

Linkages of Environmental Accounts with policies at the Sub -National level



Dr. T.V. Ramachandra

Convenor, Environmental Information System [ENVIS]

Co-ordinator, Energy & Wetlands Research Group, Centre for Ecological Sciences [CES],

Centre for Sustainable Technologies [CST],

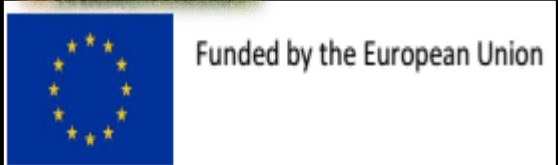
Centre for Infrastructure, Sustainable Transport & Urban Planning [CiSTUP]

Indian Institute of Science, Bangalore 560 012, INDIA

Web: <http://ces.iisc.ernet.in/energy>, <http://ces.iisc.ernet.in/biodiversity>

E Mail: tvr@iisc.ac.in; energy.ces@iisc.ac.in; envis.ces@iisc.ac.in

Tel: 080-22933099/22933503/23608661



- **Environmental Accounts at the Sub -National level**

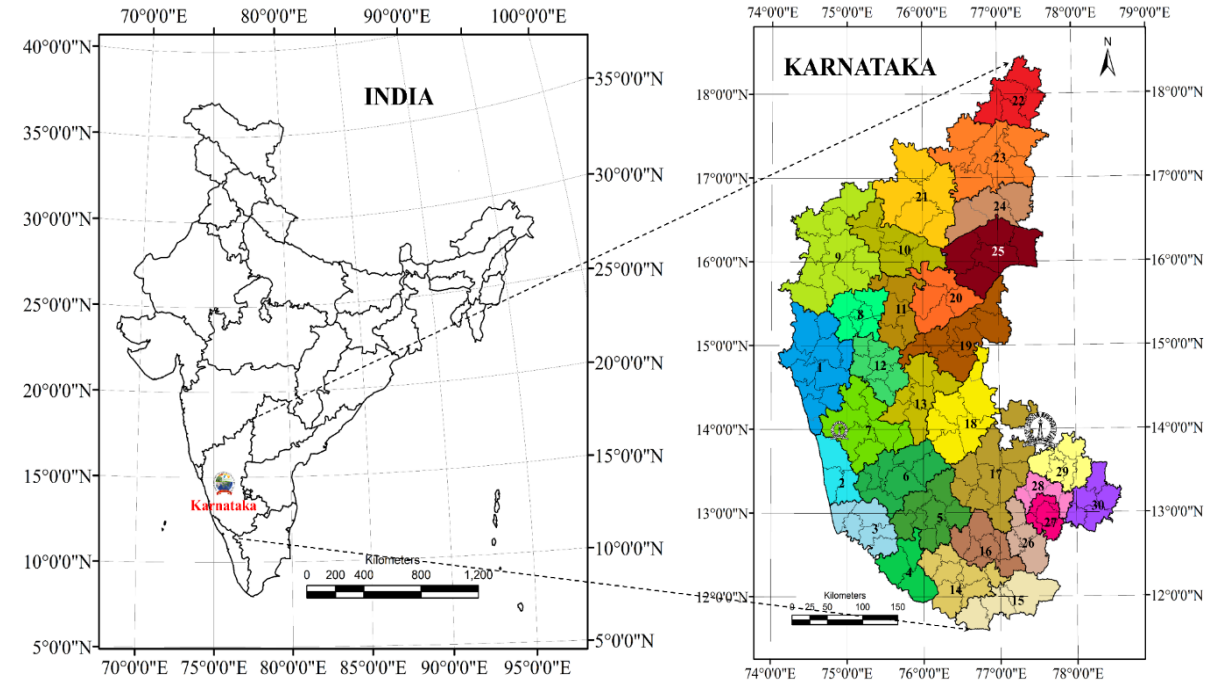
Ecosystems support human well-being through provisioning, regulating, and cultural services.

The value of all ecosystem services, including the degradation costs, needs to be understood for developing appropriate policies toward the conservation and sustainable management of ecosystems

→ GDP to GEP

Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES) – Karnataka, India

- Assessment of ecosystem extent and condition accounts for the state of Karnataka
- Valuation of the ecosystem services
- Asset accounting





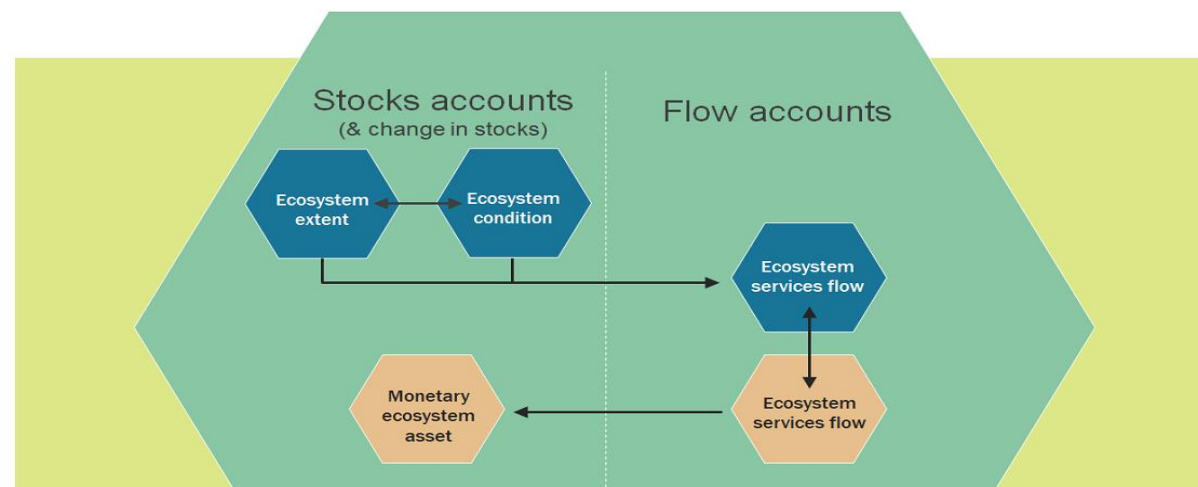
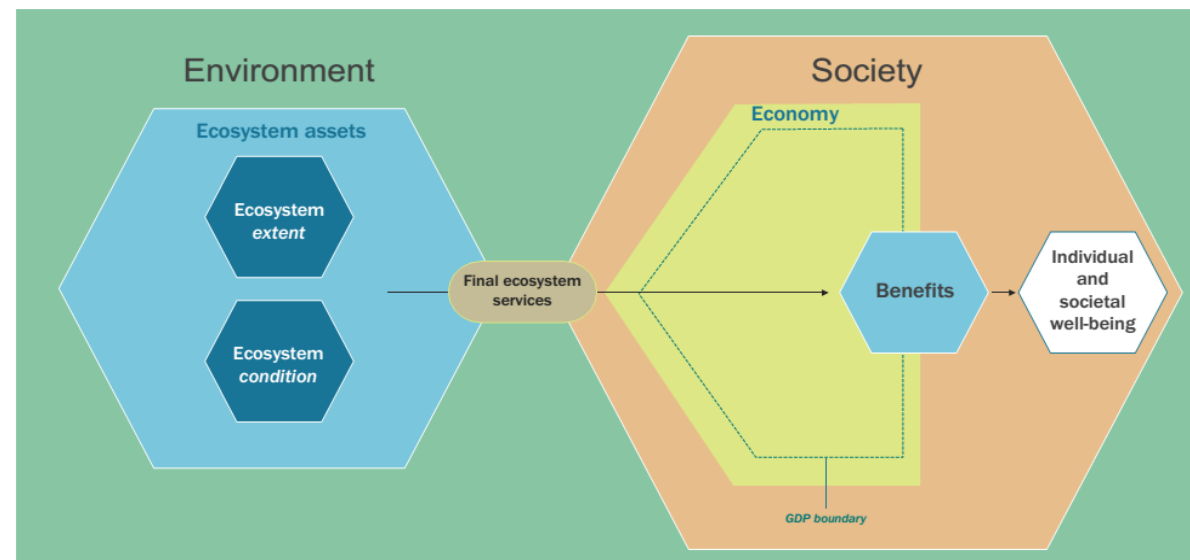
Natural Capital Accounting through **SEEA Experimental Ecosystem Accounting (SEEA EEA) Protocol**

Ecosystem extent accounts: record the total area of each ecosystem which is classified by type within an ecosystem accounting area and, over time in a specified area (e.g. State, District)

Ecosystem condition accounts: record the condition of ecosystem assets in terms of selected characteristics at specific points in time and, over time, record the changes to their condition.

Ecosystem goods and services accounts: record the supply of ecosystem services by ecosystem assets and the use of those services by economic units, including households. Ecosystem services accounts are presented both in physical and monetary units, using techniques for valuation of ecosystem services.

Ecosystem monetary asset accounts: record information on stocks and changes in stocks (additions and reductions) of ecosystem assets. This includes accounting for ecosystem degradation and enhancement.



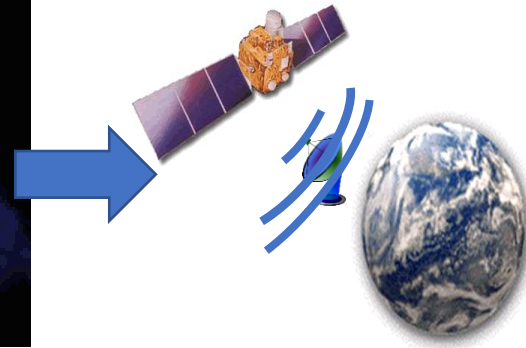
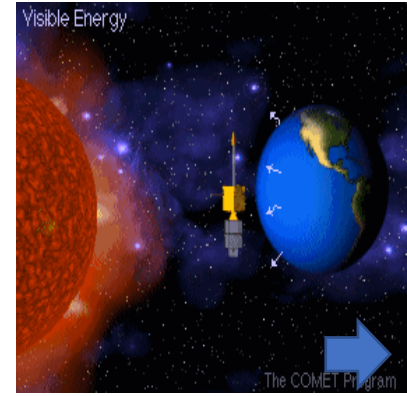
Ecosystem Extent using Big Data and
Classification through ML algorithm

Big Data:

Spatial data - Remote sensing

Big Data - RS data for Natural Capital Accounting

Time scale	Satellite / Source	Sensor	Spectral bands	Spatial resolution in metres (m)	Temporal resolution
1972 – 1999	Landsat -1, 5, and 7	MSS, TM, ETM+	PAN, VIS, NIR, MIR, TIR	15 m – 120 m (moderate spatial resolution)	16-18 days (free)
1988 – 2010	IRS-1C/1D, P6	PAN, LISS-III	PAN, VIS-2, NIR-1 (low spectral resolution)	5.8 m – 23.5 (high to moderate spatial resolution)	24 days (medium cost, moderate temporal resolution)
1999 – Till date	IKONOS	OSA	PAN, VIS-3, NIR-1	1 m (PAN) 4 m (Others) (high spatial)	1-3 days (costly)
:	:	:	:	:	:
1999 – Till date	MODIS (Terra, Aqua)	VIS, NIR, MIR, TIR	36 (high spectral resolution)	250 m – 1 km (low spatial resolution)	1-2 days (free & high temporal resolution)
2002	SRTM (Shuttle Radar Topography Mission)	---	DEM-1	90 m	1 time (free)
2002	Radar- Hydro 1K Asia	---	Precipitation, Slope, Aspect-1	1 Km	1 time (free)



112	112	109	101	103	109	109	109
108	113	105	108	108			
110	116	113	110	102			
113	119	124	109	103			
112	112	102	96	98			
112	112	102	96	98			
99	109	110	108	103	103	92	89

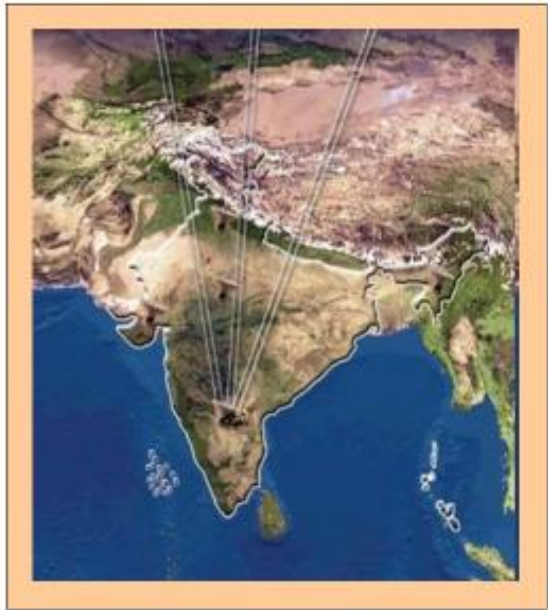
7-bit image (0 - 127)

Digital Data – Raster data



Science of obtaining information about an object or phenomena without being in contact with it

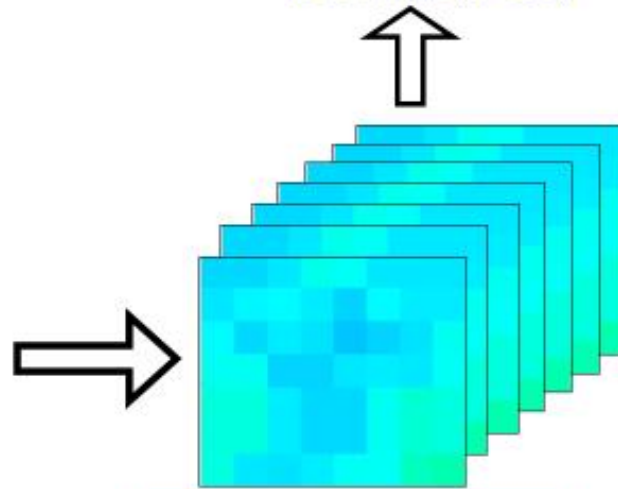
Spatial Data



Images of Earth's Surface

112	112	109	101	103	109	109	109
109	106	105	108	113	105	108	108
105	112	108	110	116	255	110	102
102	102	113	113	109	108	109	103
98	98	108	112	112	102	96	98
98	98	108	112	112	102	96	98
99	255	110	108	103	103	92	0

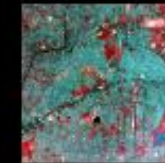
8-bit image (0 - 255)



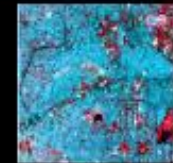
Digital Data – Raster data
(collection of pixels – DN's)

Data

- Survey of India (SOI) Topographical Sheets to generate base layers.
- RS data of various resolutions.
- Pre-calibrated handheld GPS.
- Google Earth image along with the field data for validation.



