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CARRYING CAPACITY BASED CONSERVATION AND SUSTAINABLE MANAGEMENT OF RIVERINE ECOSYSTEMS

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ABSTRACT

The conservation and sustainable management of ecosystems are the vital components in the pursuit of development goals that are ecologically, economically and socially sustainable. This requires an understanding of the complex functioning of ecosystems, and recognition of the full range and diversity of resources, values and ecological services that they represent. In this regard, the current research envisages integration of the ecological, environmental considerations into administration and management of river basins, which is a major step towards an ecological audit that eventually should result in the conservation and sustainable use of biodiversity. Ecological Carrying Capacity provides physical limits as the maximum rate of resource usage and discharge of waste that can be sustained for economic development in the region. Planning for development within the limits of carrying capacity recognises that humankind is dependent on the productive capacity of ecosystems, and therefore, a minimal level of ecosystem integrity is to be maintained for human survival. Planning for sustainable development calls for trade-offs between the desired production-consumption levels through the exploitation of *supportive capacity* within its regenerative capacity and environmental quality within the *assimilative capacity* of regional ecosystem. Assessment of the carrying capacity involves detailed study of ecology and human life in the region. Carrying capacity research in the Netravathi River basin began, through inventorying, mapping and monitoring of the vegetation and fauna. Data required for natural resource planning included spatial data such as, information of physiography of the area, land use, assets, etc. The ecological sensitivity of ecosystems refers to their ability to cope with various kinds of environmental disturbances that have the potential of adversely changing the character of the natural landscapes. Identification of Ecologically sensitive Regions (ESRs) considering spatially both ecological and social dimensions of environmental variables helps in ecological and conservation planning as per Biodiversity Act, 2002, Government of India. The current research attempts to integrate ecological and environmental considerations into administration, and prioritizes regions at Panchayat levels (local administrative unit) in Netravati River basin, Central Western Ghats, Karnataka state considering attributes (biological, Geo climatic, Social, etc.) as ESR (1-4) through weightage score metrics, corresponding to the zones of principal functions such as prohibited development zone, restricted development zone, an optimized development zone in planning. Identification of ESRs in Netravathi region would aid in sustainable planning towards the sound ecological regional development. There are 433 villages in the Netravathi river basin, of which 111 villages in ESR-1, 69 villages in ESR-2 119 villages in ESR-3 and 134 villages in ESR 4. ESR 1 and ESR 2 are to be strictly no-go area with respect to developments and ESR 4 is referred as a least possible eco-sensitive region. Degradation of these eco-sensitive region with the unplanned developmental path will only erode the sustenance of natural resources and would affect the local livelihood.

Keywords— Biodiversity, carrying capacity, ecology, eco sensitive regions, geospatial analysis, habitat fragmentation, landscape dynamics, Multi resolution remote sensing data

I. INTRODUCTION

Landscapes are composed predominantly of natural vegetation, which aid in maintain the ecosystem goods and services [1-4] The human welfare is integrally twined with the integrity of an ecosystem which sustains the availability of natural resources. However mismanagement of ecological systems with the unplanned developmental activities has impaired ecosystem services evident from the barren hill tops, conversion of perennial streams to seasonal streams, reduced biological productivities, etc. The anthropogenic activities have altered natural landscapes affecting their capacity of (i) bioremediation - filter nutrients and contaminants from water, (ii) flood mitigation - abate flood waters associated with extreme climate events, (iii) retain water, soils, and nutrients, (iv) resist invasive species establishment, and (v) provide for natural predators of pests [3,4]. The ecosystem is experiencing pressures from drivers such as land use land cover [LULC] change, changes in the climate due to enhanced GHG (Greenhouse gas) levels in the atmosphere, pollutants (air, water and land) and propagation of invasive species. This necessitates appropriate policy measures to mitigate the disturbances so as to ensure not to exceed the threshold state from which it may not recover or may take many years to return to its previous state through natural processes [5]. This entails

attaining comprehensive knowledge of the ecosystem integrity and the goods and services provided by ecosystems, and the importance of conservation for maintaining the quality of life.

