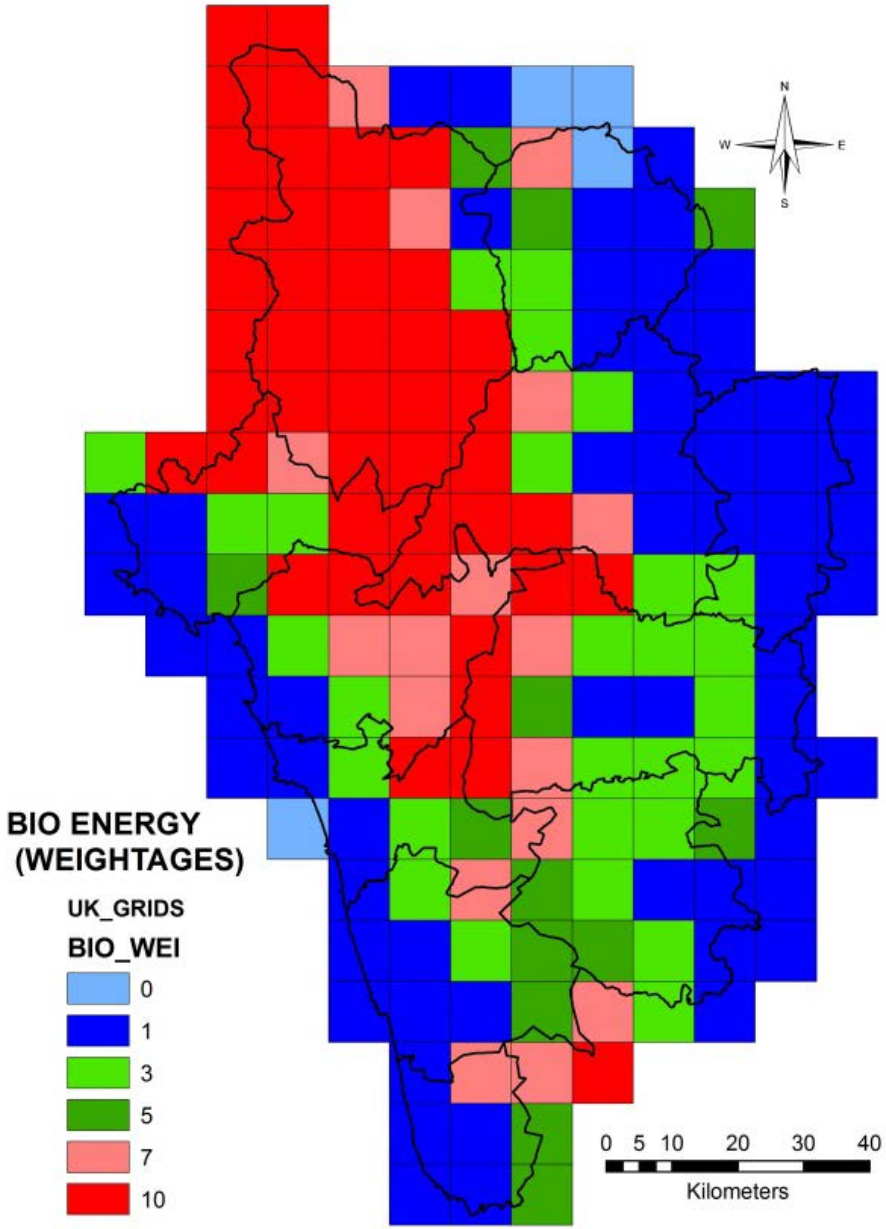


Solar energy

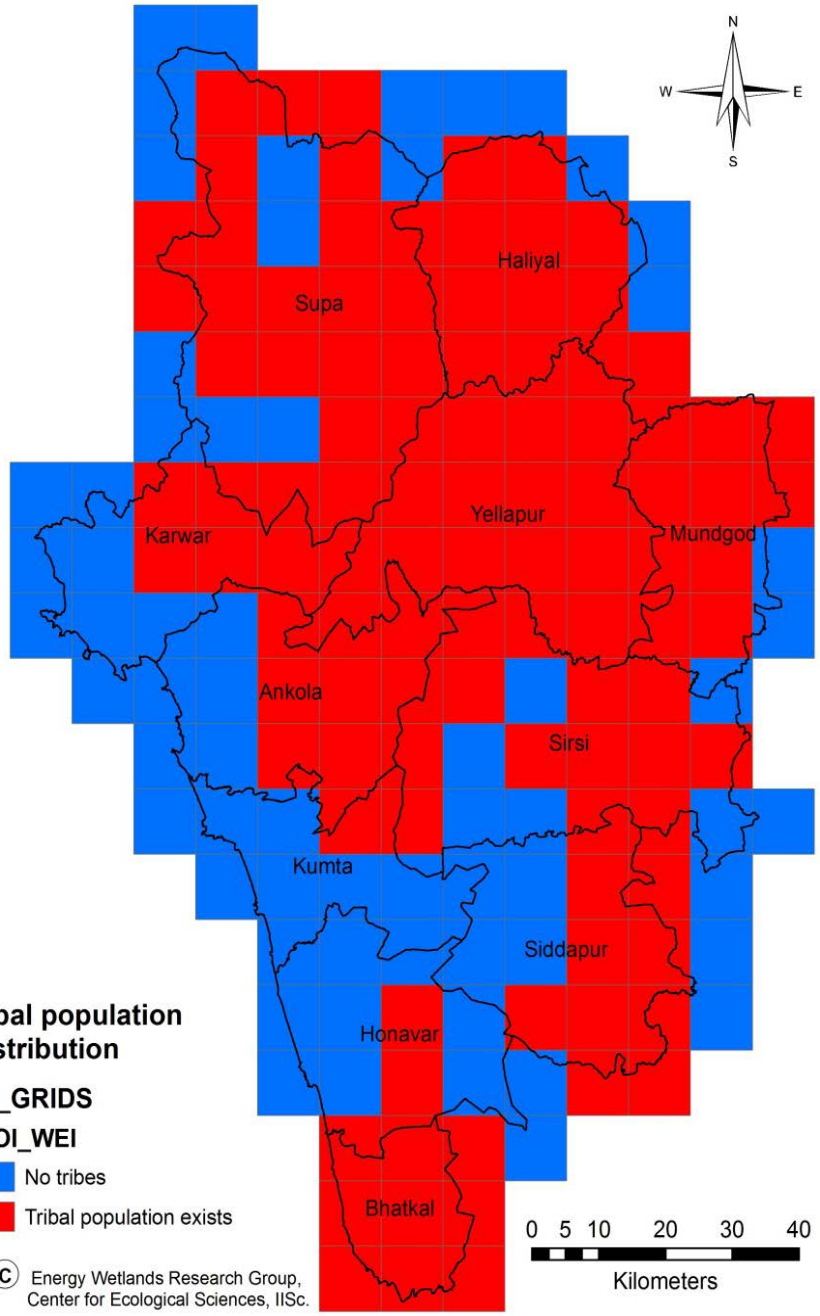
Wind energy

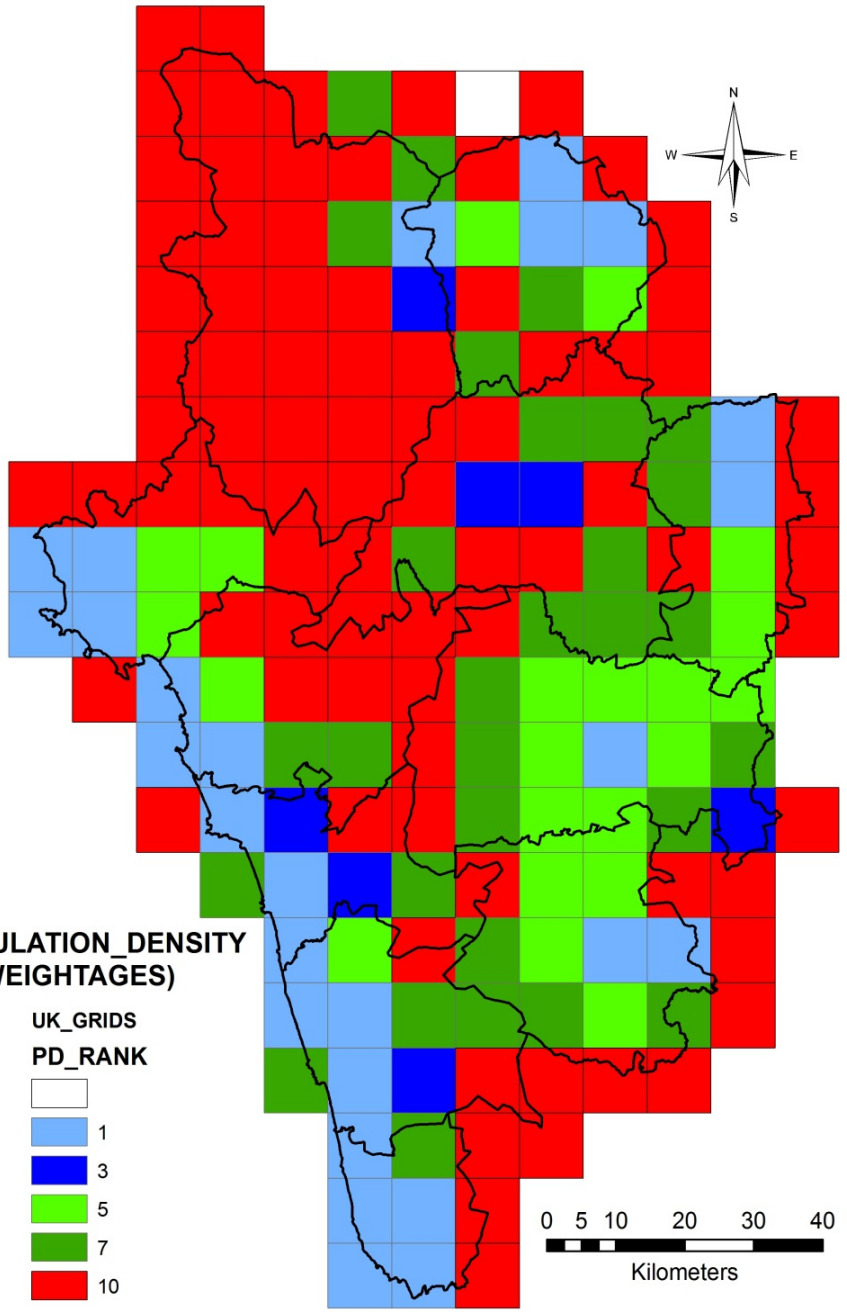


Bio energy

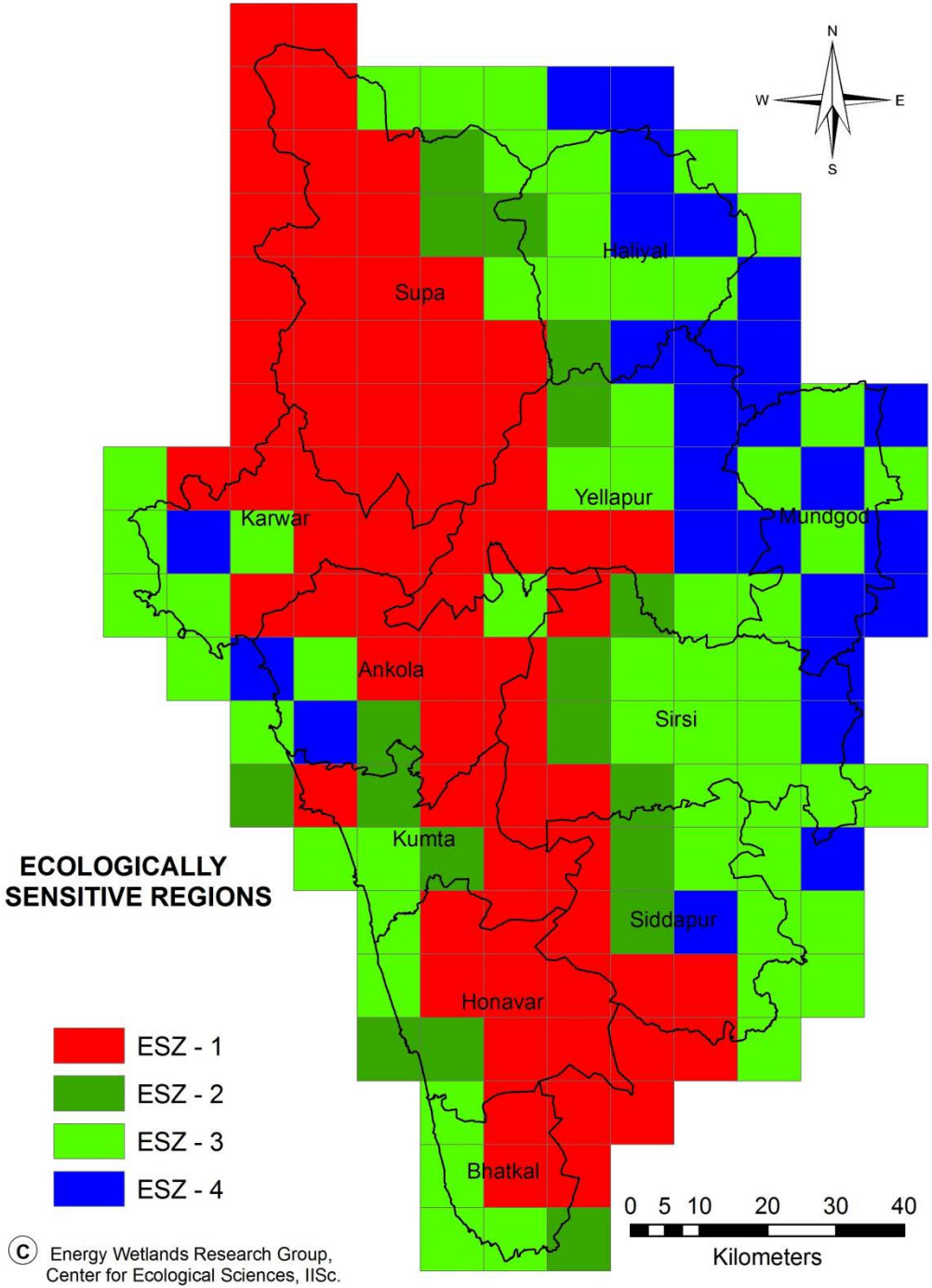


Social aspects

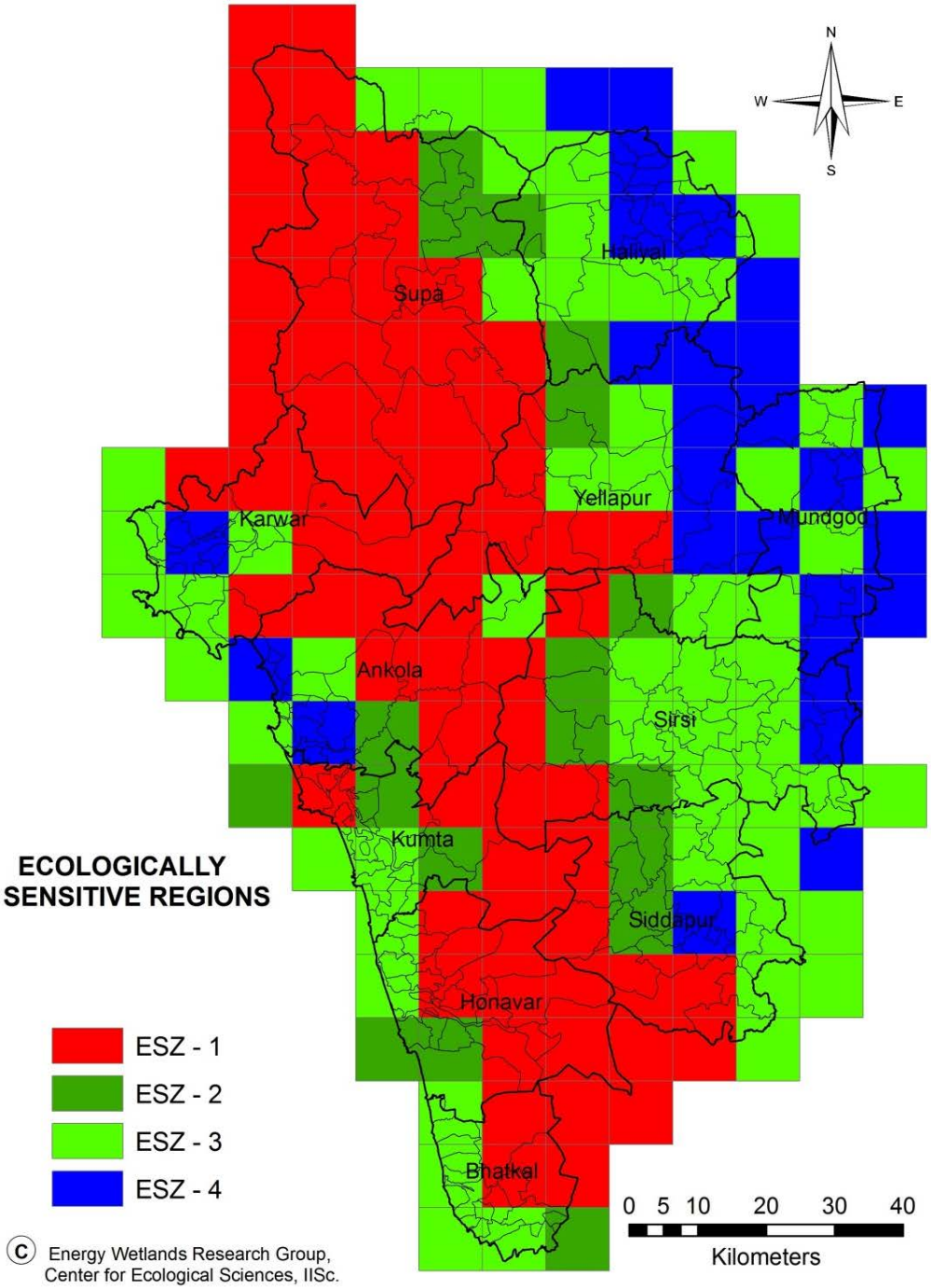




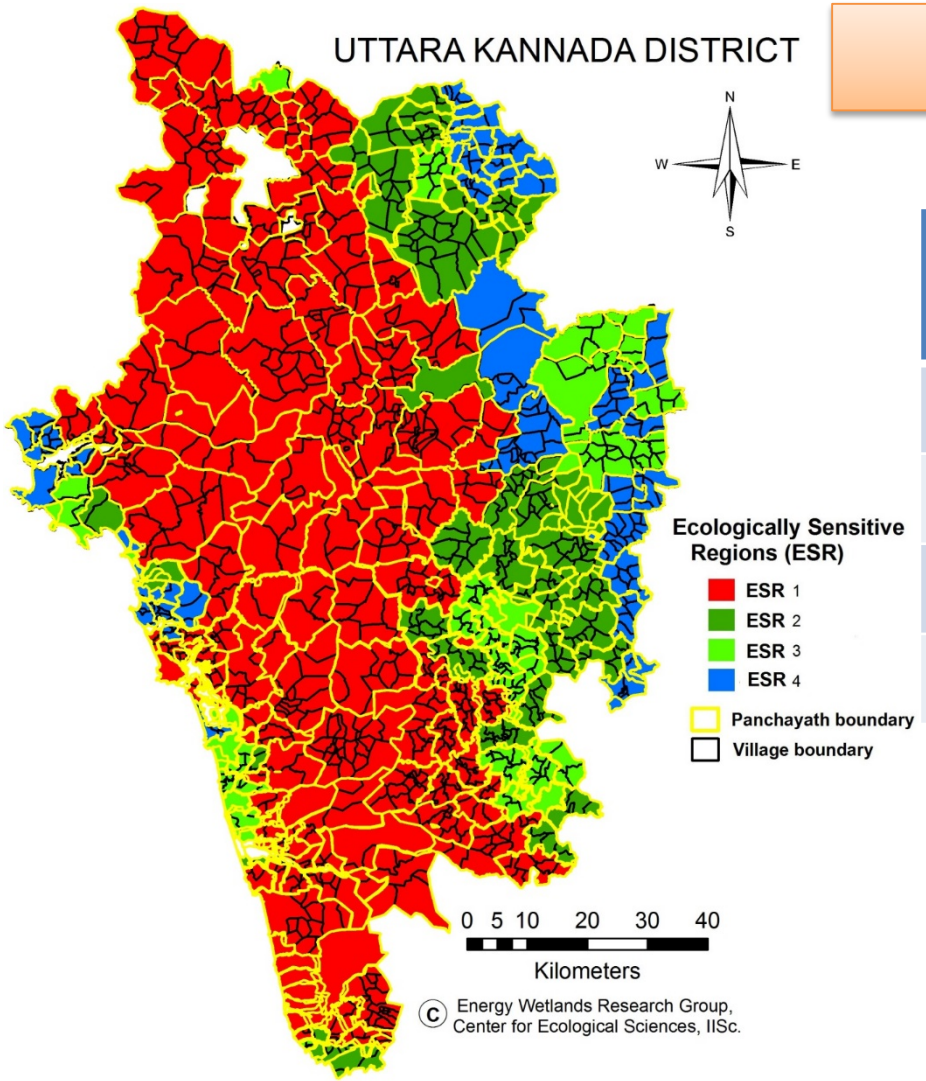
Ecological sensitive region map



Ecological sensitive regions - Panchayats

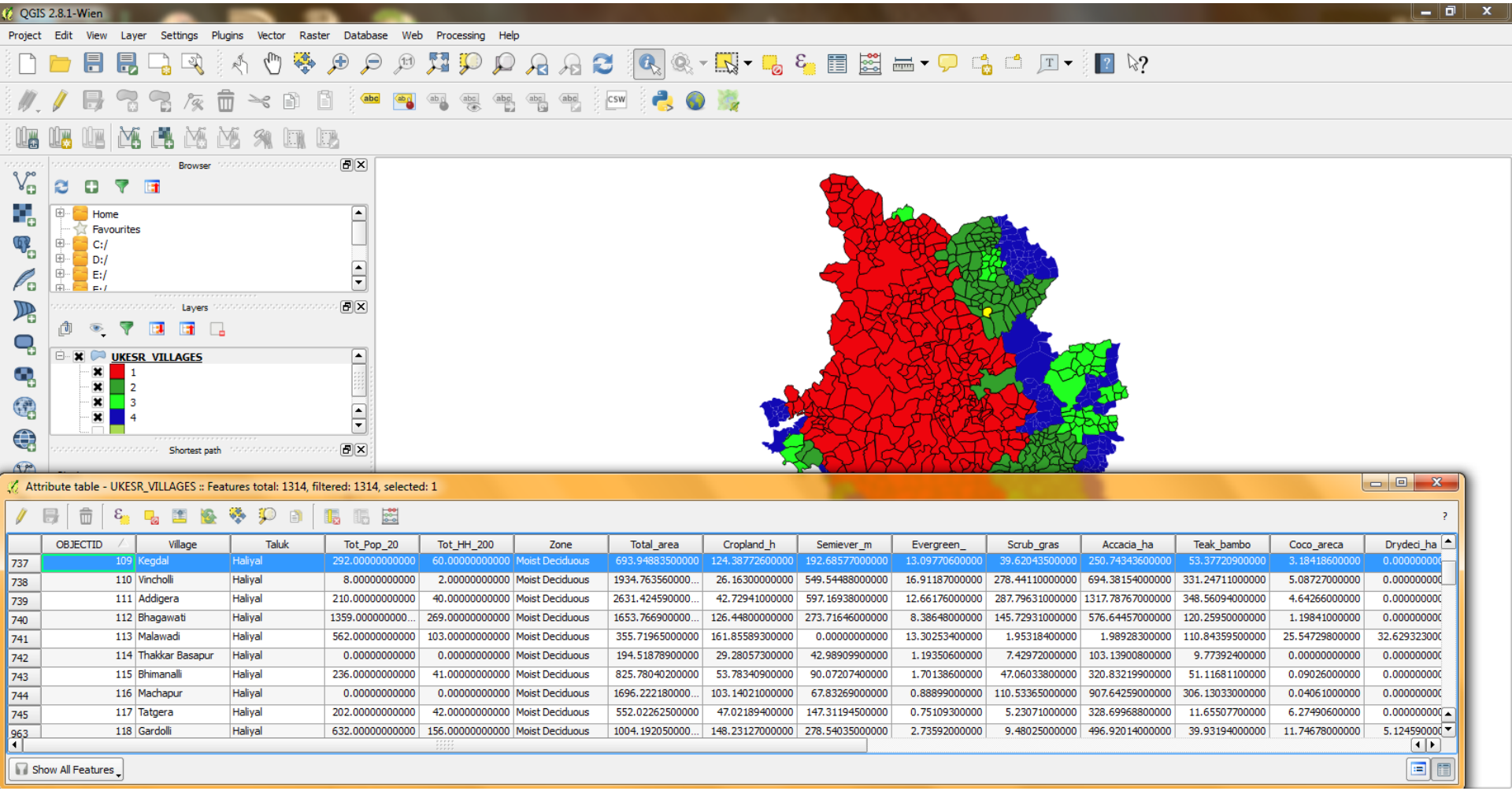


ESR	NO OF PANCHAYATS
ESZ - 1	102
ESZ - 2	68
ESZ - 3	170
ESZ - 4	40



Ecological sensitive regions – Village level

ESR	NO OF VILLAGES
ESR - 1	684
ESR - 2	184
ESR - 3	133
ESR- 4	304

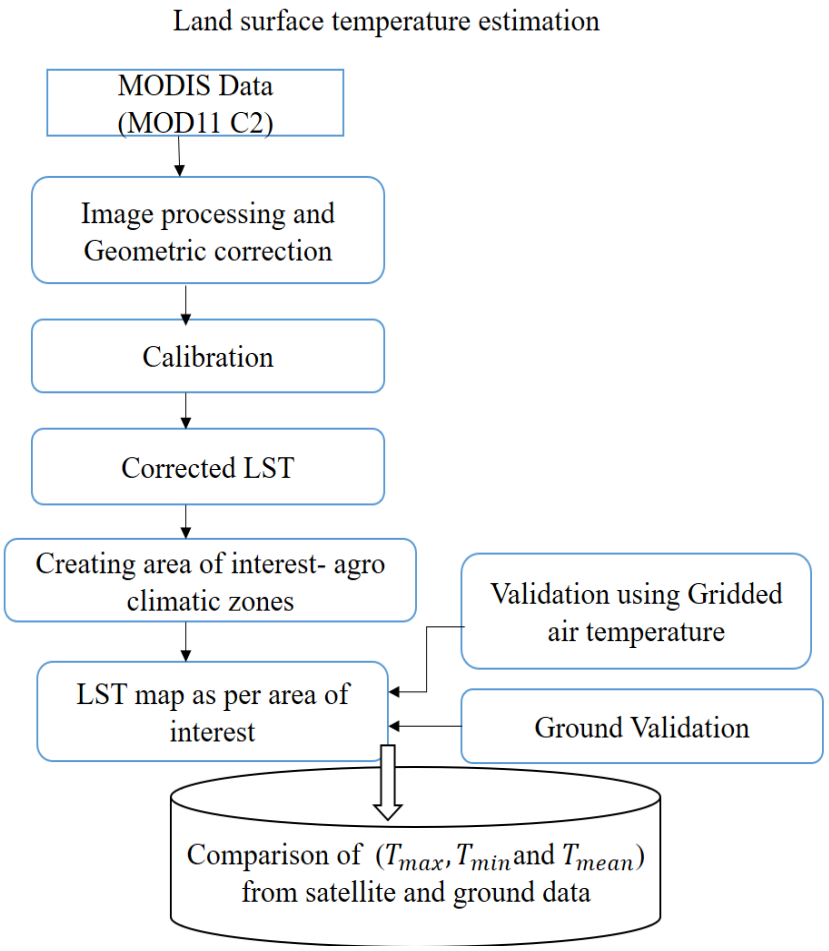