IKONOS



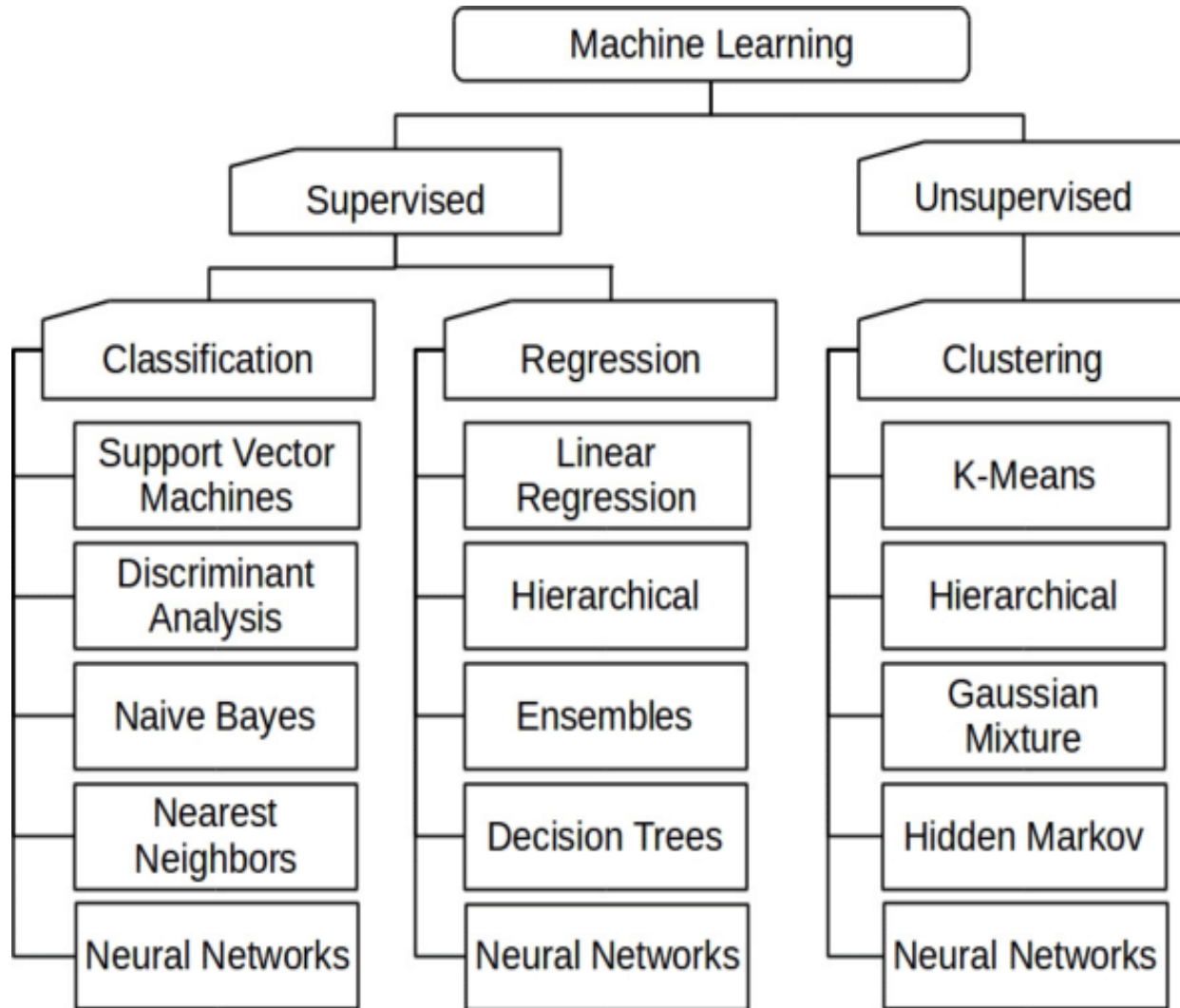
Landsat



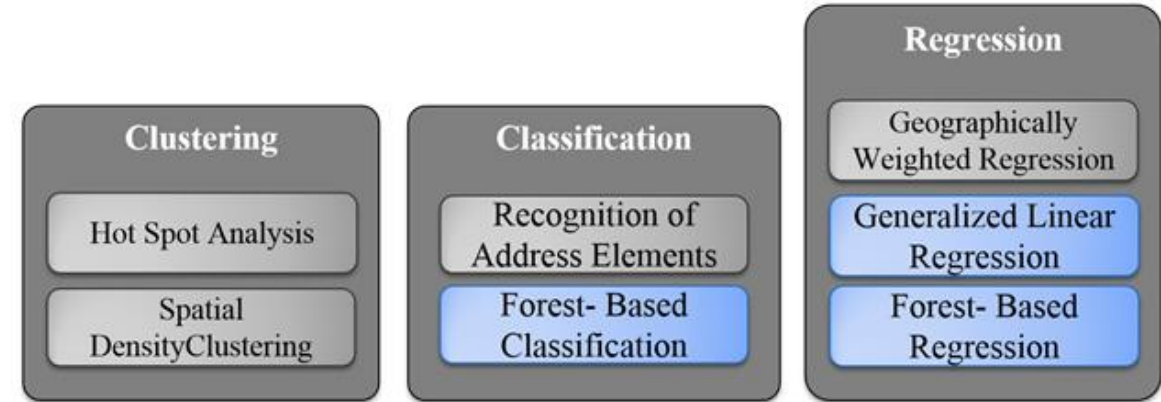
MODIS



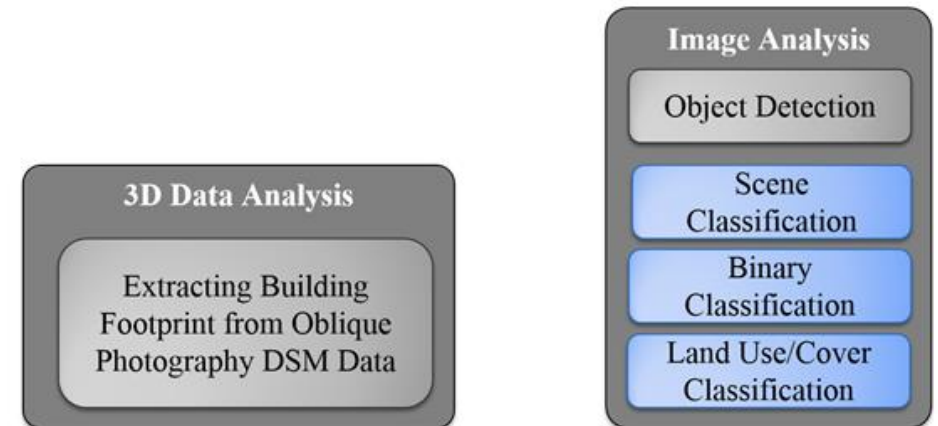
AI (ARTIFICIAL INTELLIGENCE)



Geospatial Machine Learning Operators

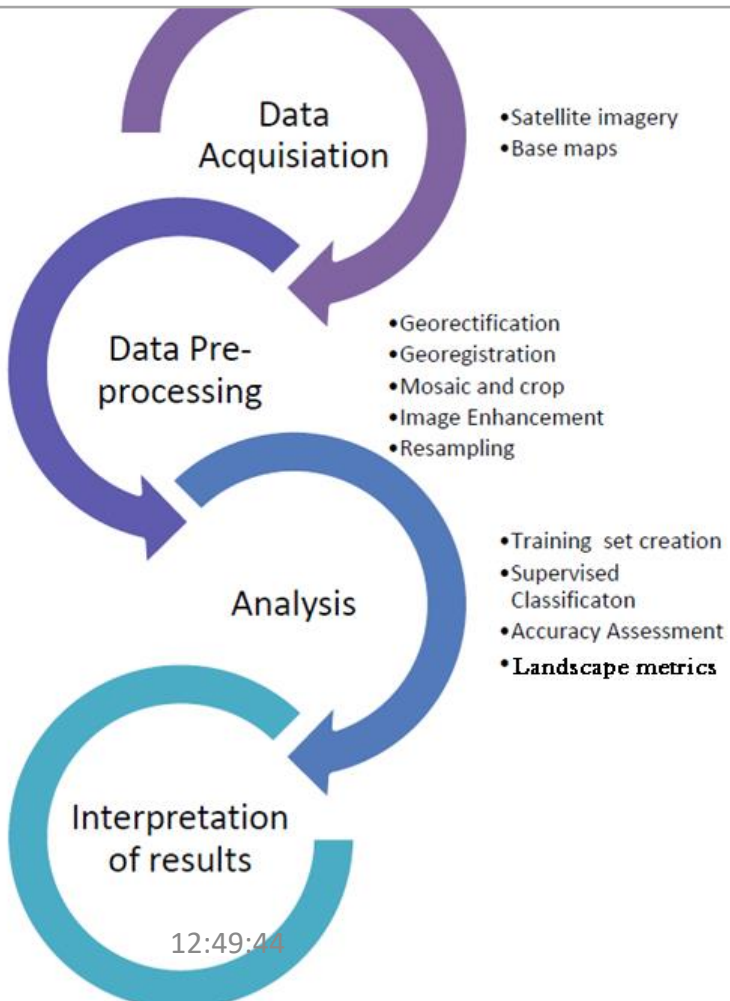


Geospatial Deep Learning Operators



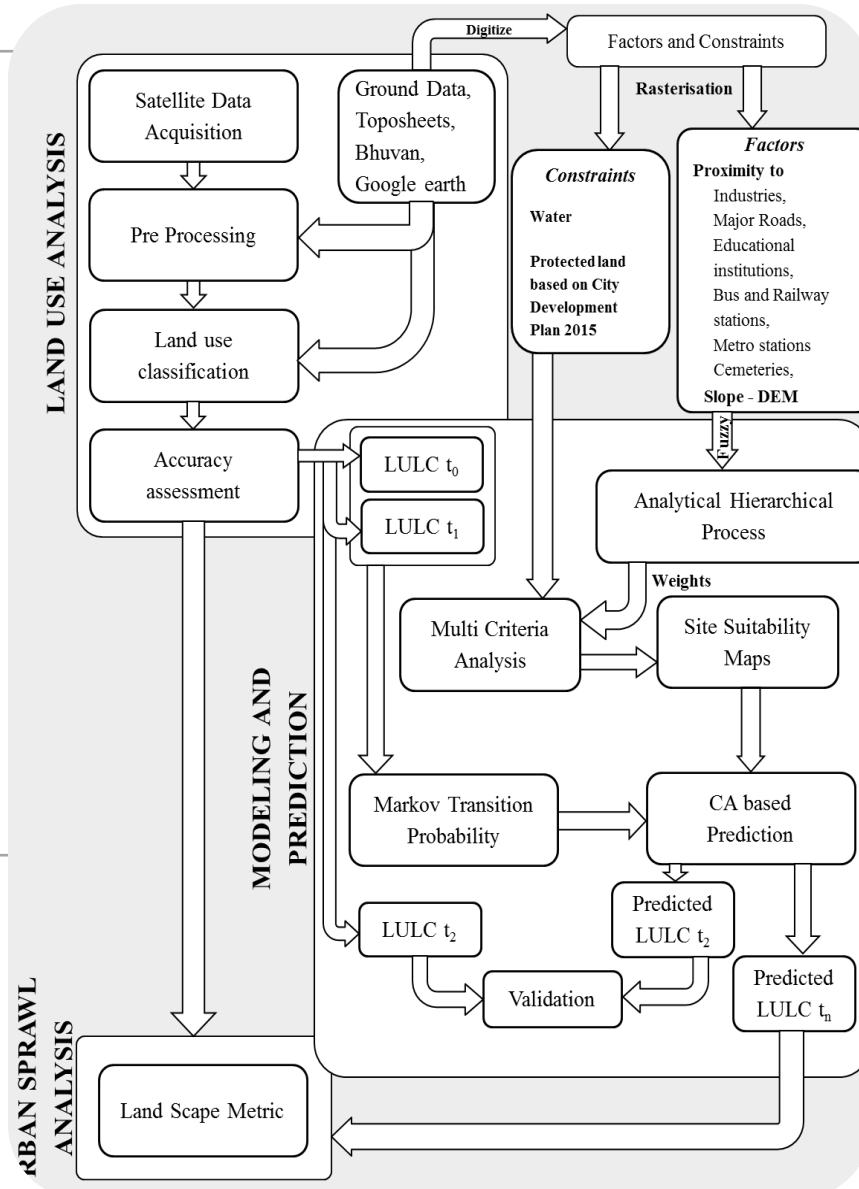
Geo-Visualisation of Land Cover Dynamics