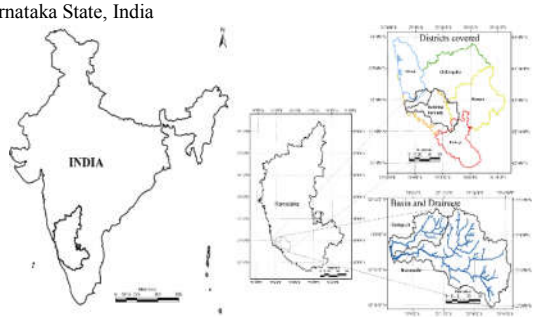
Systematic conservation planning has been increasingly encompassed of identifying or expanding conservation hotspots, protected areas or to set a threshold for resource usage and to influence land use decision making. It requires an assessment of carrying capacity of a region taking into account resource base, ecological sensitiveness, supportive and assimilative capacity of the respective ecosystems, conservation initiatives, etc. Planning also requires assessment of bio-geological systems, spatial priorities (i.e. area selection) for conservation action complemented with the sustainable development strategy in the context of stakeholder collaboration [3, 6, 7]. ESR are geographical units of land or water containing a distinct assemblage of species, natural communities, and environmental conditions, which is essential for conservation planning. Adoption of a landscape perspective (spatial composition, pattern, and position) plays a vital role in demarcating ESRs as it provides a common framework to evaluate social, economic, and cultural dynamics and their relationship to ecological services [3,4, 8-10]. Stakeholder participation in decision making of ESR (as per the Biodiversity Act, 2002) would aid in understanding the complex and dynamic nature of environmental problems and lends a flexible and transparent decision making through a diversity of knowledge and values.

The Ministry of Environment, Forests and Climate change (MoEFCC), Government of India has taken an initiative to protect forests and maintenance under section 3 of Environment (Protection) Act 1986 (EPA). Central Government can prohibit or restrict the location of industries and carry out certain operations on the basis of considerations like the ecological sensitivity under section 5 of EPA 1986. The ecological sensitivity or fragility refers to the permanent and irreparable loss of extant life forms from the world; or significant damage to the natural processes of evolution and speciation. The comprehensive knowledge of a region has become increasingly important for conservation planning and visualization of future growth to overcome the problems of haphazard, uncontrolled development in ecologically sensitive regions [3, 4, 8-10]. Unplanned developmental path through river diversions, hydro electric projects, coastal reservoirs, commercial plantations, unscientific tourism, etc. would cause irreplaceable loss of rich biodiversity and is threatening the ecologically sensitive regions in the Netravathi River basin. In this regard, the current research tries to understand land use dynamics, biodiversity, hydrology, ecology and social aspects in the Netravathi River Basin (includes Gurupura river also) and delineate ecological sensitive regions considering bio-geo climatic variables for prudent management of natural resources.

II. MATERIAL AND METHOD

Study Area: The river Netravathi originates in Bangrabalige valley, Yelaneeru Ghat of Kudremukh in Chikkamagaluru district of Karnataka, Western Ghats, India [4]. The river has a catchment area of 4409 km^2 and covers Chikmagaluru, Hassan, Kodagu, Dakshina Kannada and Udupui districts (Figure 1) in 11 taluks. Rainfall varies between 2600 mm (Plains of Mudigere and Sakleshpura taluk) to over 5500 mm (Ghats). Elevation of the basin ranges from < 0 to 1872 m It is the lifeline of Dakshina Kannada region supporting the enormous population with rich resource base and diverse cultures. This sacred river runs through numerous popular pilgrim places such as Dharmasthala, Kukke Subramanya etc.. Netravathi main course merges with the river Kumaradhara at Uppinangadi before merging into the Arabian Sea with Gurupura river [4]. The river forms major water source to the Mangalore city, Bantwal and many towns. Many valleys served by watercourses and riparian plains are the seats of the famed spice gardens growing crops like, coconut, arecanut, banana, cardamom, turmeric, black pepper, cocoa, ginger and vanilla. Netravathi river basin is part of the ecologically fragile Western Ghats, one among 35 global hotspots of biodiversity supporting diverse flora and faunal species. Netravathi River systems has numerous perennial streams with typical tropical climax evergreen forested catchment areas of high conservation value. The forest types in the basin vary from tropical wet evergreen to semi-evergreen rain forests, tropical moist deciduous forests, scrub jungles, grasslands and savannas, scattered trees along plantations and abandoned fields [4].