	OBJECTID	Village	Taluk	Tot_Pop_20	Tot_HH_200	Zone	Total_area	Cropland_h	Semiever_m	Evergreen_	Scrub_gras	Accacia_ha	Teak_bambo	Coco_areca	Drydeci_ha
737	109	Kegdal	Haliyal	292.00000000000	60.00000000000	Moist Deciduous	693.94883500000	124.38772600000	192.68577000000	13.09770600000	39.62043500000	250.74343600000	53.37720900000	3.18418600000	0.00000000
738	110	Vincholli	Haliyal	8.00000000000	2.00000000000	Moist Deciduous	1934.763560000...	26.16300000000	549.54488000000	16.91187000000	278.44110000000	694.38154000000	331.24711000000	5.08727000000	0.00000000
739	111	Addigera	Haliyal	210.00000000000	40.00000000000	Moist Deciduous	2631.424590000...	42.72941000000	597.16938000000	12.66176000000	287.79631000000	1317.78767000000	348.56094000000	4.64266000000	0.00000000
740	112	Bhagawati	Haliyal	1359.000000000...	269.00000000000	Moist Deciduous	1653.766900000...	126.44800000000	273.71646000000	8.38648000000	145.72931000000	576.64457000000	120.25950000000	1.19841000000	0.00000000
741	113	Malawadi	Haliyal	562.00000000000	103.00000000000	Moist Deciduous	355.71965000000	161.85589300000	0.00000000000	13.30253400000	1.95318400000	1.98928300000	110.84359500000	25.54729800000	32.62932300
742	114	Thakkar Basapur	Haliyal	0.00000000000	0.00000000000	Moist Deciduous	194.51878900000	29.28057300000	42.98909900000	1.19350600000	7.42972000000	103.13900800000	9.77392400000	0.00000000000	0.00000000
743	115	Bhimanalli	Haliyal	236.00000000000	41.00000000000	Moist Deciduous	825.78040200000	53.78340900000	90.07207400000	1.70138600000	47.06033800000	320.83219900000	51.11681100000	0.09026000000	0.00000000
744	116	Machapur	Haliyal	0.00000000000	0.00000000000	Moist Deciduous	1696.222180000...	103.14021000000	67.83269000000	0.88899000000	110.53365000000	907.64259000000	306.13033000000	0.04061000000	0.00000000
745	117	Tatgera	Haliyal	202.00000000000	42.00000000000	Moist Deciduous	552.02262500000	47.02189400000	147.31194500000	0.75109300000	5.23071000000	328.69968800000	11.65507700000	6.27490600000	0.00000000
963	118	Gardolli	Haliyal	632.00000000000	156.00000000000	Moist Deciduous	1004.192050000...	148.23127000000	278.54035000000	2.73592000000	9.48025000000	496.92014000000	39.93194000000	11.74678000000	5.12459000