1. Spatio-temporal pattern analyses
2. Visualisation– Agent based modelling

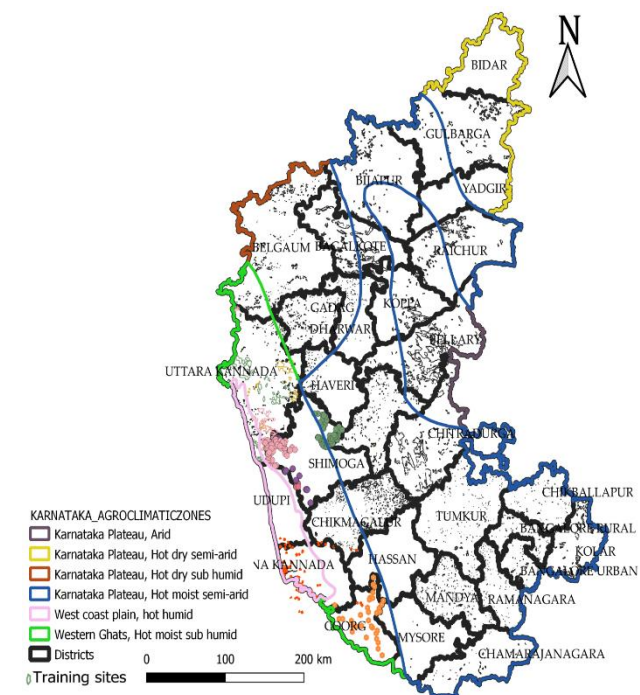
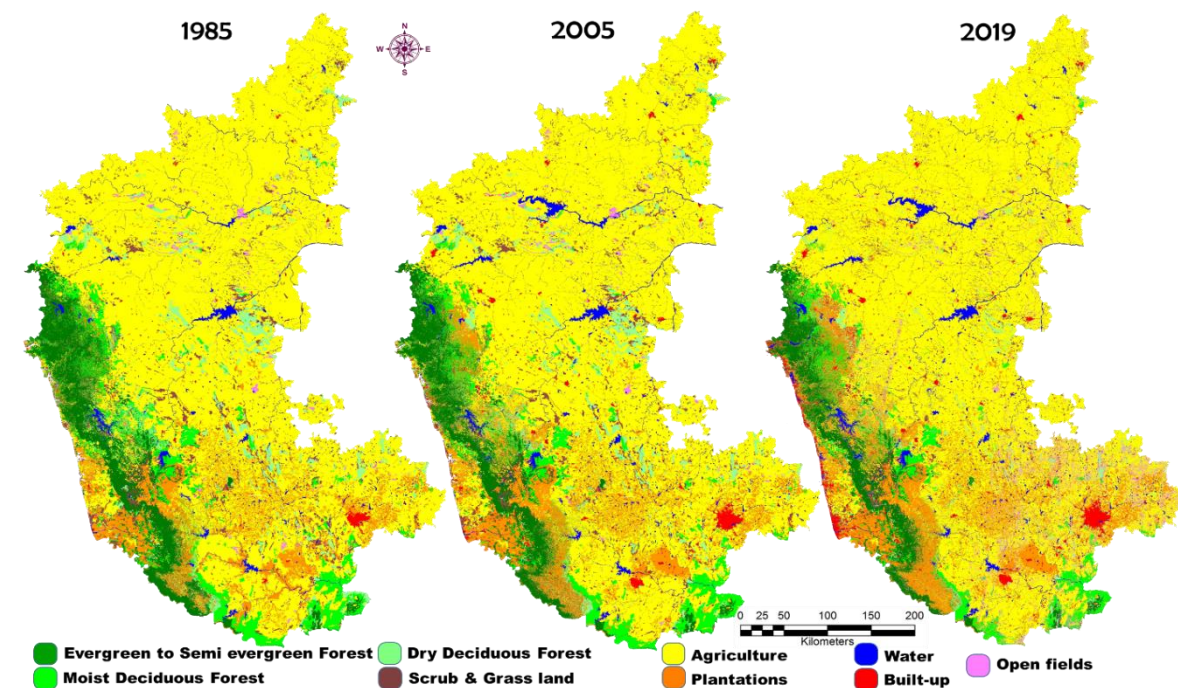
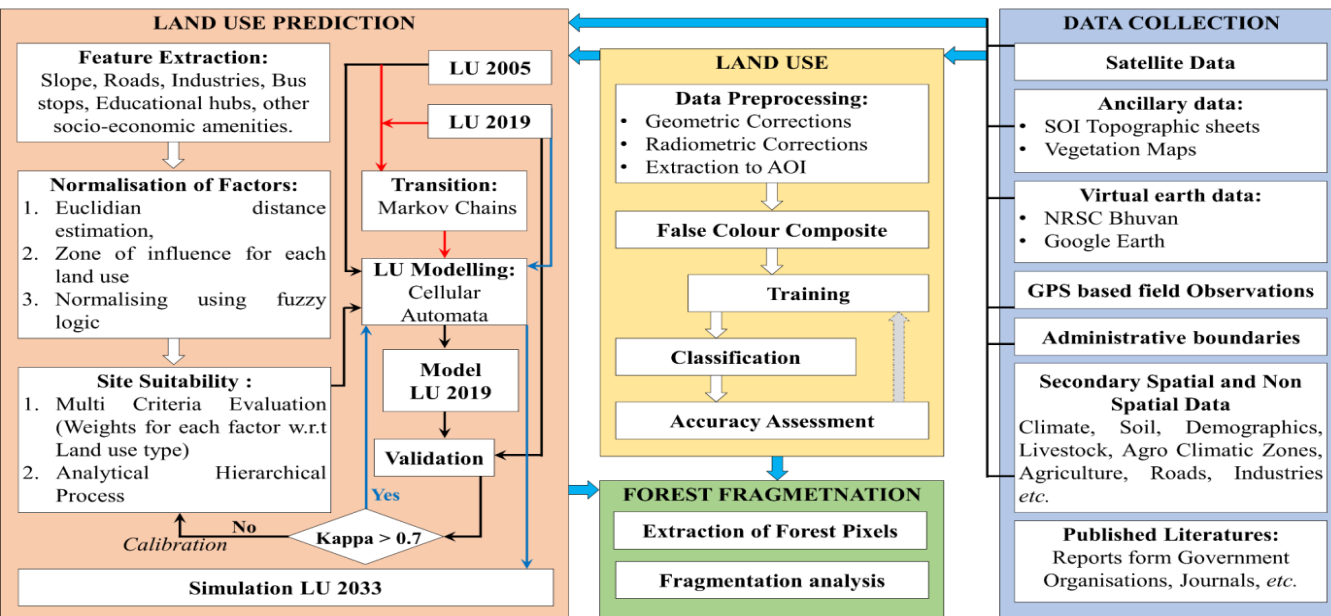


- ### Models
- Cellular Automata
 - CA-Markov
 - Geomod
 - **AHP-CA-Markov**
 - Land change modeler
 - **Multi Criteria Evaluation**
 - Regression
 - Bayesian
- Current study, combines CA, MCE, Fuzzy, AHP and Markov models

- understand the behavior of agents and its contribution in development through **Fuzzy and Analytical Hierarchical Process (AHP)**.
- AHP was used to rank each agent/parameter
- Output of AHP with constraints were used in Multi criterion evaluation to derive transition maps, inputs to CA markov



ECOSYSTEM EXTENT AND DYNAMICS



Category	1985		2005		2019	
	Asset Extent	%	Asset Extent	%	Asset Extent	%
	Sq. Km		Sq. Km		Sq. Km	
Evergreen Forest	14292.73	7.45	12444.70	6.49	10887.78	5.68
Moist deciduous Forest	10960.11	5.71	9900.18	5.16	7892.28	4.12
Dry Deciduous Forest	7621.69	3.97	7409.52	3.86	4280.94	2.23
Scrub_Grass lands	6732.90	3.51	5603.86	2.92	4906.70	2.56
Plantations	16789.65	8.75	20209.09	10.54	21325.23	11.1
Agriculture	128467.66	66.98	127196.30	66.32	127962.17	66.7
Water	4343.79	2.26	5176.70	2.70	5933.93	3.09
Built-up	904.17	0.47	2666.15	1.39	5748.34	3.00
Openland	1678.30	0.88	1184.50	0.62	2853.63	1.49
Total Area	191791					

Task 2: Ecosystem Condition Account

The SEEA Ecosystem Condition Typology (SEEA ECT)

ECT groups	ECT classes
Abiotic ecosystem characteristics	1. Physical state characteristics (soil structure, water availability)
	2. Chemical state characteristics (soil nutrient levels, water quality , air pollutant concentrations)
Biotic ecosystem characteristics	3. Compositional state characteristics (including species-based indicators)
	4. Structural state characteristics (including vegetation, biomass , food chains)
	5. Functional state characteristics (including ecosystem processes, disturbance regimes) NPP
Landscape level characteristics	6. Landscape and seascape characteristics (including landscape diversity, connectivity, fragmentation , embedded semi-natural elements in farmland), Land Surface Temperature (LST)

Ecosystem Condition

Ecosystem Condition Account for Karnataka State, India



Ramachandra T.V.¹, Bharath Settur¹, Vinay S², Rakesh D.R.¹, Bharath H Aitha²
¹Energy and Wetland Research Group, Centre for Ecological Sciences, CES TE 15, Indian Institute of Science Bangalore 560012
²Ranbir and Chitra Gupta School of Infrastructure Design and Management (RCG SIDM), Indian Institute of Technology Kharagpur
 E Mail: tvr@iisc.ac.in; energy.ces@iisc.ac.in