Figure 1: Netravathi River basin, Central Western Ghats, Karnataka State, India



METHOD:

The research involved (i) spatial data analysis – land use analyses to understand the landscape dynamics, (ii) field investigations to map flora, fauna, social aspects, etc., (iii) ESR delineations. The study region was divided [4] into 5'x5' grids (9 x 9km) for priortiosing regions with the exceptional biodiversity and ecologically fragile. Grids were assigned the weightages based on the variables listed in Table 1 and equation1 [3,4]. A weightage metric score based on multiple data sets (figure 2 and table 1) were considered to priritise the regions at panchayath levels for conservation and management planning. The weightage [3,4] is de ned by:

$$Weig\ atge = \sum_{i=1}^{n} W_i V_i \quad \ldots\ldots 1$$

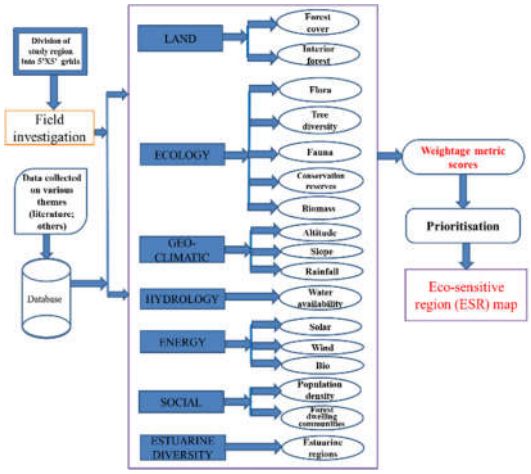


Figure 2: Method adopted for the ESR analysis

Where n is the number of data sets, V_i is the value associated with criterion i, and W_i is the weight associated to that criterion. Each criterion is described by an indicator mapped to a value normalized 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, low levels of conservation.

III. RESULTS AND DISCUSSION

Land use analysis: The forests of Netravathi river basin with the repository of rich biodiversity have been supporting the livelihood of people in the districts of Central Western Ghats. The land use analysis of Netravathi river basin depicts the status of forest cover during the year 2016 (Figure 3 and Table 2). The area under forest cover shows 51.67 % after losing significant patch of forests for mini-hydroelectric, infrastructure projects and monoculture plantations [4]. The plantations constitute 26.42 % of the basin and major forests are confined to the eastern side of the basin (Figure 3).

Table 2: Land uses in Netravathi basin.

DESCRIPTION	Ha	%
Evergreen forests, deciduous forest, degraded forests, etc.	224900	**51.67**
Horticulture and Forest plantations	115010	**26.42**
Current Sown and Fallow Agricultural lands	21800	5.01
Buildings, Roads and paved surfaces	9410	**2.16**
Open area, Grasslands, Riverbed, Sand, Quarries, Cloud and Shadow	61030	14.02
Rivers, Lakes, Ponds, Estuary	3150	0.72
TOTAL AREA	435300	

Figures 4 depicts the flora categorised as per IUCN status, compiled from field and also published literatures. The significant floral species includes *Knema attenuate, Gymnacranthera canarica, Holigarna ferruginea, Myristica malabarica, Ochreinauclea missionis, Madhuca insignis, Memecylon angustifolium, Syzygium travancoricum, Pandanus unipappilatus, Helminthostachys zeylanicus, Diplazium esculentum, Strobilanthes ciliates, Hopea ponga, Vateria indica, Euonymus indica, Carallia brachiata, Madhuca neeriifolia, Calophyllum apetalum, Elaeocarpus tuberculatus, Vitex leucoxylon Kingiodendron pinnatum* etc., and many of them are under Critically Endangered, Vulnerable, Threatened categories. The region is home to endangered Myristica swamps having Critically Endangered *Syzigium travancoricum* and *Gymnacranthera canarica* (Vulnerable) are amongst many other species [4]. The swamp ecosystem is under higher threat due to horticulture expansion and land conversion for other developmental activities. The area has a large number of medicinal plants and non-timber forest product (NTFP) yielding plants. The distribution of 429 flora species in 95 families is given in Figure 4. The region is home to many very rare, endemic and endangered wildlife (Figure 5) covering 418 species under 126 families. Main predators are tiger (*Panthera tigris*), leopard, wild dog (dhole) and sloth bear. Leopards are in good number and wild dogs are in very less number, usually sighted in KNP region and Gundia basin.

