Soil carbon stock under different land-use systems in Attapady Valley of Nilgiri Biosphere Reserve, Western Ghats, India

Sowmya Chandramouli[1], Sameer,P.A[2], Syam Viswanath[1], Nair, K.M[3]

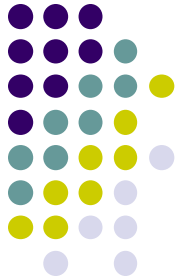
[1] *Tree Improvement and Genetics Division, Institute of Wood Science & Technology, ICFRE, Bangalore, India*

[2]*Dabur Nepal Private Ltd., Kathmandu, Nepal*

[3]*National Bureau of Soil Survey & Land Use Planning, ICAR, Bangalore*

E-mail: sowmya.chandramouli@gmail.com, sameeradam@rediffmail.com, syam.viswanath@gmail.com, nairkmn@yahoo.com

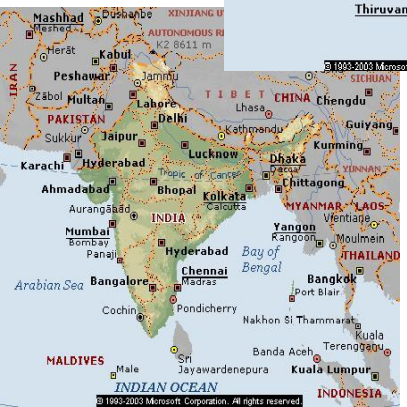
Background



- Attappady valley of Nilgiri biosphere Reserve - well known for its abundant natural wealth and indigenous people
- History of land-ownership and uses in the area - evolution of land-use problems

Location

- ✓Area: 745 km^2
- ✓Latitude: 10^0 55’ and 11^0 14’ N
- ✓Longitude: 76^0 21’ and 76^0 48’
- ✓Altitude: 450 to 2300 M above MSL



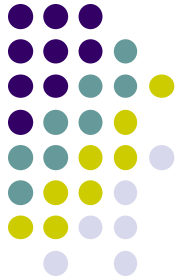
Demography

- ✓ Native Tribes (Irula, Muduga & Kurumba)
- ✓Settlers

Land use History of Attapady valley

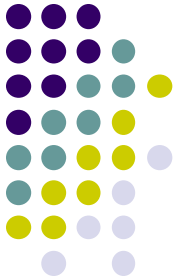
Era	Ownership	Land use Pattern
Up to 18th Century	Chera, Chola, Pandya, Vijayanagara, Mysore (Kongu) and Samothiri (Malabar) kingdoms	Dense forests, Shifting cultivation, hunting and gathering
18th–20th Century	East India Company-Kingdoms and Land Lords (Janmis)	Dense forests, Shifting cultivation, hunting and Timber extraction
1950-1970 (After Tamil Nadu Preservation of Private Forests Act, 1949)	Tribes, State Departments of Forest and Revenue	Extraction of timber and NTFP. Shifting / Kumri cultivation
1970-Onwards (After Kerala Private Forests Vesting and Assignment Act, 1971)	Adivasis, State Departments of Forest and Revenue, commercial establishments, institutions	Degraded forests, Settled Dry farming, plantations, fallows (wastelands), brick-kilns, buildings

Land-use systems (LUS) in Attapady



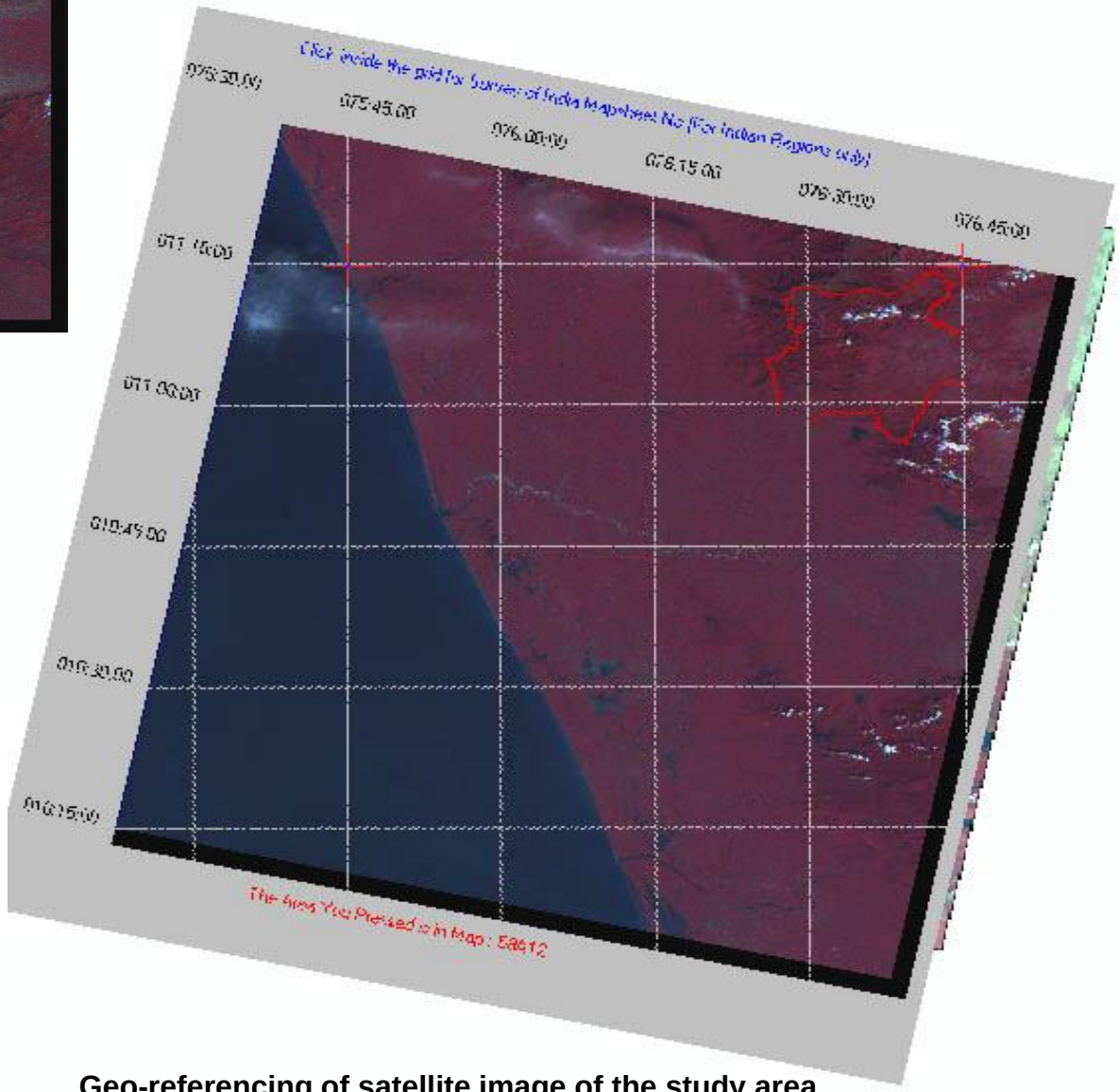
- Attapady - covered by pristine natural forest until 19th century
- Anthropogenic interventions - deforestation and vegetational changes in LUS – 1950-60
- Three newly transformed LUS
  - Agroforestry
  - Annual crop agriculture
  - Barren land