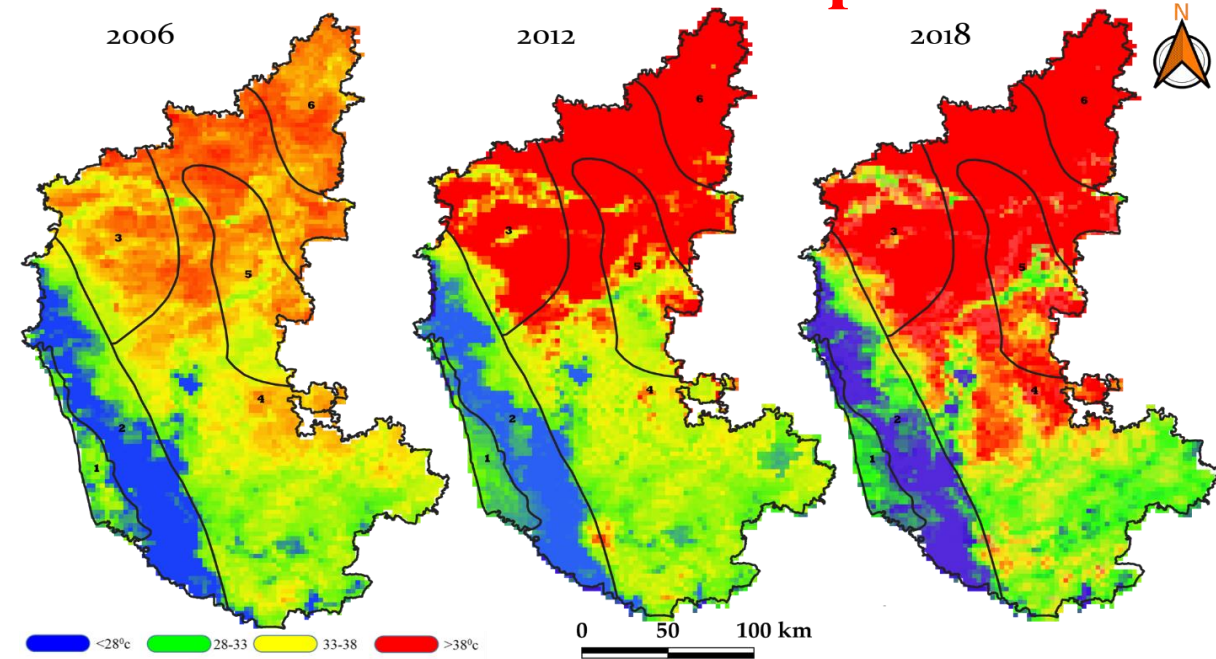
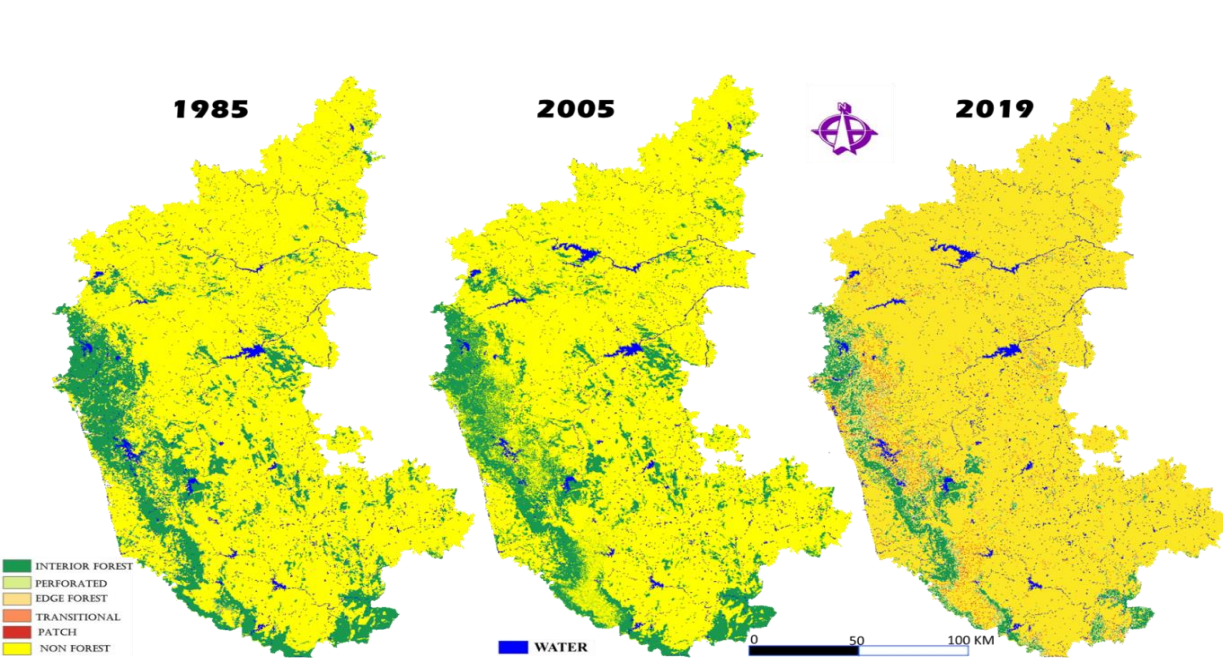









Ecosystem condition Accounts: Fragmentation of Forests & Land Surface Temperature



Fragmentation Metrics		Interior	Patch	Transitional	Edge	Perforated	Non forests	Water	Total
Year	Units								
1985	sq.km	31224	1247	211	3184	1189	150057	4680	191791
	%	16.3	0.7	0.1	1.7	0.6	78.2	2.4	
2005	sq.km	24607	1170	2359	6655	1151	150671	5178	
	%	12.8	0.6	1.2	3.5	0.6	78.6	2.7	
2019	sq.km	11335	2839	2071	7365	595	161661	5926	
	%	5.9	1.5	1.1	3.8	0.3	84.3	3.1	
Changes during 1985 to 2019									
1989	sq.km	31224	1247	211	3184	1189	150057	4680	191791
2019	sq.km	11335	2839	2071	7365	595	161661	5926	191791
Net changes during 1985 to 2019									
	sq.km	-19889	1592	1860	4181	-595	11603	1247	

Table 3.2.12: Ecosystem Condition Indicators based on Landscape level Characteristics considering land Surface Temperature in Karnataka State (district wise)

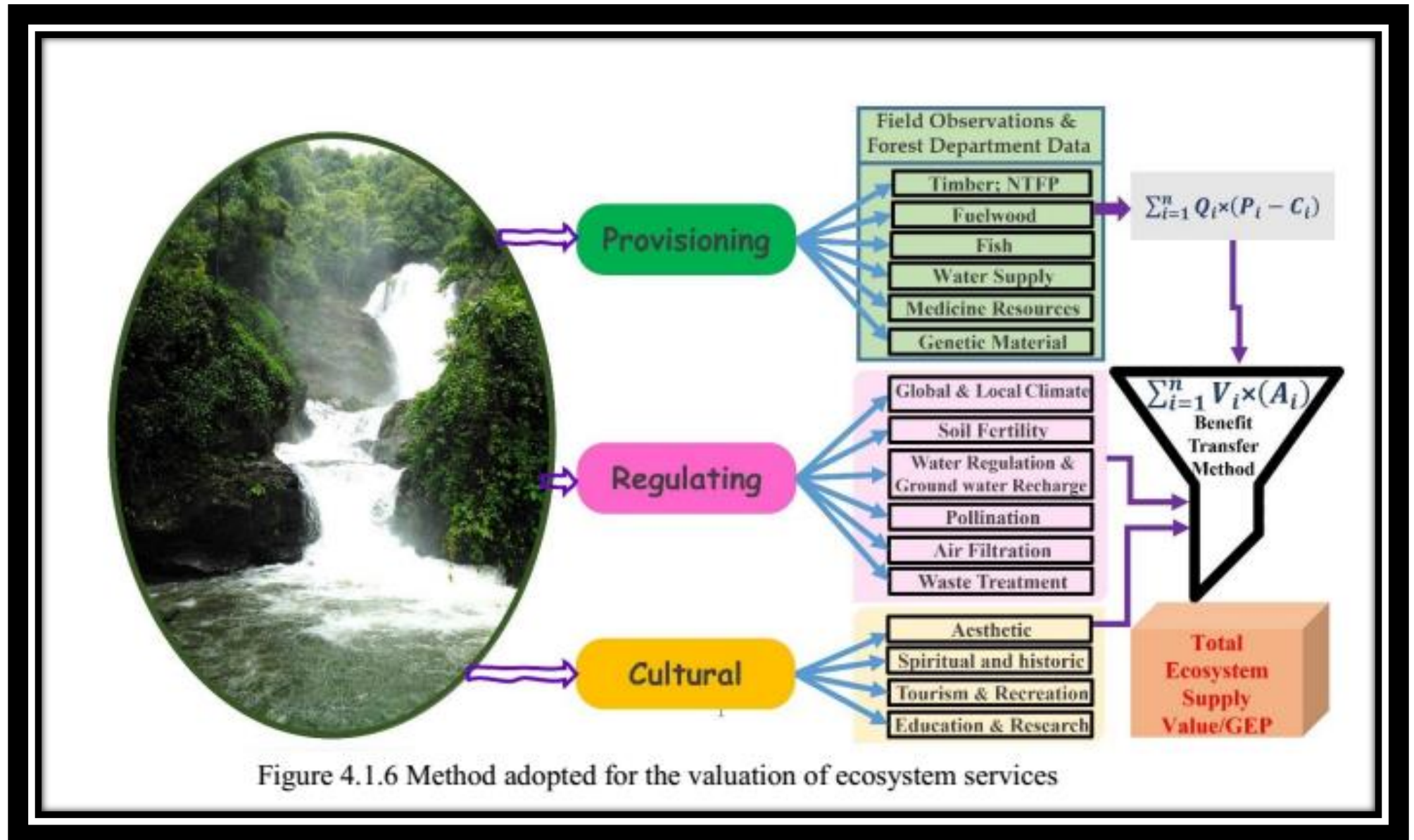
Karnataka State (district wise)					Scope : Landscape level				
Districts	units	Opening Stock 2005			Closing Stock 2019			Low (>35 °C)	
		Total	High (<30 °C)	Medium (30 -35 °C)	Total	High (<30 °C)	Medium (30 -35 °C)		
Bagalkot	Ha	688140	747	8870	678523	688140	0	11498	676642
	%		0.11	1.29	98.60		0.00	1.67	98.33
Bangalore-Rural	Ha	251101	0	3780	247321	251100	0	6596	244504
	%		0.00	1.51	98.49		0.00	2.63	97.37
Bangalore-Urban	Ha	226800	0	8771	218029	226800	0	25953	200847
	%		0.00	3.87	96.13		0.00	11.44	88.56
Belgaum	Ha	1547100	11643	68806	1466651	1547100	567	117563	1428970
	%		0.75	4.45	94.80		0.04	7.60	92.36

Table 3.6.1: Ecosystem Condition Index Account – Karnataka state (district wise)

Districts	SEEA -EA Conditions	Indicator	Parameter	weight	Opening -2005 (%)			Closing - 2020 (%)		
					High	Medium	Low	High	Medium	Low
Uttara Kannada	Abiotic ecosystem	Soil	K	0.017	0.0	84.4	15.6	0.0	99.3	0.7
		Soil	N	0.017	100.0	0.0	0.0	0.0	0.0	100.0
			P	0.017	0.0	0.0	100.0	37.6	62.4	0.0
			OC	0.017	0.0	72.4	27.6	0.0	100.0	0.0
			S	0.017	45.4	54.6	0.0	45.4	54.6	0.0
			Zn	0.017	0.0	85.8	14.2	0.0	100.0	0.0
			Fe	0.017	0.0	100.0	0.0	0.0	100.0	0.0
			B	0.017	0.0	0.0	100.0	0.0	0.0	100.0
			Cu	0.017	0.0	99.3	0.7	0.0	99.3	0.7
			Mn	0.017	0.0	100.0	0.0	0.0	100.0	0.0
	EC	0.017	100.0	0.0	0.0	100.0	0.0	0.0		
	pH	0.017	94.4	5.6	0.0	100.0	0.0	0.0		
	Biotic - Compositional State	Flora	0.05	87.8	5.5	6.7	73.1	5.5	21.4	
		Fauna	0.05	56.3	11.0	32.7	46.9	11.0	42.1	
	Biotic - Structural State	AGB	0.05	46.2	35.2	18.6	33.1	42.1	24.8	
		BGB	0.05	46.2	35.2	18.6	33.1	42.1	24.8	
	Biotic - Functional State	NPP	0.10	32.4	55.2	12.4	1.4	84.8	13.8	
	Landscape Level	Fragmentation		0.25	55.0	10.8	34.2	45.8	13.5	40.8
		LST		0.25	20.6	53.2	26.2	0.6	69.9	29.6
	Ecosystem condition Account			Index	1.00	39.6	35.9	24.5	25.8	46.3

Note: N: Nitrogen, P: Phosphorous, K: Potash, OC: Organic Carbon, Zn: Zinc, Fe: Iron, B: Boron, Cu: Copper, Mn: Manganese, S: Sulphur, EC: Electrical conductivity, AGB: Above ground biomass, BGB: Below ground Biomass, NPP: Net Primary Productivity, LST: Land Surface Temperature

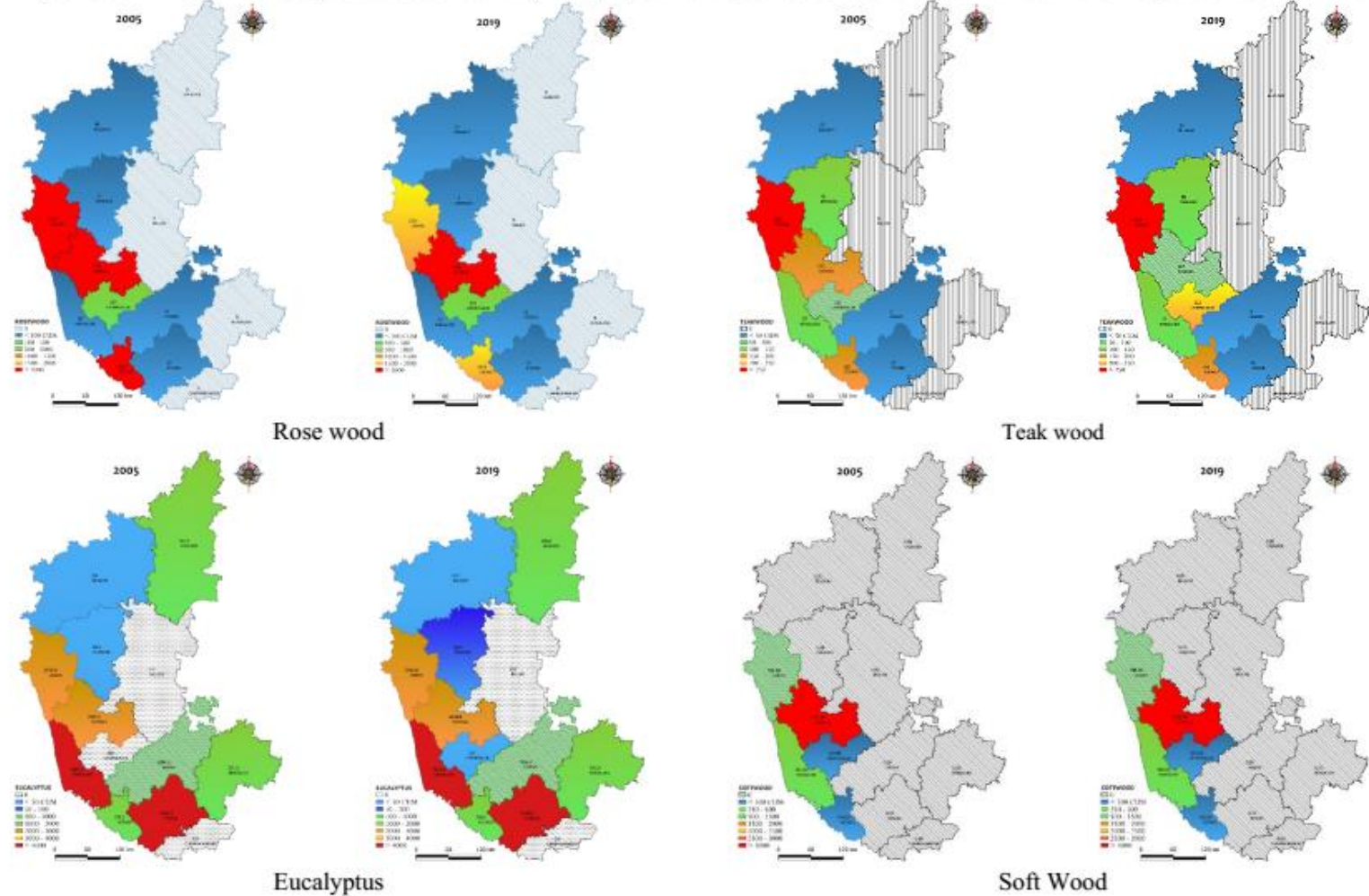
Valuation of services - Forest Ecosystems