Figure 3: Land use analysis of Netravathi river basin

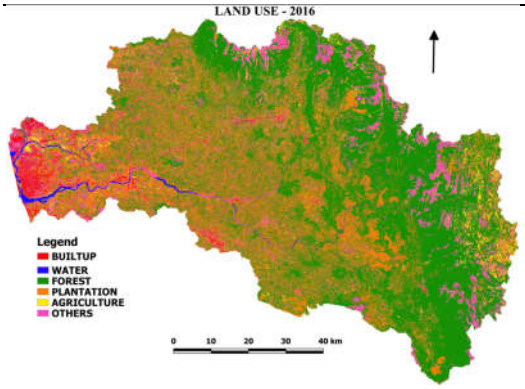


Figure 4: Flora diversity of Netravathi as per IUCN status

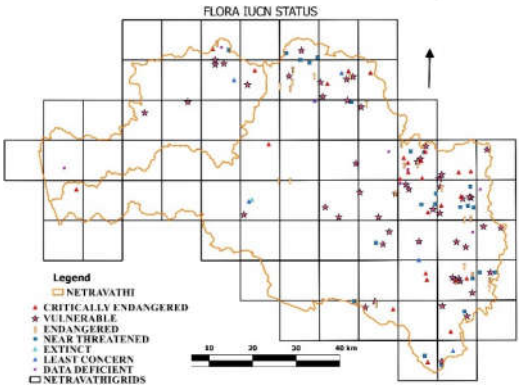


Figure 5: Faunal diversity of Netravathi as per IUCN status

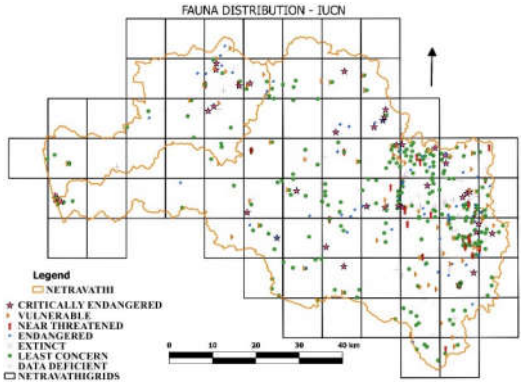


Figure 6: Elephant movement path (Mutthodi to Bannerghatta)

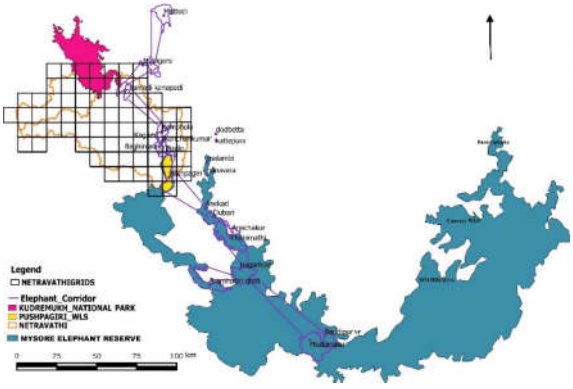


Figure 7: Ecologically Sensitive Regions of Netravathi river basin

The Bisle Reserve Forest of Netravathi basin forms a vital elephant movement path that connects the notified Mysore Elephant Reserve (total area of 6,724 sq.km, vide GO FEE 231 FWL 2000, 25/11/2002), which forms a link connecting Western Ghats and Eastern Ghats covering many wildlife sanctuaries, national parks etc. [4]. Bisle forest adjoins Kempholé Reserve Forest in north and Pushpagiri Wildlife Sanctuary in the south. It is an integral and important part of the Mudumalai-Nagarhollé-Brahmagiri-Muttodi Corridor (Figure 6).