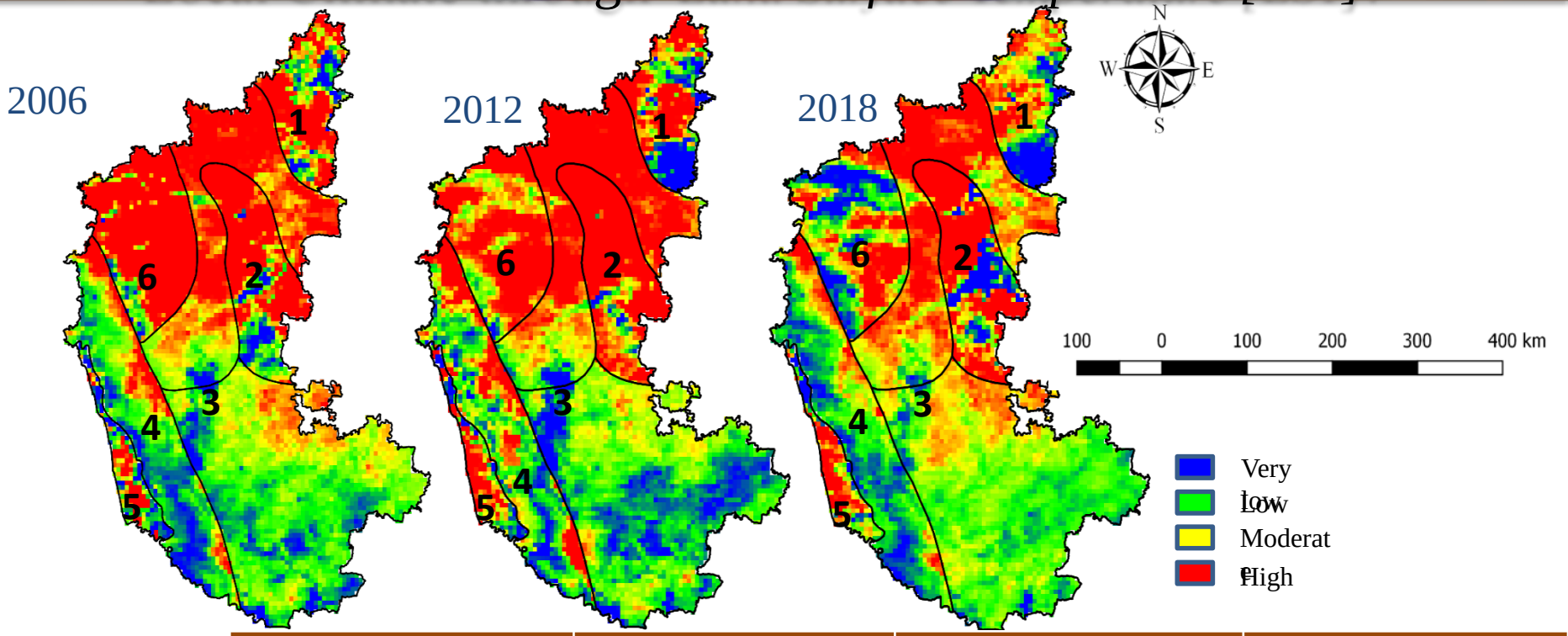
Regulating Services:
Local Climate through *Land Surface Temperature [LST]:*

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]:*

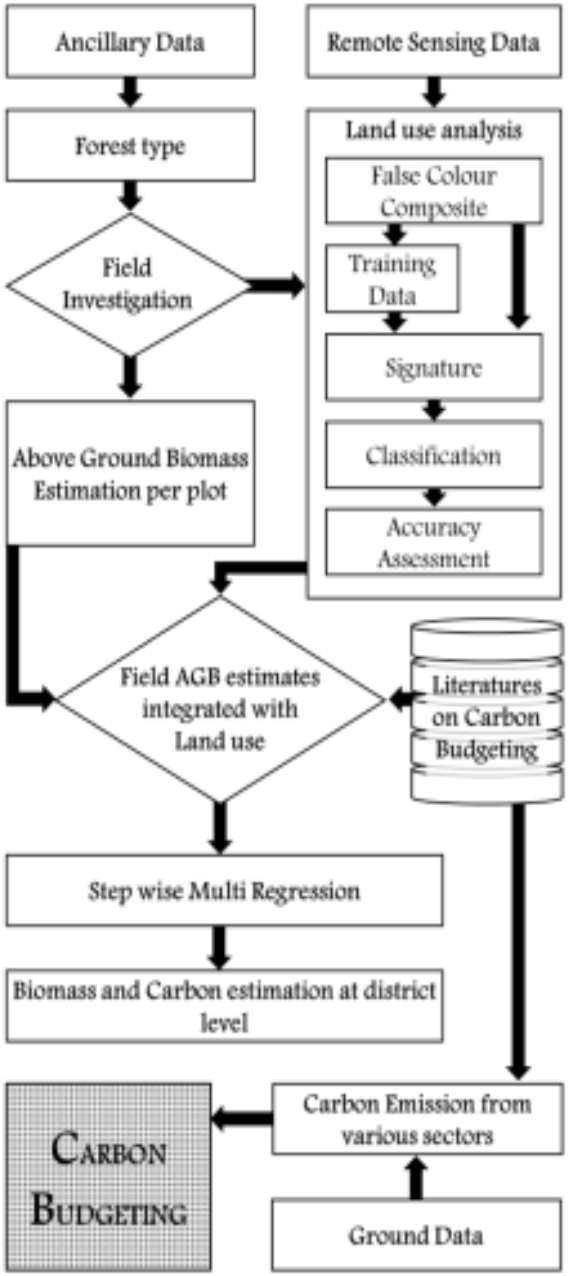


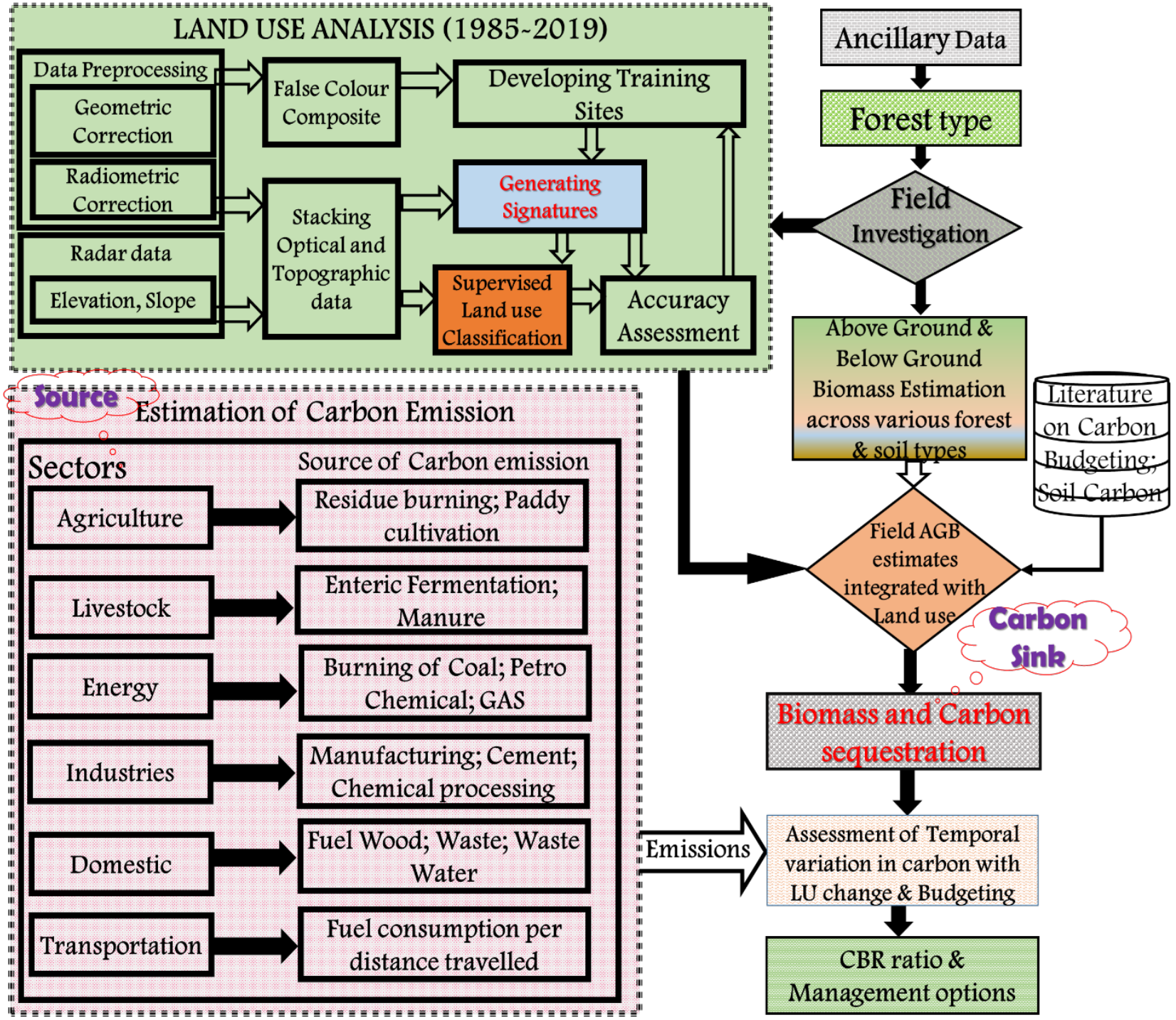
Agro-climatic regions	2006			2012			2018		
	Min	Max	**Mean**	Min	Max	**Mean**	Min	Max	**Mean**
Hot dry semi arid (1)	38.55	41.92	**40.24**	40.35	43.5	**41.925**	43.27	48.46	**45.865**
Arid (2)	33.57	38.08	**35.825**	29.39	33.88	**31.635**	37.21	41.25	**39.23**
Hot moist semi arid (3)	26.91	41.58	**34.245**	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**