Ecosystem services supply accounts (physical units) & Valuation of the ecosystem services



Figure 5.3.1 Timber, Bamboo, and canes extracted (in the physical units) across forest circles in Karnataka for the years 2005 and 2019

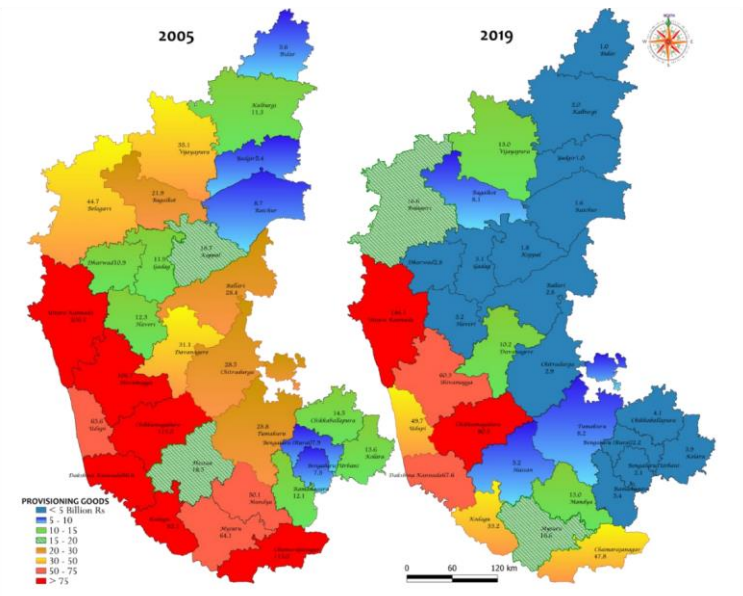


Provisioning Services

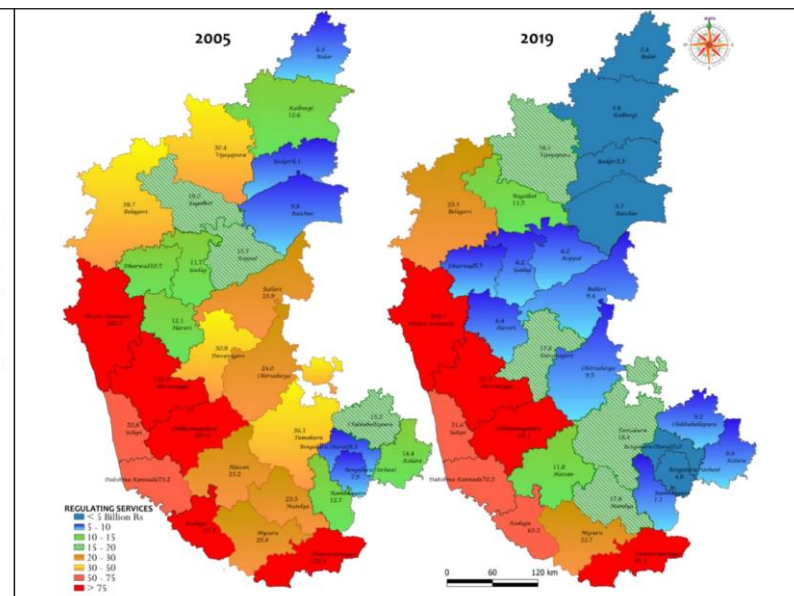
Regulating Services

Cultural Services

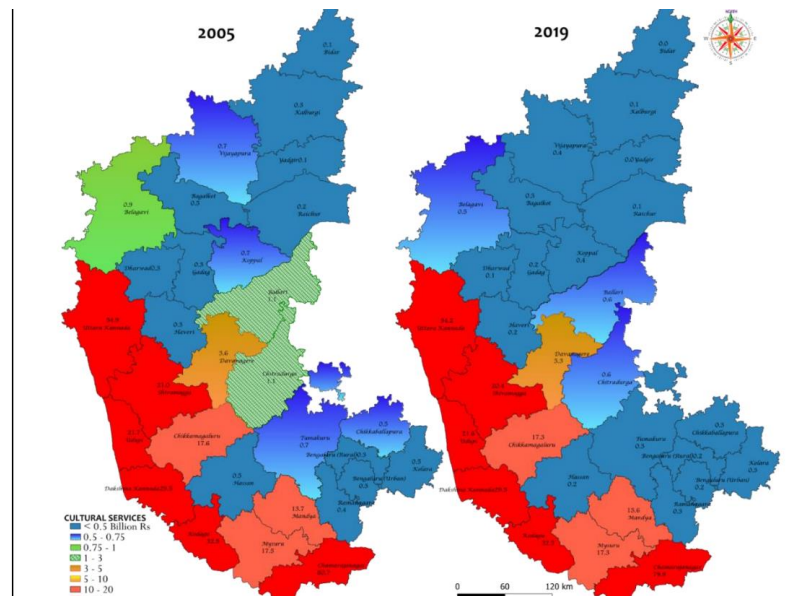
Provisioning Services



Regulating Services



Cultural Services



TESV - GEP
Total Ecosystem Supply Value (TESV) of forest ecosystems in Karnataka
2894 billion INR/year (2005) and 1835 billion rupees/year (2019).

TESV

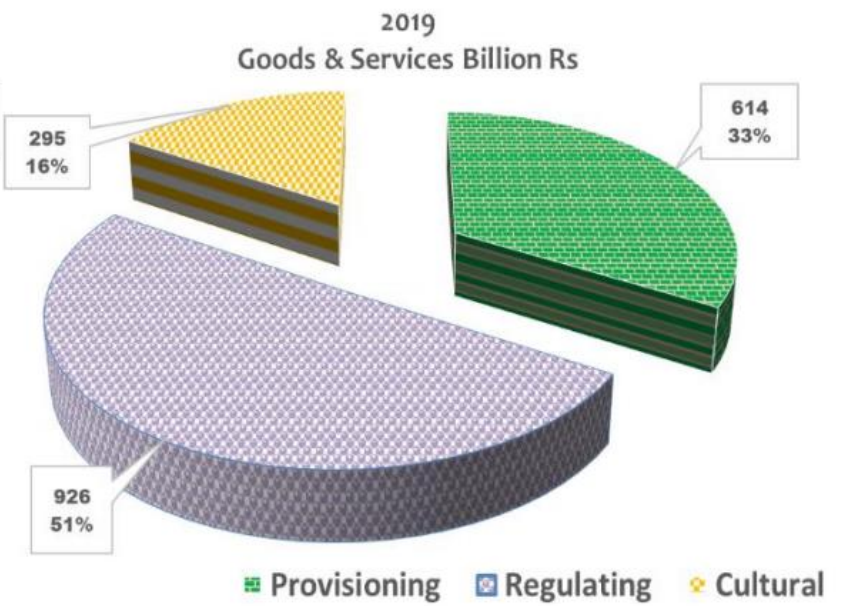
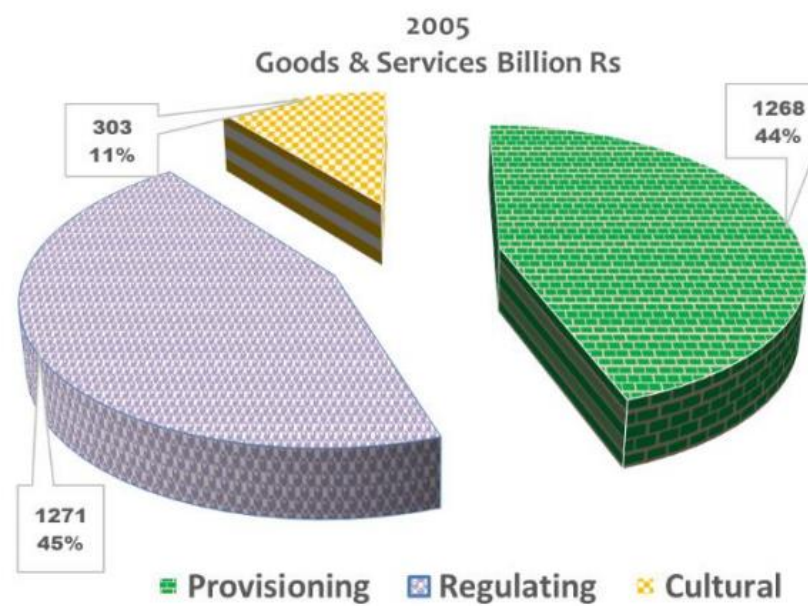
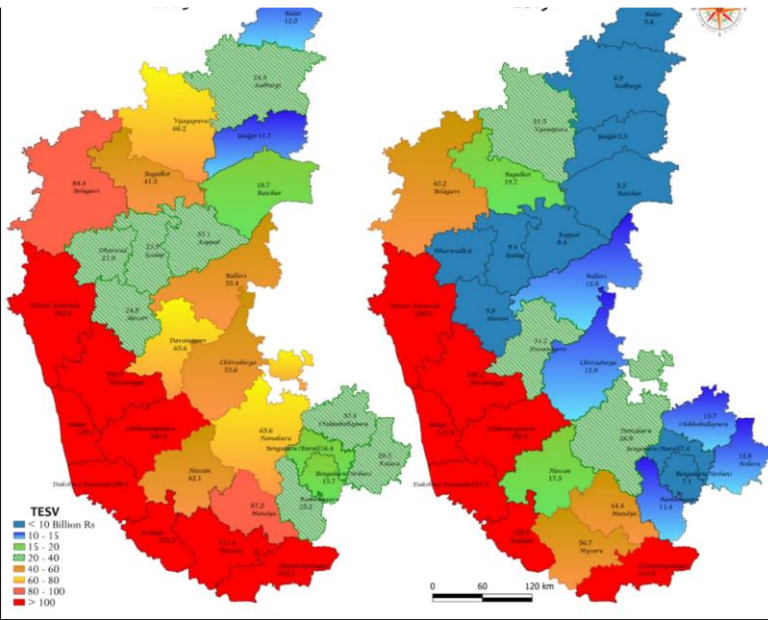


Figure 5.3.32. District-wise TESV (Total Ecosystem Supply Value) of forest ecosystem in Karnataka,

Ecosystems	Year	Units	Provisioning	Regulating	Cultural	TESV
Forests	2005	Million ₹	12,67,528	12,70,583	3,03,034	28,41,145
		%	44.6	44.7	10.7	100
Agriculture (croplands and horticulture)		Million ₹	4,11,834	3,44,933	21,819	778,586
		%	52.9	44.3	2.8	100
Total		Million ₹	16,79,361	16,15,516	3,24,854	36,19,731
		%	46.4	44.6	9.0	100
Forests	2019	Million ₹	6,13,883	9,26,346	2,94,955	18,35,184
		%	33.5	50.5	16.1	100
Agriculture		Million ₹	5,89,283	4,59,037	29,305	10,77,625
		%	61.2	36.3	2.5	100
Total		Million ₹	12,03,166	13,85,383	3,24,260	29,12,809
		%	41.3	47.6	11.1	100



Ecosystem	Rs/Ha/yr			
	Provisioning	Regulating	Cultural	TESV
Forest	219494.8	331216.4	105461.6	656172.8
Agriculture	39473.2	30748.6	1963.0	72184.8
Terrestrial	258967.9	361965.0	107424.6	728357.6