Theme wise grid based spatial layers (land use, flora, fauna, protected area, geo-climatic (altitude, slope, rainfall, etc.), litology, porosity, soil type, soil depth, drainage network, perenniality of streams, annual runoff, social aspects, population density, estuarine diversity and productivity) with the relative weights were overlaid, which aided in prioritising the ecologically sensitive regions (ESR) based on the cumulative scores (grids with the spatial themes). These grids with the cumulative weights (scores) were grouped into four categories. Figure 7 shows prioritised grids: 28 grids represent ESR 1, 12 grids represent ESR 2, 14 grids represent ESR 3 and the rest 20 grids represent ESR 4. The 38% of the area of grids represents ESR 1, 16% of the area shows ESR 2, 19 % of the area shows ESR 3 and only 27 % area covers ESR 4 (Table 3). ESR 1 represents zone of highest conservation, no further degradation allowed. ESR 1 can be treated as a highly sensitive region and more conservation is to be imposed by regulatory authorities as well as VFCs (Village forest committees). ESR 2 represents a zone of higher conservation and forms a transition for highest conservation and moderate conservation regions. ESR 3 represents moderate conservation region and only regulated development is allowed in these areas. ESR 4 represents least diversity areas and the developments are allowed as per the requirement by strict vigilance from regulatory authorities. It is recommended that these regions are also has a lot of scope for further enrichment of environment by stakeholders and forest department intervention. In ESR 2 & ESR 3 further developments are allowed only after critical review of regulatory and extensive consultations with stakeholders.

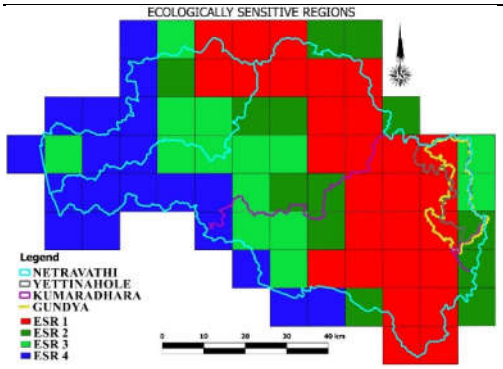


Figure 8: Ecologically Significant areas of Netravathi river basin

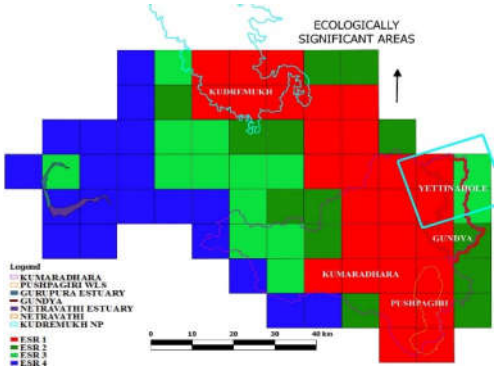


Figure 9: Village level Ecologically Sensitive Regions

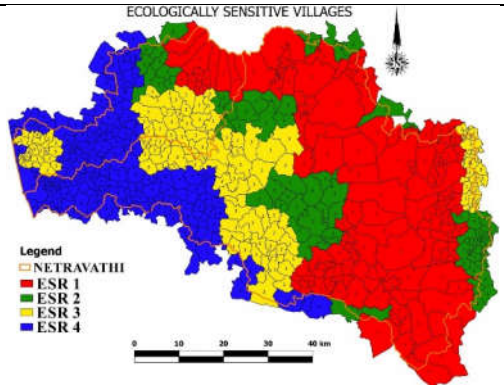


Figure 8 shows ecologically very sensitive regions such as Gundya, Pushpagiri WLS, Kudremukh NP, Yettinaholé regions. These areas are majorly covered in ESR-1 & 2 which signifies the necessity of protecting these regions from further degradations. The village wise ESR delineation is given in Figure 9. The ESR-1 shows 111 villages, ESR-2 shows 69 villages, ESR-3, 4 shows 119 and 134 villages respectively. The Dakshina Kannada district has 307 villages out of which 62 villages depict ESR-1. Forests of these villages need to be protected on priority. The prohibited and regulated activities in each ESR region are listed in Table 4.