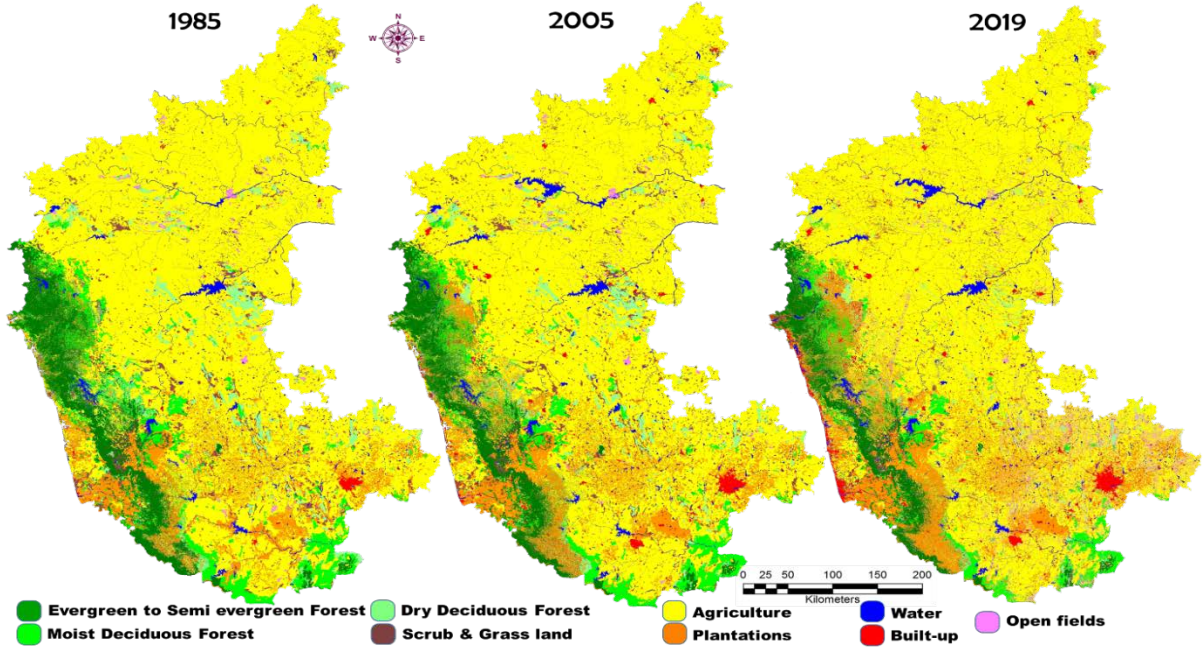
Estimation of Carbon Sequestration

- 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.

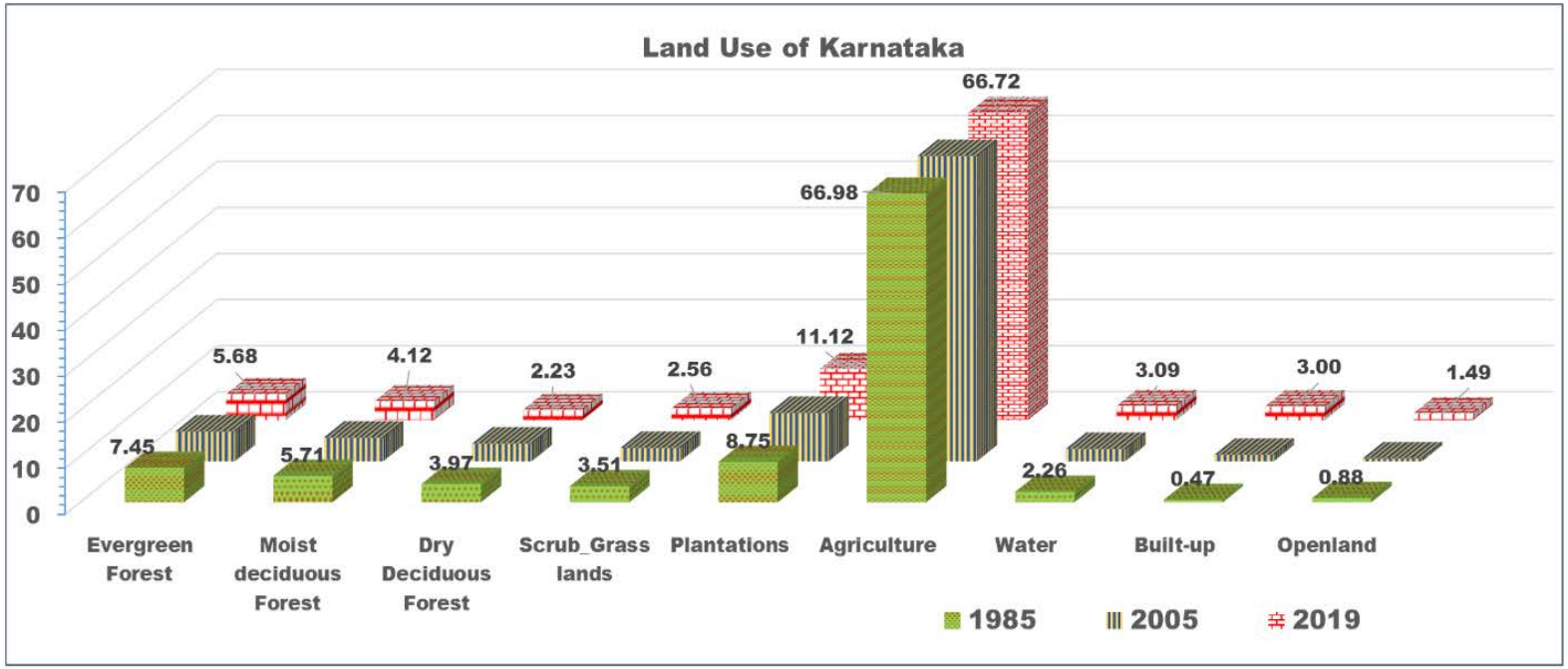
Index	Equation	Significance	Region applied
Basal area (BA) (m^2)	$(DBH)^2/4\pi$	To estimate basal area from DBH values	All
Biomass (T/Ha)	$(2.81 + 6.78 \times BA)$	Effective for semi evergreen, moist deciduous forest cover types and having moderate rainfall	Coastal
Biomass (T/Ha)	$(21.297 - 6.953(DBH)) + 0.740(DBH^2)$	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