NPV - Monetary asset account (2005-2019)

	Units	Forest ecosystem	Agriculture ecosystem	Total NPV
Opening stock – 2005 (at 2019 values)	Billion ₹	73,099	20,031	93,130
Changes (absolute)	Billion ₹	-25,885	7,693	-18,192
Changes	%	-35.4	38.4	-19.5
Provisioning	%	-51.6	43.1	-28.4
Regulating	%	-27.1	33.1	-14.2
Cultural	%	-2.7	34.3	-0.2
Closing stock - 2019	Billion ₹	47,214	27,724	74,938

SCENARIO-BASED ASSESSMENT OF POLICY INTERVENTIONS IN KARNATAKA STATE, INDIA



Ramachandra T.V¹., Bharath Setturu¹, Vinay S², Chandan M.C² and Bharath H Aithal²

¹Energy and Wetland Research Group, Centre for Ecological Sciences, CES TE 15, Indian Institute of Science, Bangalore 560012

²Ranbir and Chitra Gupta School of Infrastructure Design and Management (RCG SIDM), Indian Institute of Technology Kharagpur

E-Mail: tvr@iisc.ac.in; energy.ces@iisc.ac.in; envis.ces@iisc.ac.in



System of Environmental Economic Accounting



(i) Business as usual scenario (BAU)	BAU assumes the current development will continue and evaluates the various agents responsible for the change and forecast what would be the future landscape status
Policy Context	
(ii) Agent based land use transition scenario (ALT)	Various driver's (agents) such as proposed (new) developments by the government, existing and proposed (i) industries, (ii) liner projects, (iii) urbanization, (iv) slope, (v) core built-up areas, (vi) special economic zones (SEZ) etc., responsible for the land use changes in the neighborhood.
(iii) Reserve Forest Protection (RFP) and stringent conservation of national parks and sanctuaries scenario	Spatial extent of reserve forests, national parks, sanctuaries are maintained with strict regulations. Absence of abrupt land use change.
(iv) Afforestation (High conservation) scenario (AF)	Considering afforestation initiatives, agents are - same as (ii); Spatial extent of afforestation data (during the past decade) and proposed afforestation
(v) SDP-Sustainable Development Policy Scenario	Sustainable development policy scenario ensures (i) the protection of reserve forests and (ii) afforestation and hence includes the constraints same as scenario 3 & 4 and allows the growth in regions other than forest area.

Modeling of landscape dynamics
 Hybrid Fuzzy Analytical
 Hierarchy Process (AHP)
 based Spatial
 Markov chains (MC)
 Cellular automata (CA)
 (Fuzzy AHP-MCA)
 technique
 using temporal data.

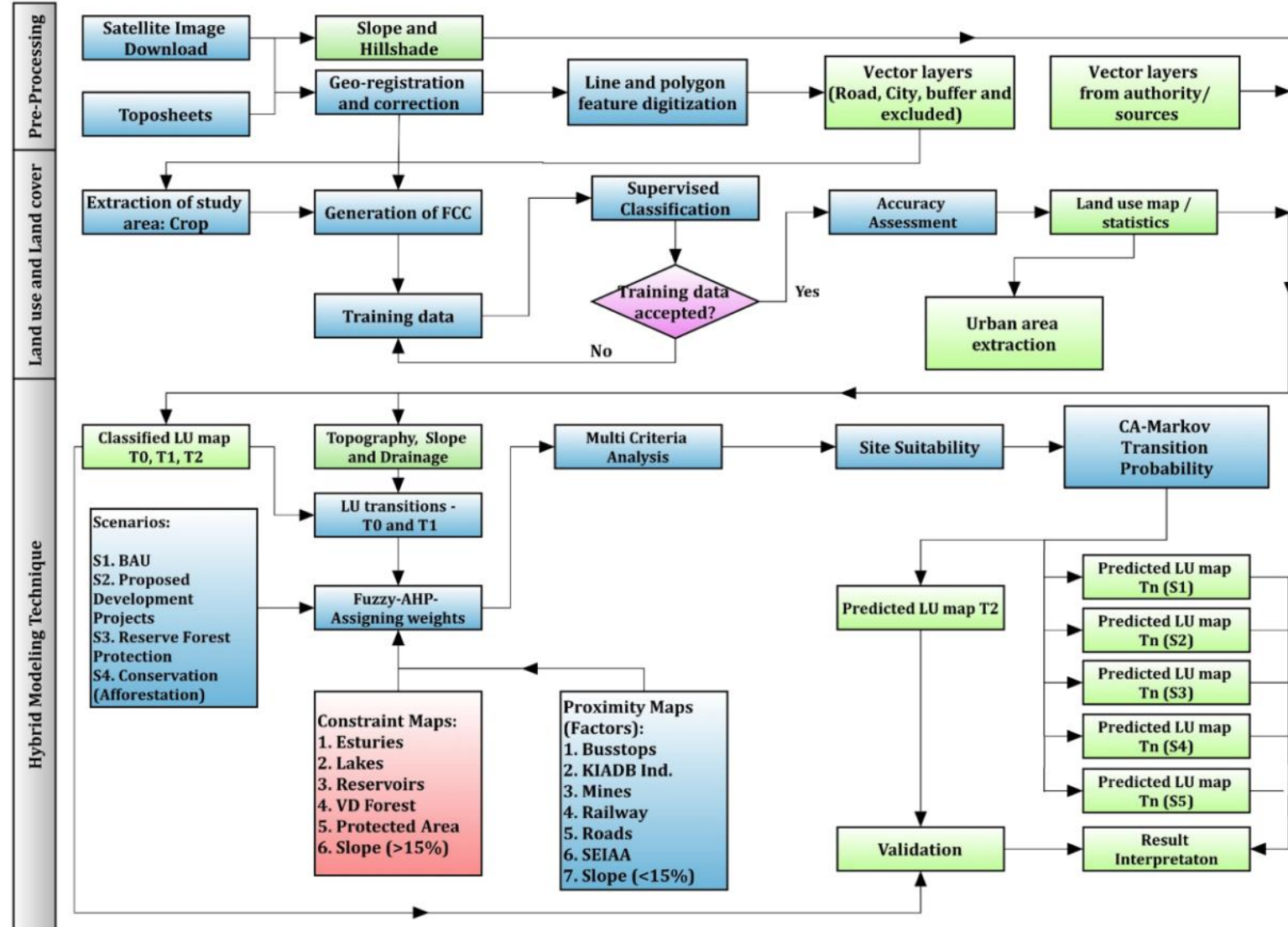


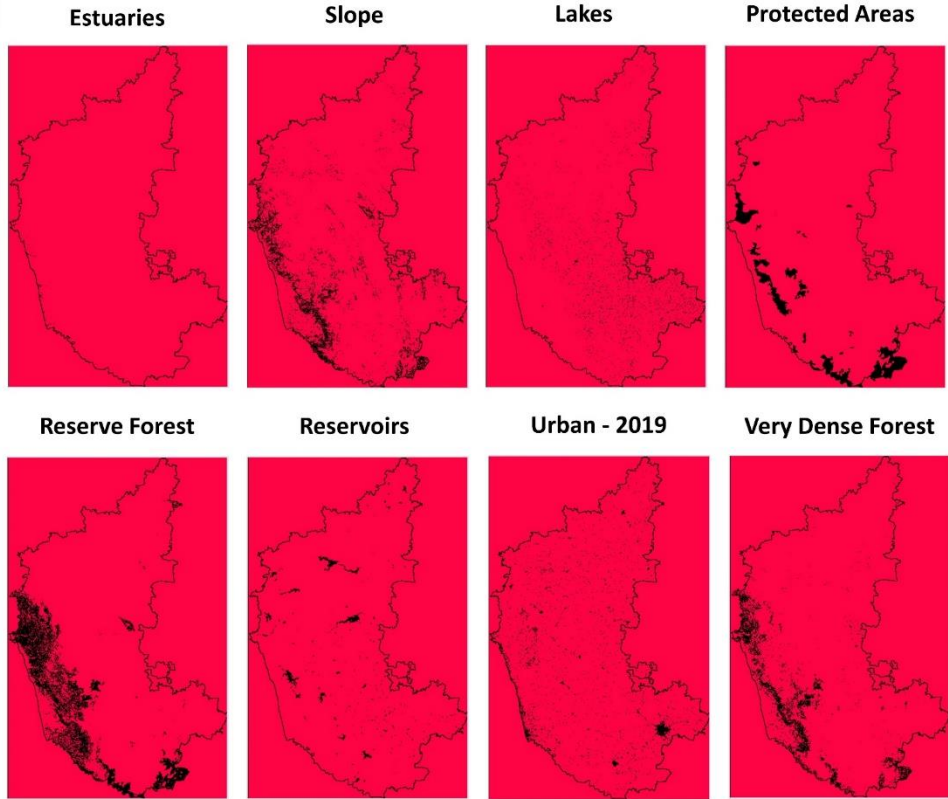
Figure 4.5: Method adopted to analyze land use transitions in the Karnataka region

Model Constraints:

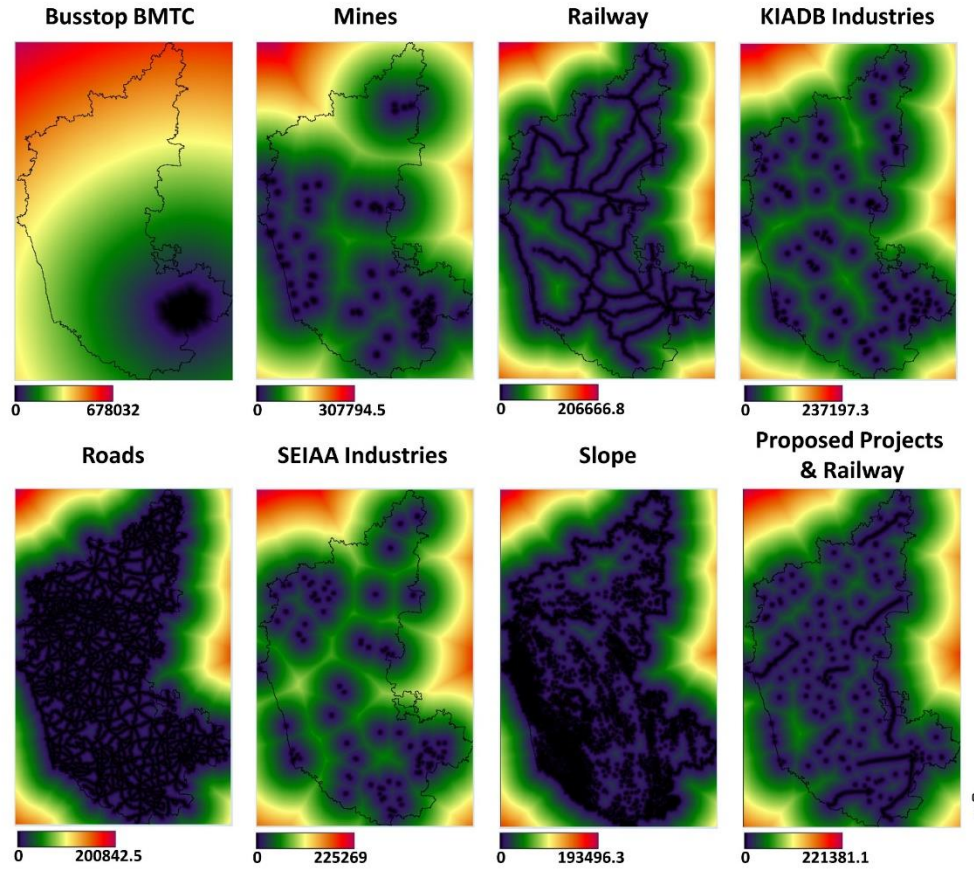
Agents

CONSTRAINT MAPS

DISTANCE MAPS



■ Non-constraint Feature
■ Constraint Feature



N
 0 75 150 km

Agents	Industries, proximities to roads, railway stations, metro stations, educational institutes, religious places, service infrastructure such as police stations, hotels, hostels etc.
Constraints	Drainage network, slope, water bodies, Reserved regions for non-development, Protected areas, catchment areas, etc.