Study procedure

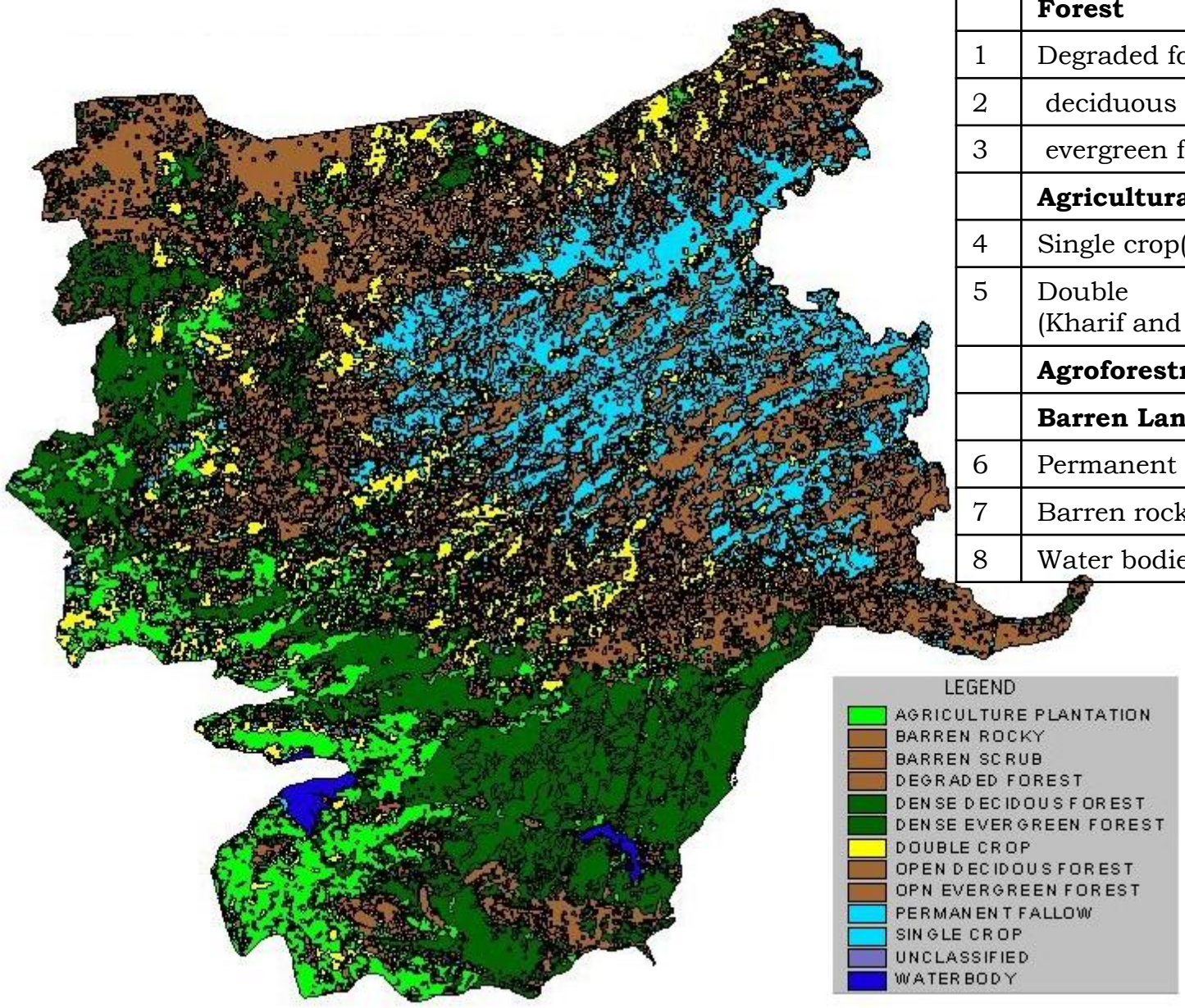


- Spatial delineation of the study area
- Climatic analysis
- Selection of sites
- Study of land and soil at selected sites
- Soil Sampling
- Laboratory analysis of soils
- Data processing and interpretations