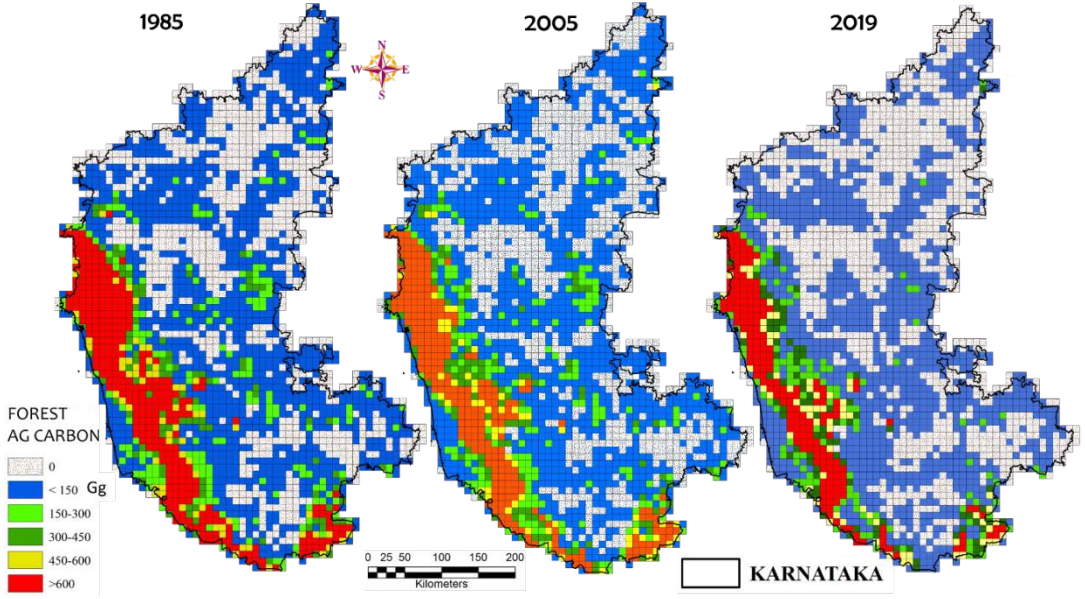



LAND USE ANALYSIS (1985-2019)
Data Preprocessing
Geometric Correction
Radiometric Correction
Radar data
Elevation, Slope
False Colour Composite
Stacking Optical and Topographic data
Developing Training Sites
Generating Signatures
Supervised Land use Classification
Accuracy Assessment
Ancillary Data
Forest type
Field Investigation
Above Ground & Below Ground Biomass Estimation across various forest & soil types
Literature on Carbon Budgeting; Soil Carbon
Field AGB estimates integrated with Land use
Carbon Sink
Biomass and Carbon sequestration
Assessment of Temporal variation in carbon with LU change & Budgeting
CBR ratio & Management options
Source
Estimation of Carbon Emission
Sectors
Source of Carbon emission
Agriculture
Residue burning; Paddy cultivation
Livestock
Enteric Fermentation; Manure
Energy
Burning of Coal; Petro Chemical; GAS
Industries
Manufacturing; Cement; Chemical processing
Domestic
Fuel Wood; Waste; Waste Water
Transportation
Fuel consumption per distance travelled
Emissions



Fgure 3. Spatio temporal land use changes in Karnataka.





Temporal variation in carbon sequestration in the forest s of Karnataka.

Annual increment of carbon in forest from 1989-2019

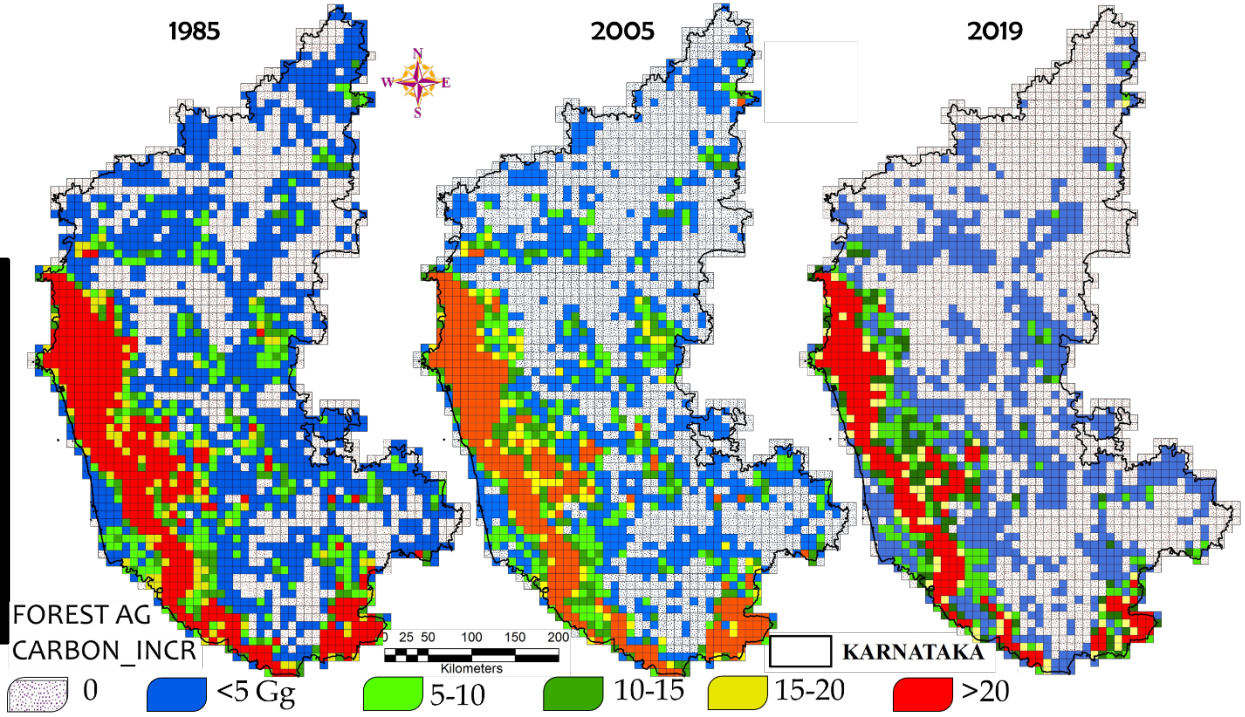
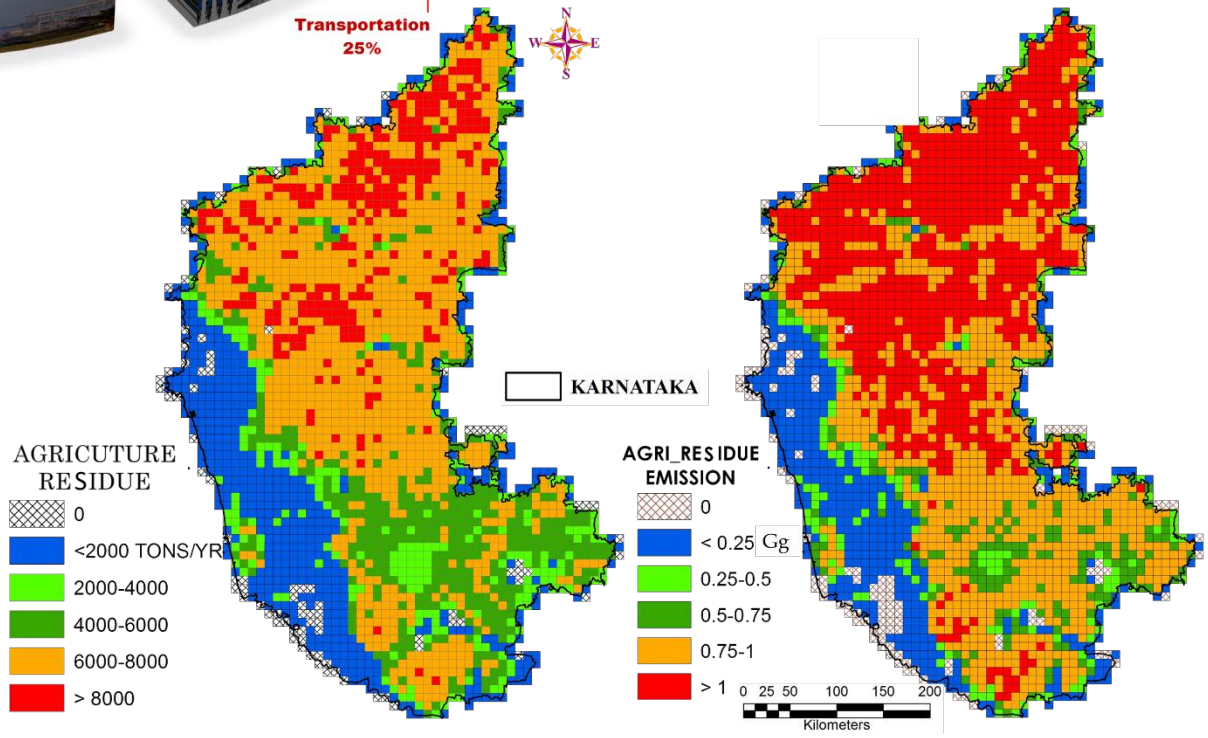


Figure 17. CO_2 emission from various sources in Karnataka.