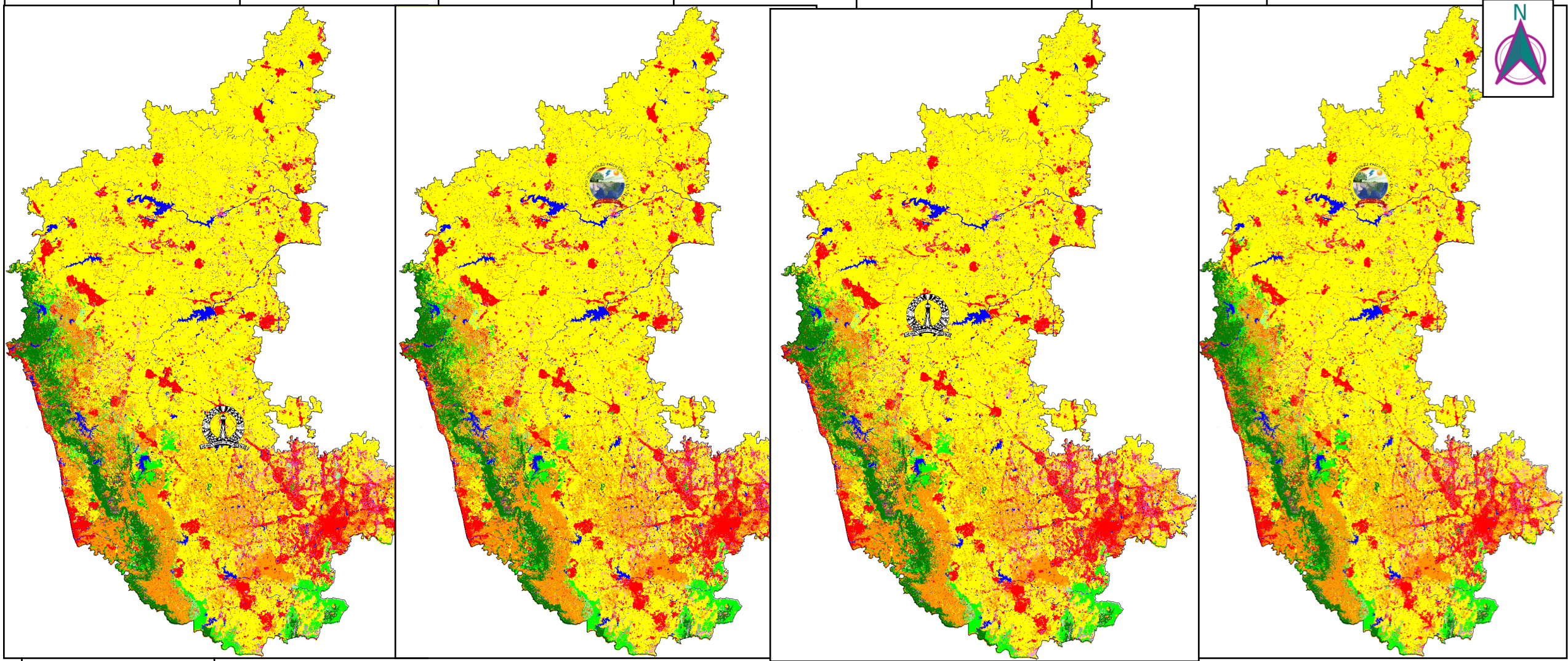
Scenarios: BAU, ALT, RFP, AF

BAU: 2033

ALT: 2033

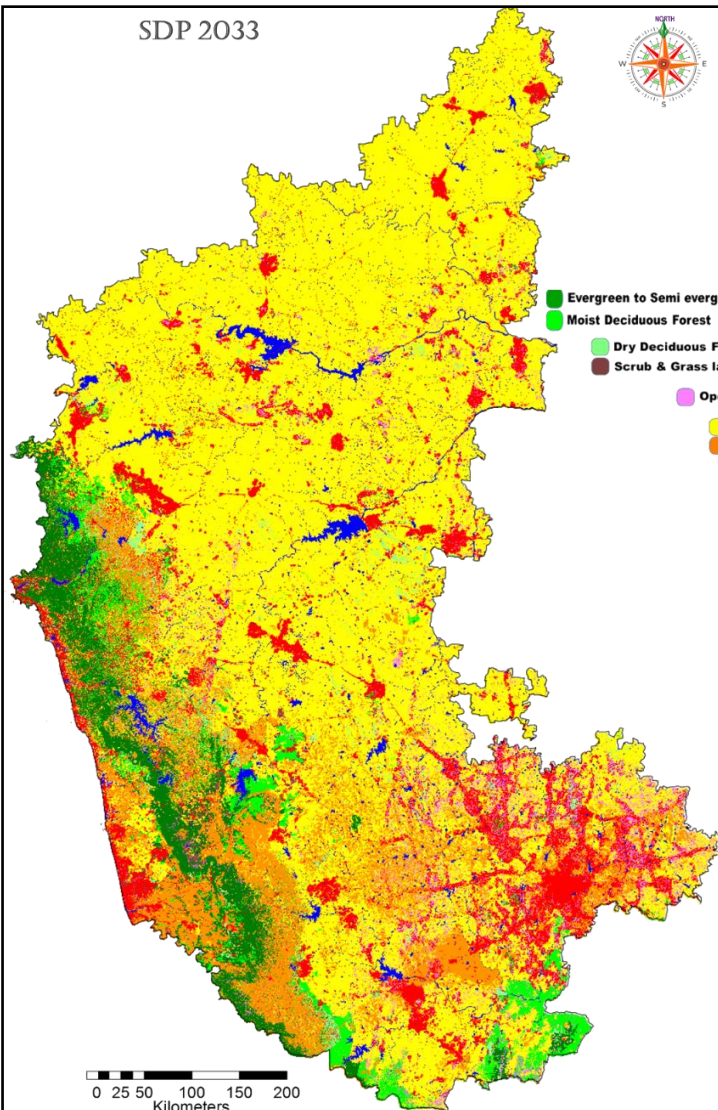
RFP: 2033

AF: 2033



- Evergreen to Semi evergreen Forest
- Moist Deciduous Forest
- Dry Deciduous Forest
- Scrub & Grass land
- Agriculture
- Plantations
- Water
- Built-up
- Open fields

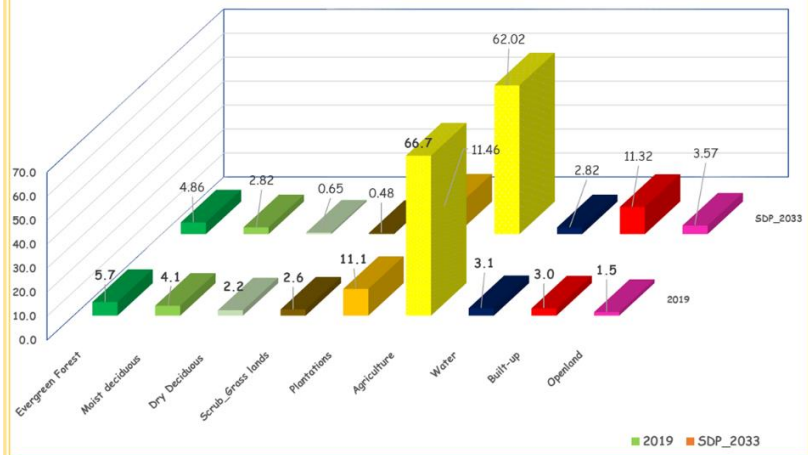
SDP 2033



- Evergreen to Semi evergreen
- Moist Deciduous Forest
- Dry Deciduous Forest
- Scrub & Grass land
- Open fields
- Agriculture
- Water
- Plantations
- Built-up

0 25 50 100 150 200
Kilometers

Land Use 2019 vs SDP 2033



Scenarios: BAU, RFP, ALT, AF, SDP

Land use categories	BAU_2033		ALT_2033		RFP_2033		AF_2033		SDP_2033	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Built-up	22,01,515	11.48	28,10,015	14.65	21,70,349	11.32	21,46,203	11.19	20,71,994	10.76
Agriculture	1,17,64,649	61.34	113,30,926	59.08	1,18,94,624	62.02	1,18,58,568	61.83	1,16,67,178	60.88
Plantation	21,77,670	11.35	20,66,713	10.78	21,98,428	11.46	21,69,239	11.31	21,52,053	11.23
Open fields	6,68,824	3.49	6,68,824	3.49	6,85,063	3.57	6,68,824	3.49	6,85,063	3.57
Evergreen Forest	9,20,948	4.80	9,15,179	4.77	9,32,811	4.86	9,59,097	5.00	9,72,489	5.07
Moist Deciduous Forest	5,77,449	3.01	5,72,085	2.98	5,41,381	2.82	5,75,213	3.00	6,66,957	3.48
Dry Deciduous	1,52,389	0.79	1,51,217	0.79	1,24,597	0.65	1,56,922	0.82	2,36,863	1.24
Scrub_Grass	1,15,952	0.60	1,14,432	0.60	91,496	0.48	97,938	0.51	1,96,677	1.01
Water	5,99,704	3.13	5,49,709	2.87	5,40,351	2.82	5,47,096	2.85	5,29,826	2.76
Total	1,91,79,100									

Ecosystem: Forests (in Billion Rupees) Policy Scenarios

Services Type	2019	BAU	ALT	RFP	AF	SDP
Provisioning Goods	613.90	524.23	521.67	533.69	530.82	540.33
Regulating Services	926.36	724.85	716.94	720.78	725.33	824.59
Cultural Services	294.97	291.69	291.62	291.67	291.68	293.23
Total	1835.23	1540.77	1530.23	1546.14	1547.83	1658.15

Figure 5.14: Relative share of ecosystem services (forest ecosystems), %

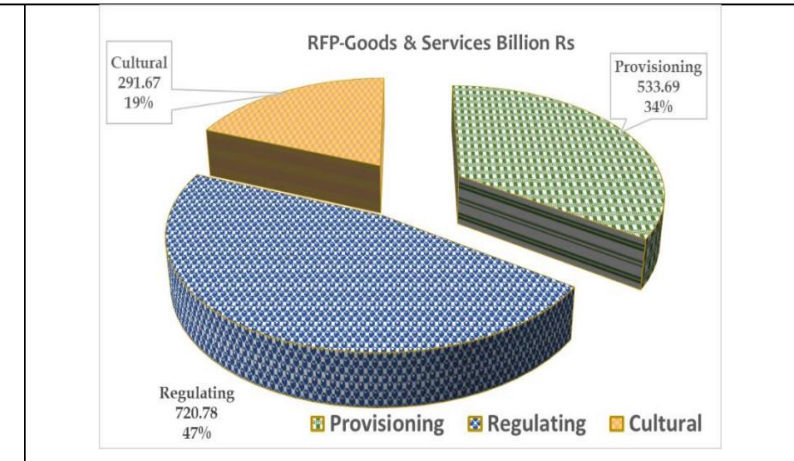
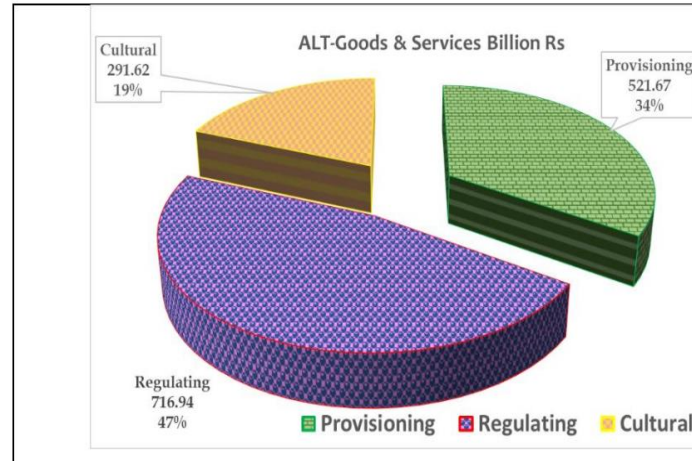
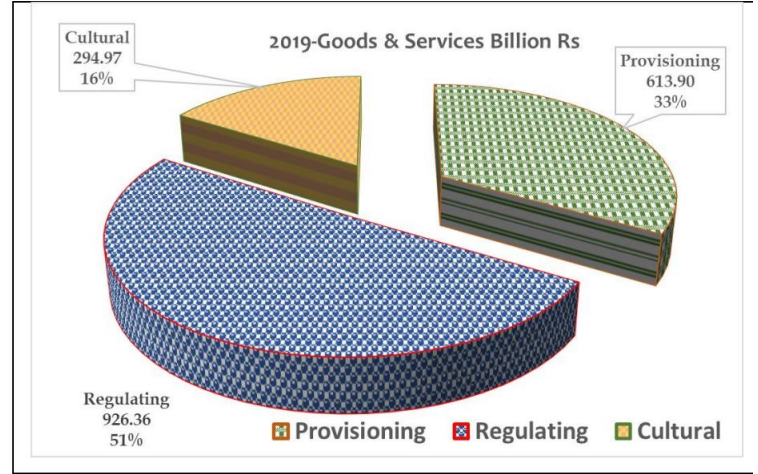
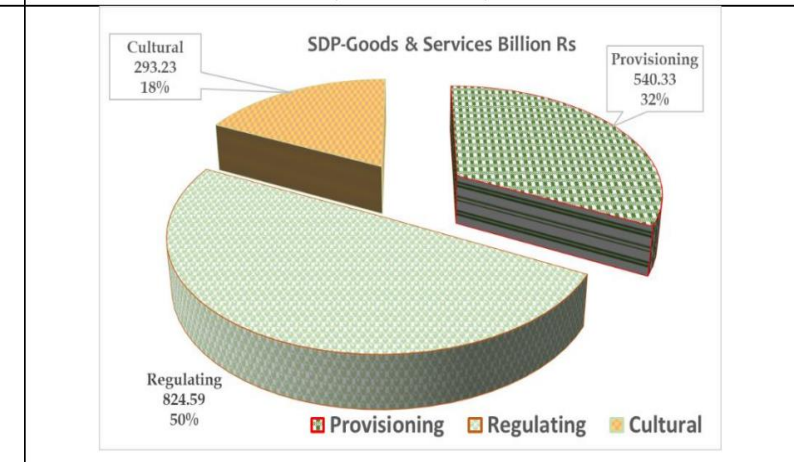
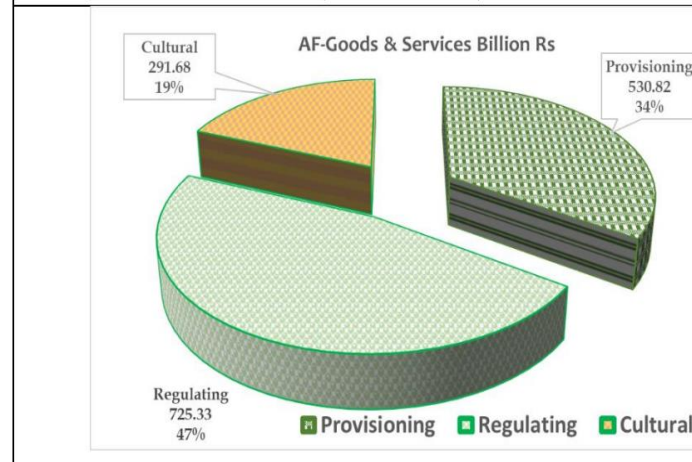
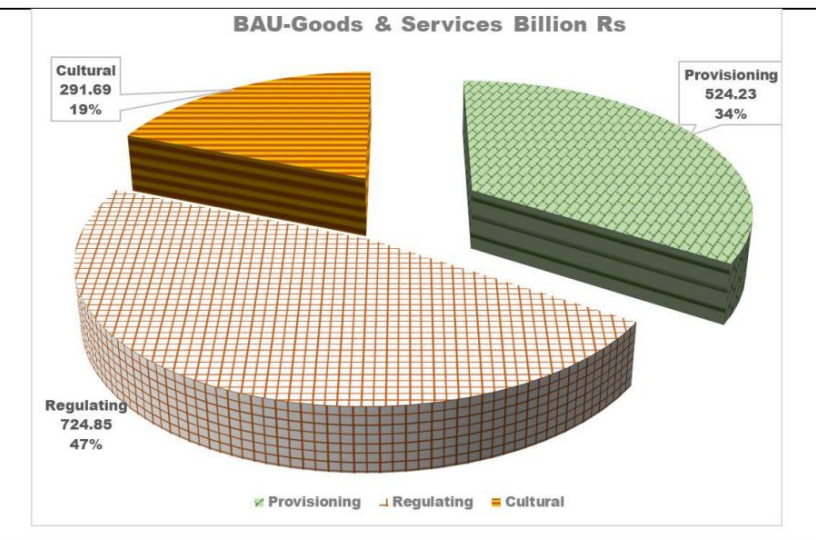