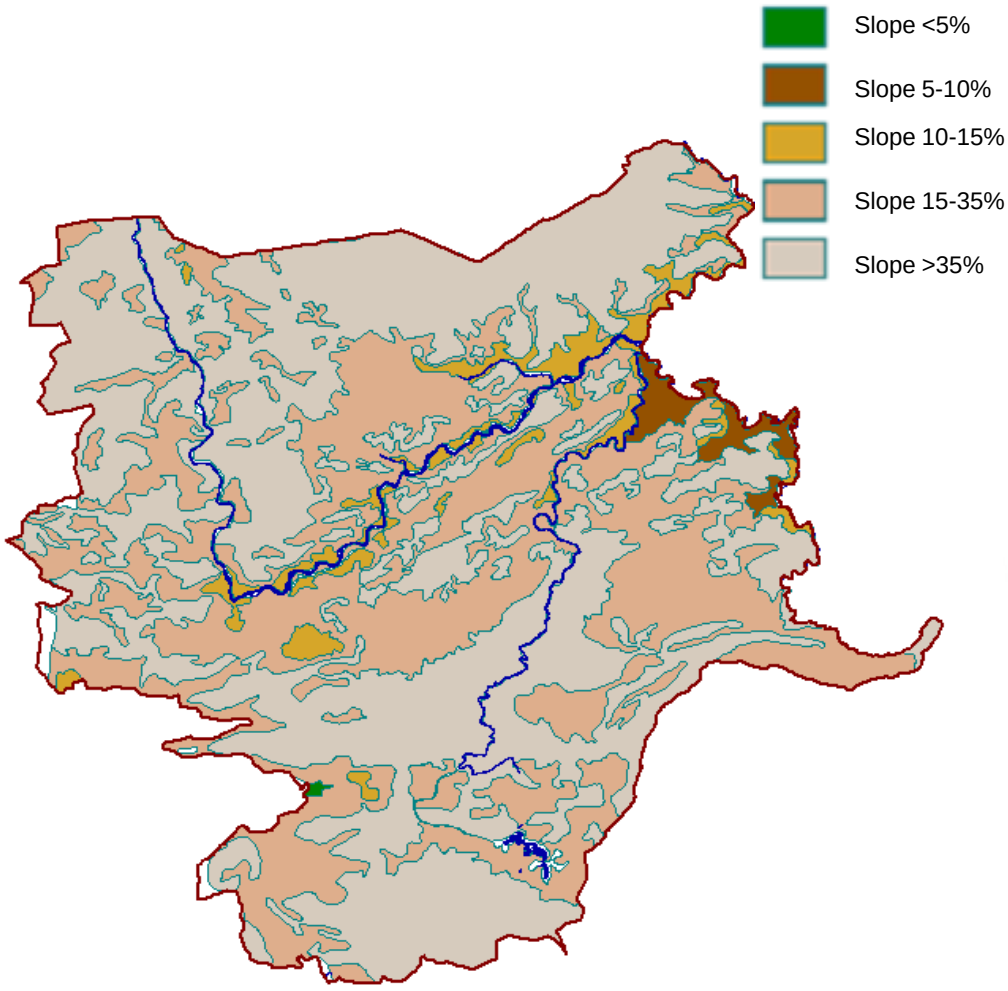
Satellite image of the study area (LISS-2)



Geo-referencing of satellite image of the study area



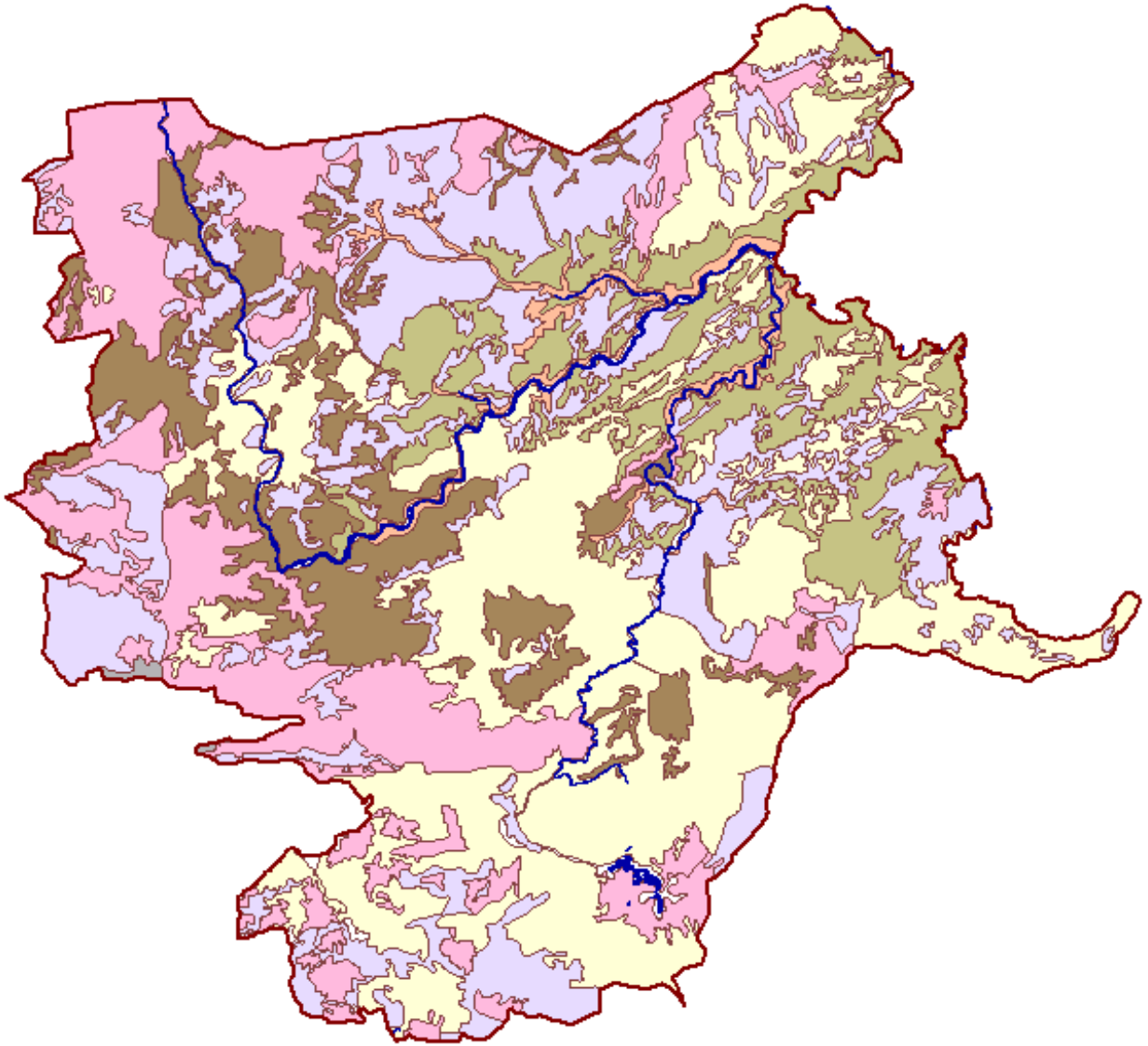
No	Land Use	Area Sq.km	% area
	Forest		
1	Degraded forest	355.30	47.7
2	deciduous forest	27.38	3.6
3	evergreen forest	80.75	10.8
	Agricultural land		
4	Single crop(Kharif)	41.43	5.5
5	Double crop (Kharif and Rabi)	66.00	8.8
	Agroforestry	92. 69	12.4
	Barren Land		
6	Permanent fallow	50.56	6.8
7	Barren rocks	27.38	3.7
8	Water bodies	2.81	0.3