Table 3: ESR Villages under various districts of Kali river basin.

DISTRICT	ESR-1	ESR-2	ESR-3	ESR-4	TOTAL
D K	**62**	31	95	119	307
Udupi	**1**	6	0	15	22
Chikmagaluru	**9**	7	0	0	16
Hassan	**33**	21	24	0	78
Kodagu	**6**	4	0	0	10
RIVERBASIN	**111**	69	119	134	**433**

CONCLUSION

Ecosystem carrying capacity is assessed based on the consortium of species the region can support, allowing for seasonal and random changes, without degradation of the environment and without diminishing carrying capacity in the future. Ecological carrying capacity provides physical limits as the maximum rate of resource usage and discharge of waste that can be sustained for economic development in the region. Identification of ESRs in Netravathi region would aid in sustainable planning towards the sound ecological regional development. The ESRs have been delineated at the village levels and there are 433 villages in the Netravathi river basin and among these 111 villages are in ESR-1, 69 villages in ESR-2 119 villages in ESR-3 and 134 villages in ESR 4. ESR 1 and ESR 2 are to be strictly no-go area with respect to developments and ESR 4 is referred as a least possible eco-sensitive region. The Community-based Conservation (CBC) approaches in ESR 2 and 3 would help in the conservation of biological diversity (or wildlife). Degradation of these eco-sensitive region with the unplanned developmental path will only erode the sustenance of natural resources and would affect the local livelihood.

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Table 1: Various attributes considered and their weightages

Themes	Weightages				
	1	3	5	7	10
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%
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
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	1<SD<2	SD>2
GEO-CLIMATIC					
Altitude					
Slope	-	-	-	Slope > 20%	Slope > 30%
Precipitation					
HYDROLOGY					
Stream flow	WA<4	4<WA<6	6<WA<9	9<WA<12	WA=12
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	
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

Table 3: Prohibited and regulated activities in ESR -1, 2 3 & 4.

SNO	ACTIVITIES	ECOLOGICALLY SENSITIVE REGIONS			
		ESR-1	ESR-2	ESR-3	ESR-4
1	**ENERGY** (A) Solar (Rooftop)	✓	✓	✓	✓
	(B) Wind power	×	✓	✓	✓
	(C) Bio energy	×	✓	✓	✓
	(D) Coal based (Thermal power)	×	×	×	×
	(E) Gas or liquid fuel based	×	×	×	✓
	(F) Hydro power (Major)	×	×	×	×

	(G) Hydro power (Micro)	×	×	×	✓
	(H) Nuclear power	×	×	×	×
2	**FORESTS**	×	×	×	×
	(A) Land use change (Forest to non-forest usages)				
	(B) Monoculture plantations	×	×	×	×
	(C) Extraction of medicinal plants (with strict regulations)	×	×	✓	✓
	(D) Forest improvement through VFCs	✓	✓	✓	✓
	(E) NTFP collection	✓ (Strict regulation by department)	✓	✓	✓
3	**AGRICULTURE**	✓	✓	✓	✓
	(A) Agroforestry				
	(B) Organic farming	✓	✓	✓	✓
	(C) Land use change / Encroachments	×	×	×	×
	(D) Genetically modified crops	×	×	×	×
	(E) Animal Husbandry	✓	✓	✓	✓
4	**HORTICULTURE**	✓	✓	✓	✓
	(A) Organic farming				
	(B) Nitrogen and Phosphorus (N&P) fertilizers	×	×	×	✓ Dosage as prescribed by Agriculture department
	(C) Endosulfan	×	×	×	×
	(D) Pesticide	×	×	×	✓
	(E) Watermelon & Muskmelon farming	×	✓	✓	✓
5	**INDUSTRIES (Larger scale)**	✓	✓	✓	✓
	(A) Agro-processing industries				
	(B) Information Technology industries (IT)	×	×	✓	✓
	(C) Red category (Polluting) industries	×	×	×	×
	(D) Garment industries	×	×	✓	✓
	(E) New establishment of Industries	×	×	×	✓ (Allowed only after critical review by local stake holders and experts)
	(F) Nonpolluting (Green) Industries	×	×	✓	✓
6	**INDUSTRIES (Small scale)**	×	✓	✓	✓
	(A) Garment industries				
	(B) <u>Domestic (Home based) industries</u> a. Papad	✓	✓	✓	✓
	b. Mango processing	✓	✓	✓	✓
	c. Areca nut processing & Coir industries	×	✓	✓	✓
	d. Milk products and processing	✓	✓	✓	✓
	e. Dry fruits & Spices	✓	✓	✓	✓
	f. Fruit processing (Ex: Kokum Juice *(Garcinia indica)*)	✓	✓	✓	✓
	g. Fish products processing	✓	✓	✓	✓
	h. Bee keeping and bee nurseries	✓	✓	✓	✓
	i. Pongamia plantations for biofuel (in private lands)	×	✓	✓	✓
	j. Bio pesticides manufacturing	×	✓	✓	✓
	k. Poultry farms and powdered eggs	×	✓	✓	✓
	l. Vegetable dyes; fruits and vegetables preservation	✓	✓	✓	✓
	m. Medicinal plants cultivation and processing	✓	✓	✓	✓
	n. Aromatic plants and essential oil distillation; orchids and cut flowers harvesting industries	×	✓	✓	✓