Figure 5.13b: Relative Share of Forest Ecosystem Services, 2033 (ALT Scenario)

Figure 5.13c: Relative Share of Forest Ecosystem Services, 2033 (RFP Scenario)



Wetlands – goods and services

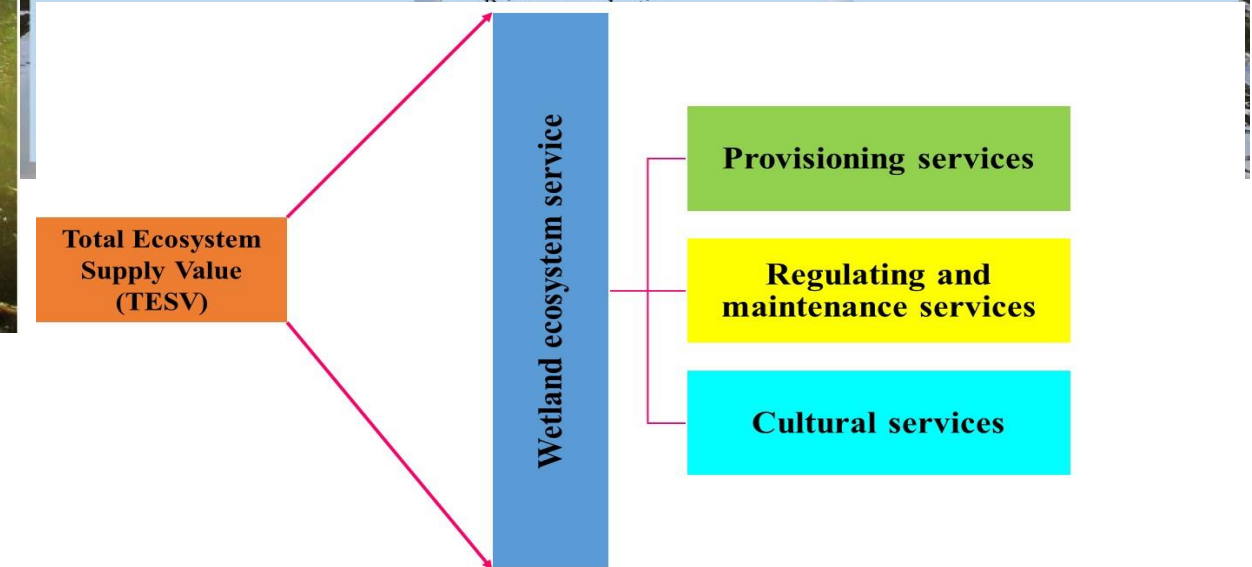
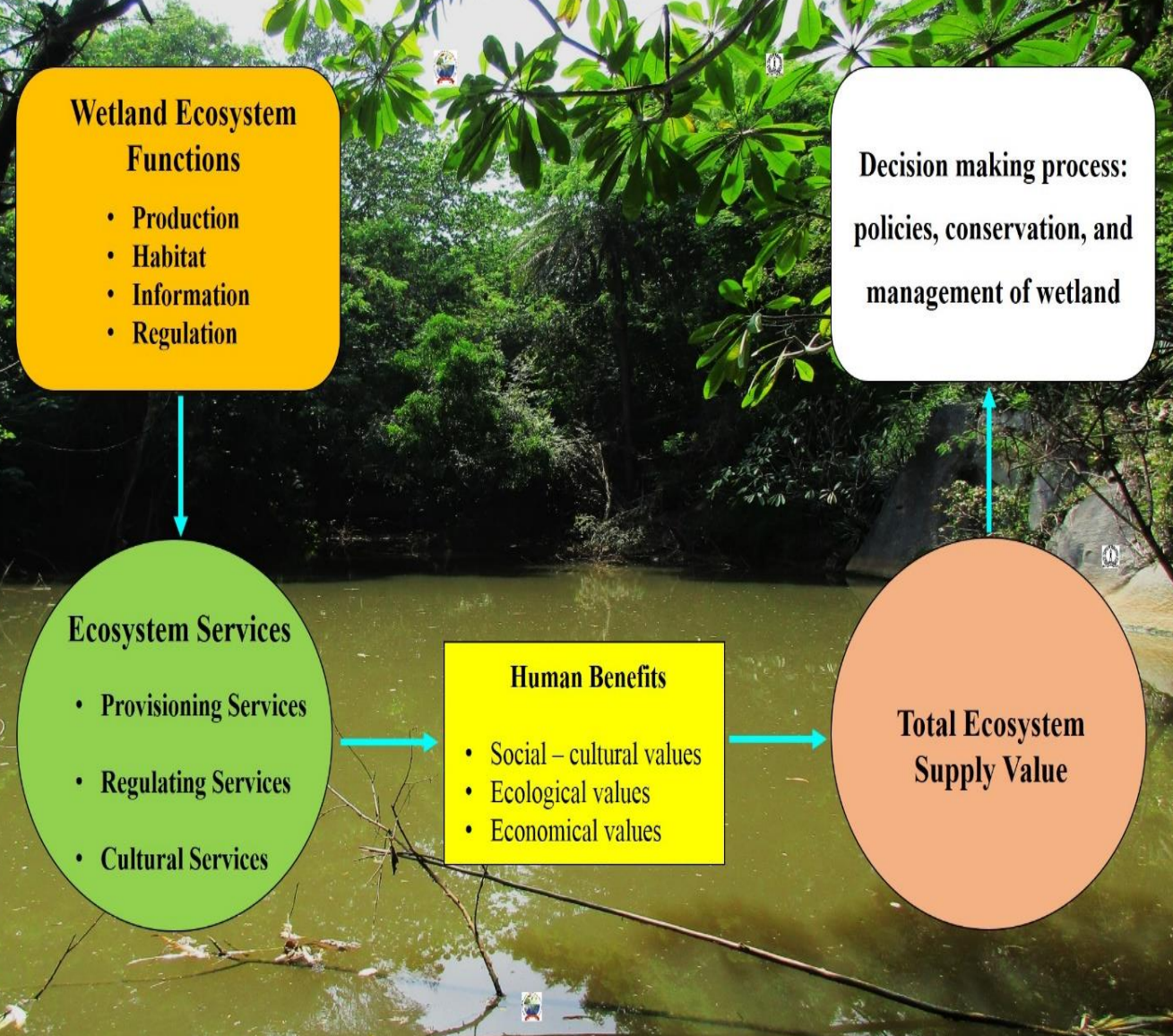
UNPOLLUTED

- Rachenahalli Lake– Rs 10500/day/hectare
 - (fish, fodder, agriculture in command area, flood mitigation, GW recharge, recreation,...)

POLLUTED

- Amruthhalli Lake: Rs 20/day/hectare
(Most waterbodies are Sewage fed)

Wetlands - Services



Total ecosystem value of Karnataka wetlands

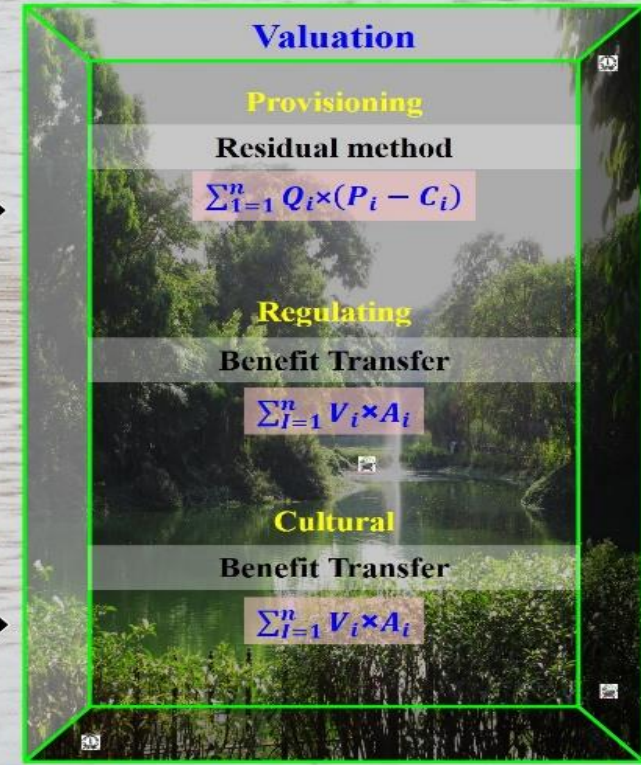
Services	Details	
	Wetland: Total area (ha) based on grid	281299.5
Provisioning Service	Total Rs/yr (in Billion Rupees)	49.70
	Production Rs/ha/yr (in Lakhs)	1.8
	% distribution	18
Regulating and Maintenance Service	Total Rs/yr (in Billion Rupees)	196.89
	Production Rs/ha/yr (in Lakhs)	7
	% distribution	69
Cultural Service	Total Rs/yr (in Billion Rupees)	37.93
	Production Rs/ha/yr (in Lakhs)	1.3
	% distribution	13
TESV	Total Rs/yr (in Billion Rupees)	284.52
	Production Rs/ha/yr (in Lakhs)	10.1
NPV	NPV in Billion Rupees	7320.6

VALUATION OF AQUATIC ECOSYSTEMS

Freshwater ecosystem



Estuarine ecosystem



Ecosystem	Provisioning Services (Rs/ha/yr)	Regulating Services (Rs/ha/yr)	Cultural Services (Rs/ha/yr)	TESV (Rs/ha/yr)
Inland Wetland	176681	699941	134822	1011444
Coastal	289928	557451	64357	911736
Aquatic	183328	691577	130686	1005591

Green GDP

3 Cultural

- ❖ The work is part of the international EU-funded, Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES) project
- ❖ The NCAVES project is being carried out as a collaboration between United Nations environment programme (UNEP), United Nations Statistics Division (UNSD), the Ministry of Statistics and Programme Implementation (MoSP), Government of India and The ENVIS division, The Ministry of Environment Forests and Climate Change (MoEFCC), Government of India.



<http://wgbis.ces.iisc.ernet.in/energy>

<http://iisc.ac.in>



tvr@iisc.ac.in, envis.ces@iisc.ac.in