Physiography of the study area (not to scale)**.**

Drainage network of the study area (not to scale)

Soil Series map of the study area (NBSS& LUP) (not to scale)

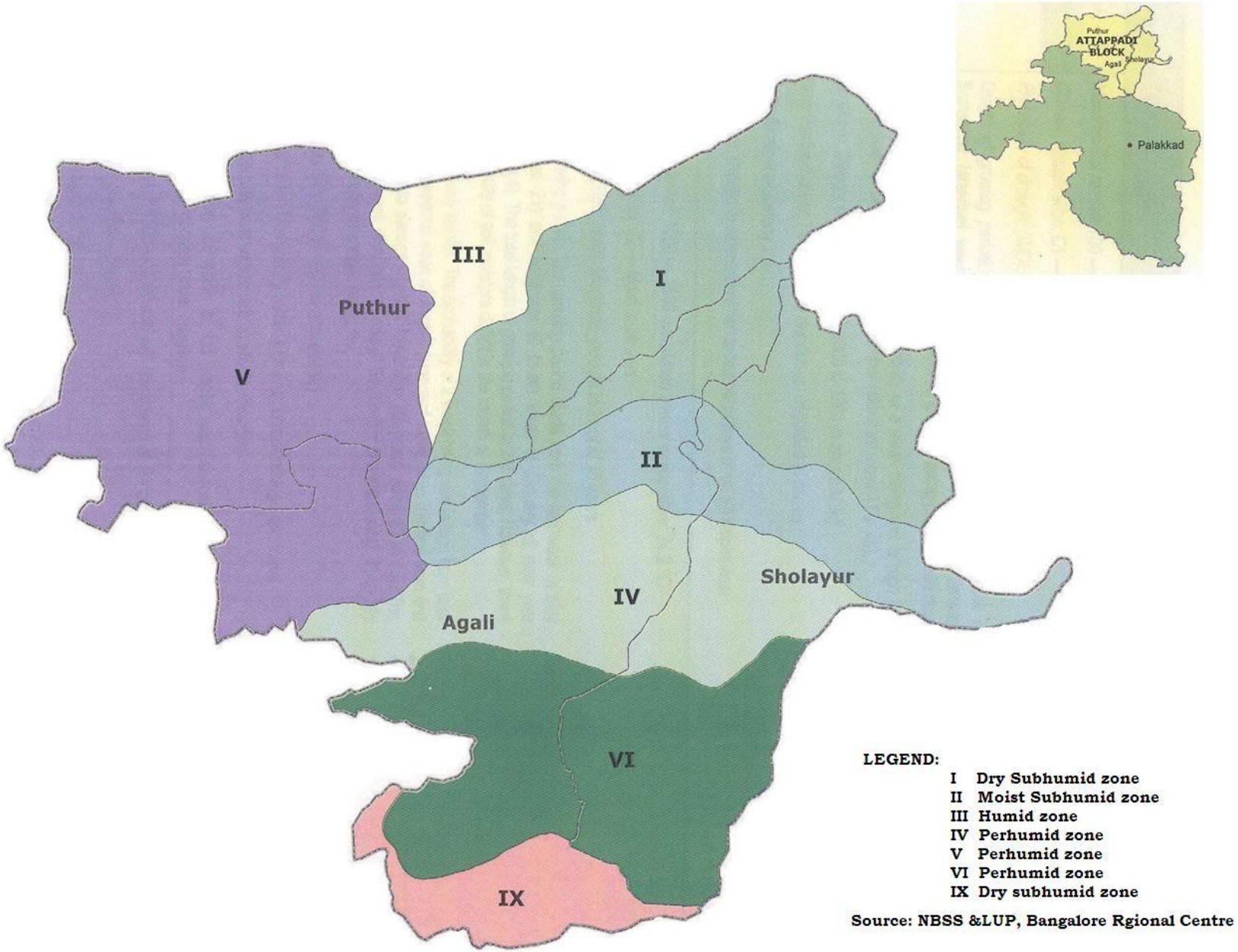


Site selection

- Study area was delineated in to 3 agroecological zones and 4 prevalent land-use systems (LUS)
- Study sites identified in each category keeping all other pedogenic factors (slope, geology etc) constant.
- Soil Profiles were exposed up to the parent material
- soil organic carbon (SOC) estimated.