7	**TOURISM INDUSTRY**	×	✓	✓	✓
	(A) Ecotourism				
	(B) Organic village and homestay	✓	✓	✓	✓
	(C) VFC managed tourism	✓	✓	✓	✓
	(D) VFC managed homestay tourism in higher forest cover regions and protected areas	×	✓	✓	✓
	(E) Arts and handicrafts museum and trade center	✓	✓	✓	✓
8	**MINING AND MINERAL EXTRACTION**	×	×	×	×
	(A) Iron ore				
	(B) Manganese	×	×	×	×
	(C) Bauxite	×	×	×	×
	(D) Limestone	×	×	×	✓
	(E) Quartz	×	×	×	✓
	(F) Sand extraction (on sustainable basis by Ban on exporting)	×	×	✓	✓
9	**WASTE DISPOSAL**	×	×	×	×
	(A) Hazardous waste processing units				
	(B) Solid waste disposal	×	×	×	✓ (For composting and manure preparation)
	(C) Liquid waste discharge	×	×	×	✓ (Treatment plants (STP) for processing)
	(D) Recycling and waste processing and units	×	×	×	✓(compliant with PCB)
10	**TRANSPORTATION**	×	×	×	✓(Allowed only after strict EIA)
	(A) Roads and expressways				
	(B) Rail and freight corridors	**Subject to EIA; Strict regulation and social audit**			
	(C) Up gradation of existing infrastructure	×	×	✓(Subject to EIAs, strict regulation and social audit)	✓

Remarks

- The ESR_1 represents a zone of highest conservation, no further degradation allowed. ESR-2 has the potentiality to become as ESR-1 provided with strict regulations and improvement of forests and its environs by more protection. A small change in ESR-2 will have more adverse effects in ESR-1.
- Forest Rights Act to be implemented in its true spirit by reaching out to people.
- Monoculture plantations are not allowed, existing exotics should be replaced by planting endemic species.
- Promote decentralized electricity, use of renewable energy sources such as (solar, wind power).
- No river diversions (under the guise of drinking water projects, mainly to circumvent the environmental norms)
- Restrictions on linear projects (road widening, new roads, etc. that fragments vital forest habitats)
- The local bio resource based industry should be promoted. All should be strictly regulated and be subject to social audit.
- Adapt development projects which will have a least environmental impact by involving local community members in decision making and environmental monitoring.
- No new major roads, railway lines are allowed, except when highly essential and subject to EIA, by imposing strict regulation and social audit.
- Tourism Master Plan should be based on MoEFCC regulations (after taking into account social and environmental costs).
- Controlled activities are permitted based on socio-economic importance and activities such as depriving wetlands, natural forests, the introduction of alien invasive species are not permitted.