Figure 18. Residue quantity and emission from agriculture sector



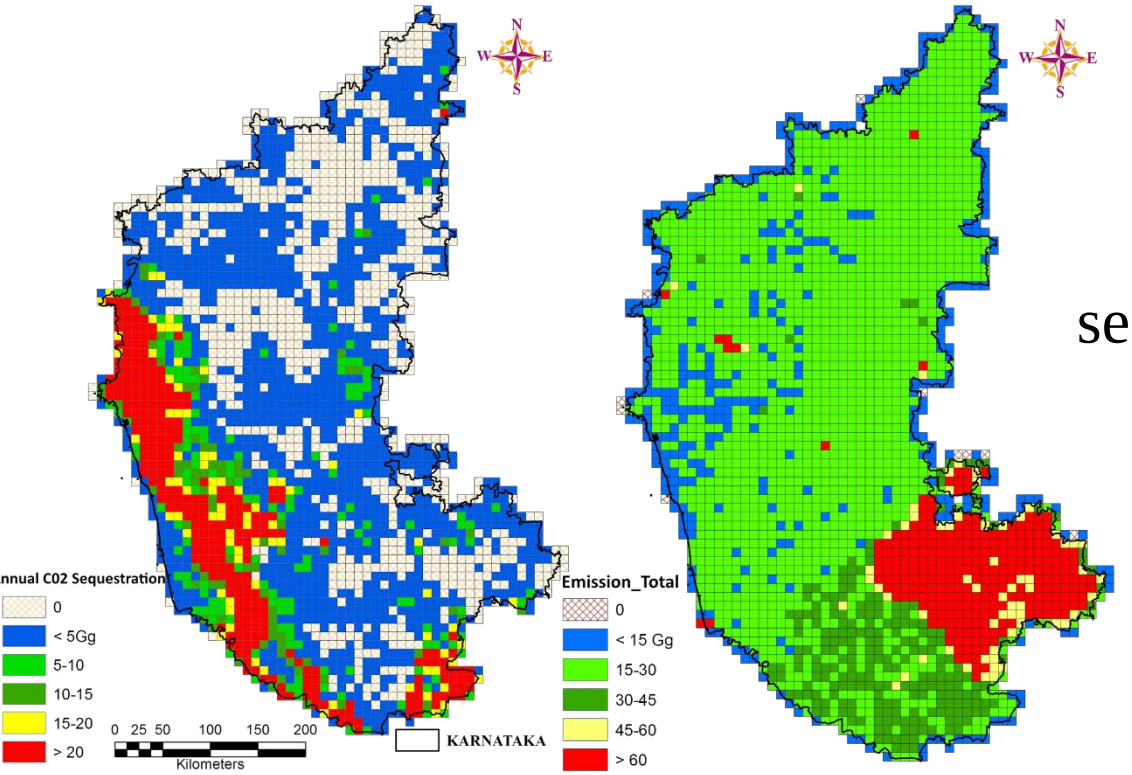
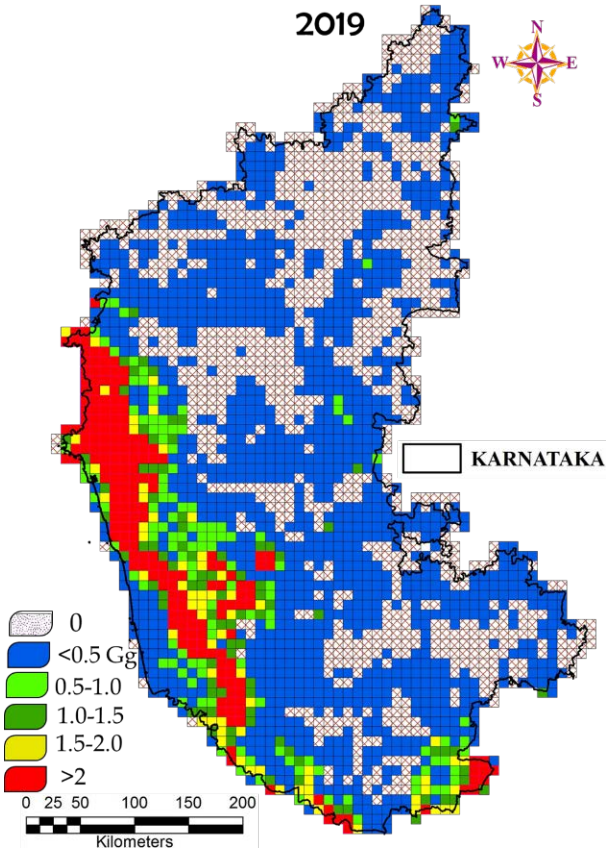
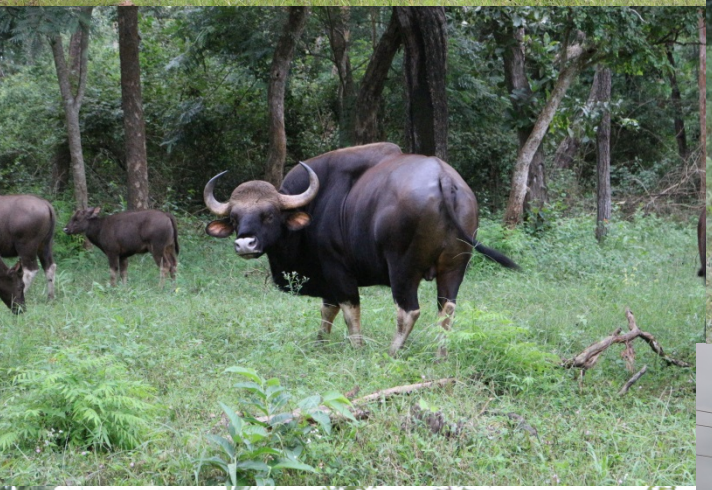
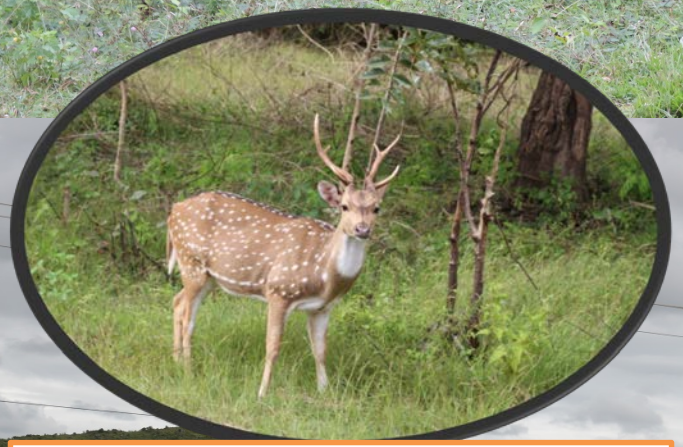


Figure 25. Annual carbon sequestration and emission of Karnataka.

Figure 26. Carbon ratio for the year 2019







Thank You