Agroclimatic zonation

S.No.	Agroecological unit	Site
1	Per-humid A – (precipitaion 2000-2500 mm/yr)	Mukkali
2	Per-humid A – (precipitaion 2000-2500 mm/yr)	Chittoor
3	Per-humid A – (precipitaion 2000-2500 mm/yr)	Jellippara
4	Moist sub-humid zone C-2 (precipitaion 1000-1500 mm/yr)	Thavalam
5	Moist sub-humid zone C-2 (precipitaion 1000-1500 mm/yr)	Vechappathy
6	Dry sub-humid zone C-1 (precipitaion 7000- 1000 mm/yr)	Puthoor
7	Dry sub-humid zone C-1 (precipitaion 7000- 1000 mm/yr)	Anakkatty
8	Dry sub-humid zone C-1 (precipitaion 7000- 1000 mm/yr)	Cheerakadavu

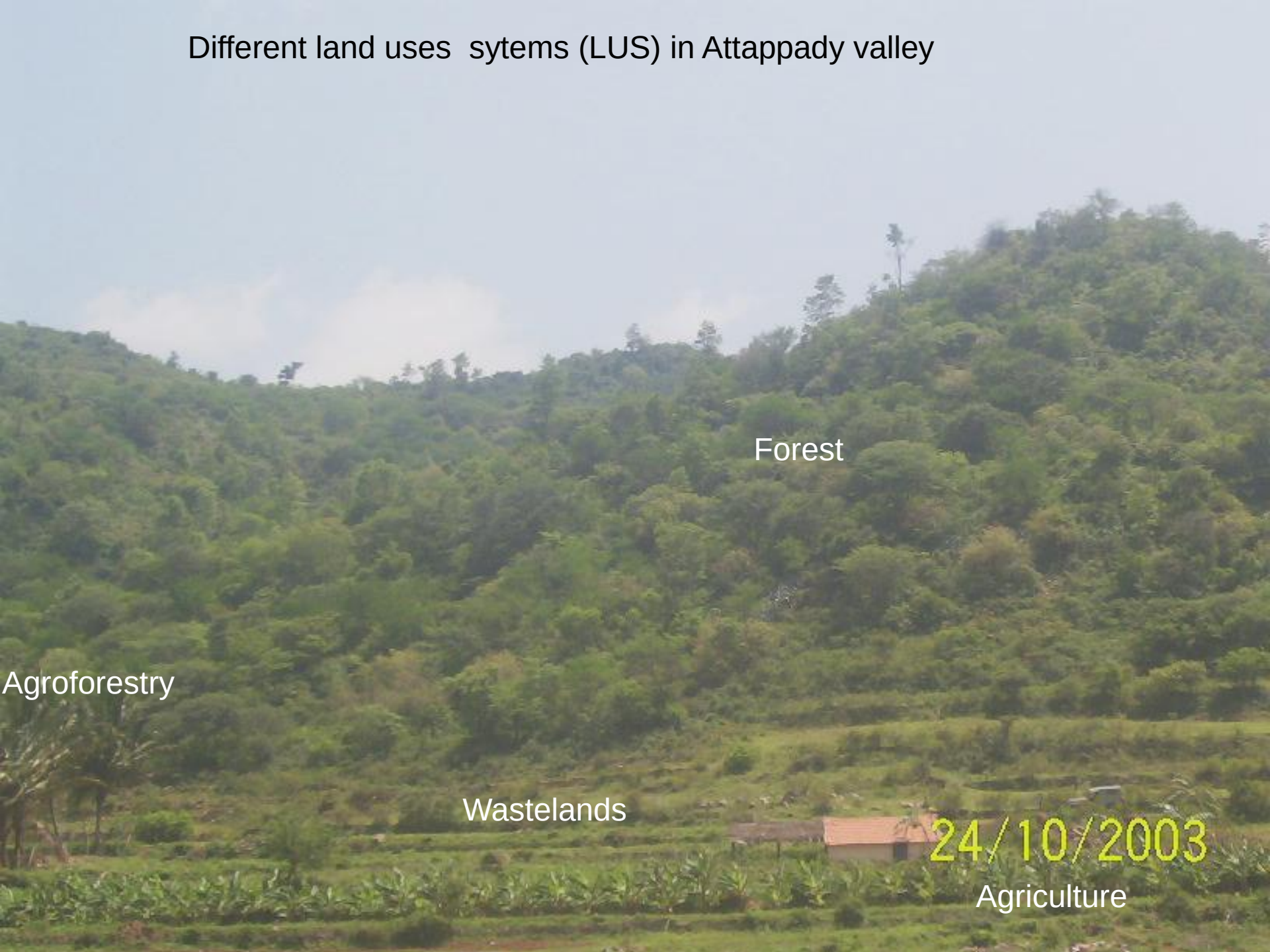


Agro ecological zonation map of the study area (not to scale)

Land-use systems (LUS) identified for study in Attapady

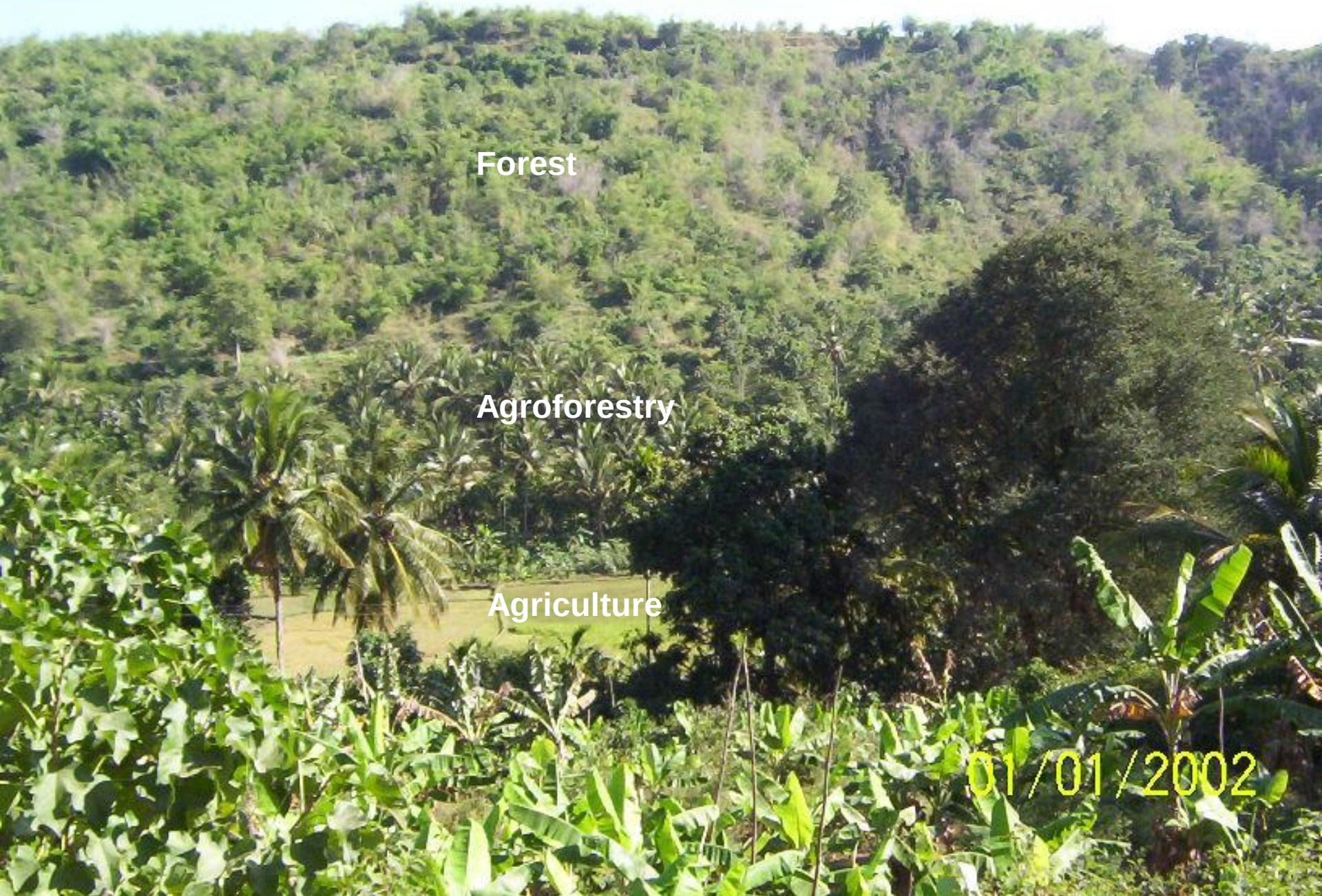
- Pristine Natural forests - dense evergreen and deciduous forests
- Agroforestry - *Cocos nucifera* and *Areca catechu* based homestead gardens with diverse agricultural horticultural and forest species
- Agriculture - vegetable crops cereals, millets, *Saccharum* spp. and medicinal plants like *Coleus aromaticus*
- Barren lands - degraded forest land devoid of trees and the deforested lands left fallow under private ownership

Different land uses sytems (LUS) in Attappady valley




forest
Different land uses sytems (LUS) in Attappady valley
Agroforestry
Agriculture
Wastelands
01/01/2002

Different land uses sytems (LUS) in Attappady valley



SOC status

- Comparisons of the present SOC status across these four LUS
- Vegetation and debris were cleared in one m^2 area in the identified sites
- SOC analyzed by Walkley-Black procedure

A soil profile in forest LUS

A soil profile in agroforestry LUS

A typical agriculture LUS

with exposed soil profile

A typical wasteland/barren land (LUS) soil profile

Soil bulk density in sites selected in each LUS and agroclimatic zone

Sites selected in each LUS and agroclimatic zone	Forest LUS			Agroforestry LUS			Agriculture LUS			Barren Land LUS		
	0-30 cm	30-100 cm	0-100 cm	0-30 cm	30-100 cm	0-100 cm	0-30 cm	30-100 cm	0-100 cm	0-30 cm	30-100 cm	0-100 cm
Perhumid												
Mukkali	1.48	1.54	1.51	1.52	1.56	1.53	1.54	1.55	1.56	1.57	1.59	1.58
Chittoor	1.45	1.53	1.5	1.49	1.57	1.48	1.5	1.58	1.54	1.51	1.65	1.58
Jellippara	1.41	1.49	1.45	1.42	1.51	1.47	1.53	1.58	1.56	1.56	1.64	1.6
Mean	1.44	1.52	1.48	1.47	1.54	1.49	1.52	1.57	1.55	1.54	1.62	1.58
Moist deciduous												
Thavalam	1.49	1.56	1.53	1.52	1.54	1.53	1.56	1.59	1.7	1.56	1.62	1.59
Vechappathy	1.49	1.54	1.52	1.5	1.57	1.54	1.51	1.6	1.56	1.56	1.62	
Mean	1.49	1.55	1.52	1.51	1.55	1.53	1.53	1.59	1.63	1.56	1.62	1.59
Dry deciduous												
Puthoor	1.47	1.6	1.54	1.49	1.62	1.56	1.55	1.65	1.6	1.58	1.68	1.63
Anakkatty	1.4	1.5	1.45	1.49	1.58	1.54	1.54	1.64	1.59	1.62	1.68	1.65
Cheerakadavu	1.48	1.52	1.5	1.5	1.57	1.54	1.54	1.6	1.57	1.58	1.62	1.6
Mean	1.45	1.54	1.49	1.49	1.59	1.54	1.54	1.63	1.58	1.59	1.66	1.62
Over all mean	1.46	1.53	1.49	1.49	1.56	1.52	1.53	1.59	1.58	1.56	1.63	1.59

Measurement of C efflux from soil in the study sites

- $Ce = (A \times D \times \rho b \times SOC \times f)$

- **Ce is the C efflux from soil to atmosphere,**
- **A is the area of land conversion ,**
- **D is the soil depth in m,**
- **ρb is the soil bulk density as the weighted average for all depths.**
- **f is the SOC fraction efflux by the change in land use.**

Houghton (1995)

Measurement of SOC depletion

- $Ci = \sum_{n=0}(SOCt - SOCf)\rho b.\, d$
- Ci is the carbon lost during degradation from the soil,
- SOCt is the SOC before degradation and SOCf is the SOC after the degradation
- ρb is the soil bulk density of the horizon of thickness 'd' and
- 'n' refers the number of diagnostic horizons.

(Bouwman 1990)

Soil Organic Carbon Stock (SOC) and Total Carbon stock of different land use systems in Attapady Valley, Kerala

Land use	Area (Sq km)	Mean SOC in kg m^{-2}			Carbon stock in Mg ha^{-1}		
		0-30 cm	30-100 cm	0-100 cm	0-30 cm	30-100 cm	0-100 cm
Dense evergreen forest	80.74	9.56	7.49	17.05	772	605	1377
Dense deciduous forest	27.38	7.68	5.43	13.11	210	149	359
Agroforestry	92.68	7.14	3.02	10.17	662	280	942
Agriculture	107.43	4.79	2.07	6.86	514	223	737
Wastelands	405.85	3.60	0.87	4.47	1461	354	1814
Total					3619	1611	5229

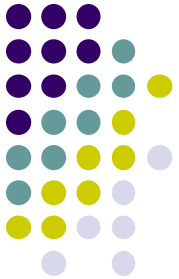
SOC stock at top 100cm in Attapady Valley

- Undisturbed forest (15.14% of area) accounted for 33.20% of SOC stock
- Agroforestry (12.98 % of area) held 18.02% of SOC stock
- Agriculture landscapes (15.04 % of area) held 14.09 % of SOC stock
- Barren lands (56.3% of the study area) accounted for 34.6% of the total SOC stock

Soil Organic Carbon Stock (SOC) depletion in study sites in different LUS in 3 Agroecological zones in Attapady Valley, Kerala

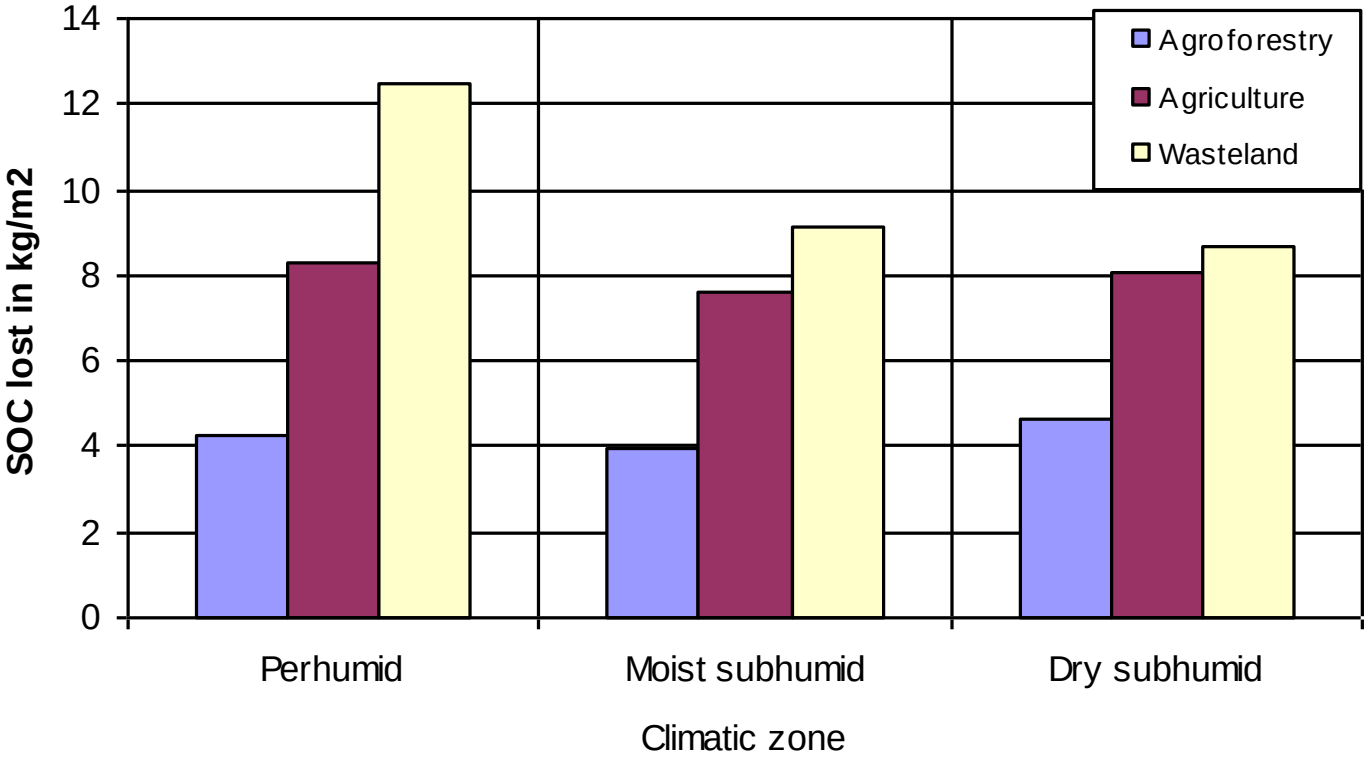
Site	SOC Stock decline Agroforestry Kg m-1			SOC Stock decline Agriculture Kg m-1			SOC Stock decline Wasteland Kg m-1		
	0-30 cm	30-100 cm	0-100 cm	0-30 cm	30-100 cm	0-100 cm	0-30 cm	30-100 cm	0-100 cm
Perhumid									
Mukkali	0.31	3.02	3.33	3.95	5.19	9.14	4.17	5.36	9.53
Chittoor	3.51	5.13	8.64	5.96	5.53	11.50	8.78	7.52	16.29
Jellippara	0.29	0.43	0.72	2.02	2.18	4.20	4.61	6.94	11.55
Mean	1.37	2.86	4.23	3.98	4.30	8.28	5.85	6.61	12.46
Moist deciduous									
Thavalam	0.09	4.81	4.04	1.95	5.54	7.49	4.41	6.19	10.60
Vechappathy	2.11	1.71	3.82	3.75	4.01	7.76	3.68	4.01	7.68
Mean	0.67	3.26	3.93	2.85	3.99	7.63	4.04	4.64	9.14
Dry deciduous									
Puthoor	2.94	3.63	6.57	4.89	3.74	8.62	5.38	4.42	9.80
Anakkatty	0.58	4.18	4.76	3.04	4.72	7.69	3.80	4.93	8.73
Cheerakadavu	0.83	1.71	2.54	3.24	4.54	7.78	3.48	4.11	7.59
Mean	**1.45**	**3.17**	**4.62**	**3.72**	**3.84**	**8.03**	**4.22**	**4.49**	**8.71**
Over all mean	**1.16**	**3.10**	**4.26**	**3.52**	**4.04**	**7.98**	**4.71**	**5.25**	**10.10**

SOC stock depletion



- Major depletion of SOC - top 30cm soil
- Estimated depletion around 1.16 kg m^{-2} on conversion to agroforestry
- 3.52 kg m^{-2} on conversion to agriculture
- 4.71 kg m^{-2} on conversion barren lands
- barren land > agriculture land > agroforestry> forestland

Magnitude of SOC decline at top 100 cm of soil due to shifting from forest to different LUS in different agroecological zones in Attapady Valley



CO_2 released (kg m^{-1}) during LUS shift in the 3 different agroecological zones in Attapady Valley			
Site	**Agroforestry**	**Agriculture**	**Wasteland**
Perhumid			
Mukkali	12.21	33.51	34.96
Chittoor	31.68	42.15	59.74
Jellippara	2.62	15.40	42.35
Mean	15.51	30.35	45.68
Moist deciduous			
Thavalam	14.80	27.48	38.88
Vechappathy	14.00	28.45	28.17
Mean	14.40	27.97	33.53
Dry deciduous			
Puthoor	24.08	31.62	35.93
Anakkatty	17.44	28.21	32.02
Cheerakadavu	9.32	28.53	27.83
Mean	16.95	29.45	31.93
Over all mean	15.62	29.26	37.05

CO_2 emission from different LUS

- Maximum loss (59.74 kg m^{-1}) occurred in conversion of evergreen forest LUS to barren land LUS at Chitoor in Perhumid zone

- Minimum loss (2.62 kg m^{-1}) on conversion of forest LUS to agroforestry LUS at Jellipara in Perhumid zone

CO_2 stored under different LUS in Attapady Valley

Land use system (LUS)	Area (Sq km)	CO_2 trapped ($Mg\ m^{-1}$)
Dense evergreen forest	80.75	5048
Dense deciduous forest	27.38	1317
Agroforestry	92.69	3455
Agriculture	107.43	2702
Wastelands	405.85	6652
Total		19174

SUMMARY

Forest LUS had a carbon reserve 3.2 times greater than barren land LUS.

Nearly 19 Tg of C is estimated to be fixed as SOC through current prevalent LUS

If the natural forest had been retained, 45 Tg C could have been potentially fixed, which may be significant contribution to SOC stock in Attapady valley

Deforestation has caused a depletion of 25 Tg from this potential SOC stock.

Conclusions

- Deleterious effects of converting climax natural forest area to agroforestry LUS or agriculture LUS may not be as serious as natural forest LUS conversion to barren lands

- Need for systematic planning for converting barren lands in a sequential stepwise process towards natural forest land LUS

- Participatory approach - considering issues like land tenure, land policy issues and stake holder preferences

- This study can be a benchmark for the evaluation and monitoring of further restoration activities

Acknowledgement

- Dr.V.P.Tewari, Scientist, Wood energy Division, IWST, Bangalore
- Dr.Christoph Kleinn, Professor of Forest Inventory and Remote Sensing, Burckhardt-Institute at the Faculty of Forest Sciences and Forest Ecology, Georg-August-Universität Göttingen


Thank you for your kind attention…