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INSIGHTS FROM LANDSCAPE DYNAMICS TO MITIGATE LOSS OF LIVELIHOOD IN COORG

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ABSTRACT

Land use and land cover (LULC) of a landscape expresses the structure and functionality of the landscape and its capacity to support a variety of species and ecosystem services. The large and continuous forest cover provides a critical habitat for diverse floral species as well as wildlife. The land transformation, rapid expansion of linear developments such as roads, power lines have irreversible loss of habitat, result in forest fragmentation by impacting local ecological processes. The Kodagu (Coorg) district is blessed with thick evergreen rain forests and also acting as a prime economic center for Karnataka. Kodagu forests are lifeline for Karnataka, Tamilnadu, Kerala states. However, imbalances due to the large scale LULC changes have caused alterations in the structure of the landscape affecting the water security and landscape stability which will threaten the livelihood of people. The spatio temporal land use analysis of the region highlights the loss of forest cover due to uncontrolled expansion of coffee plantations and other driving forces. The major cover of evergreen forest (40.47 to 27.14%) has lost due to interventions in terms of road, built-up areas and other changes. Around 66,892 ha of pristine forest cover was lost due to un-interrupted exploitation. The Fuzzy-AHP-CA. Forecasting future land use change suggests that the greatest loss of forest (5 % from 2018 to 2026) at the expansion of non-forest land uses. Ecological fragile zones are the ecological units with the exceptional biotic and abiotic elements where mismanagement of these zones will result in imbalance in the ecosystem. Identification of ecological fragile zones has been done by considering both ecological and social dimensions spatially. The ecological fragile zone map at the village wise, elucidates ecological significance at village level that depicts 117 villages under high ecological fragile, 143 under moderate, 35 under medium-1 and 5 villages are under medium-2 ecological fragile status. The unplanned developmental activities for short-term gains would spell doom on Cauvery water sustenance as 95% the regions fall under high ecological fragile zones.

Keywords: Land use land cover (LULC); Agent Based Modelling; Hybrid FUZZY-AHP-CA; Kodagu; Ecological Fragile Zones

INTRODUCTION

Forests cover < 30 percent today globally as opposed to 50 percent of the earth's land area 8000 years ago depleted with the expanded extents of croplands, pastures, plantations, and urban areas (FAO 2011). The Earth's land surface has lost 40 percent of natural forest by 1990 due to the expansion of cropland and permanent pasture (Ramachandra and Shruthi 2007). The accelerating rates of land use land cover (LULC) changes across globe are affecting forest landscapes and climate. There are ample evidences of these fast changes, which are affecting forest ecosystem worldwide (Nelson et al., 2006; Azevedo et al., 2014). The uncontrolled land use changes, such as intensification of agriculture, industrialisation, often associated with fast population growth are triggering forest cover loss and fragmentation especially in tropical and subtropical regions (DeFries et al., 2010; Bharath et al., 2014; Ramachandra et al., 2016; Ramachandra and Bharath, 2018). LULC changes are influenced by resource-led or policy-led (Gollin et al., 2016) by exerting sustained pressure on land scape (Zhou et al., 2017). The rampant land transformation and urbanisation due to accelerated economic performance across the regions stressing the environment, degrading vital natural resources. The 10% of the world's population lives in wooded mountain regions, with livestock contributing significantly to their economy, which signifies the pressure on forests (Pranab, 2016). The abrupt changes in forest landscape resulting in imbalance of ecosystem and climate interactions (Bharath et al., 2013; Ramachandra et al., 2018a). LULC change impulses a range of environmental challenges by disrupting the processes of biogeochemical and hydrological systems at the local, regional (Vinay et al., 2013) and global scales (Fletcher et al., 2013).

Conservative natural resource management should take into account the sustenance of natural resources and people's livelihood aspects. This entails holistic approaches in development of forested regions for appropriately preserve the areas of various LU classes considering the ecological and environmental services for maintaining the inter-generational equity. The sound knowledge on natural and human-induced forces of landscape changes helps ecologists and decision makers to focus on the development of sustainable solutions to curtail future ecological implications. The numerous simulation models are developed in recent time which attempts to gather sound knowledge of landscape change process and the possible paths of a landscape protection (Sirakoulis et al., 2000). The fuzzy analytical hierarchical process with cellular automata (Fuzzy-AHP-CA) modeling technique is considered as effective approach of LULC change modelling and prediction. The hybrid modelling techniques provides more advantageous of integrating agents along with rule based approaches (Ramachandra et al., 2017). The standalone CA-Markov or agent based modelling suffers with limitations of agents and neighbourhood behavior in the simulation (Ramachandra e al., 2018a). Hybrid approaches exhibit an extensive knowledge base on how the agents of changes interact with each other to be responsible for social and physical environment of forested regions and their immediate vicinity.

The focus on ecological security, in addition to sustainable human development projects, have raised concerns for preservation of food sources and ecosystems in recent time (Vihervaara et al., 2010). The identification of ecological fragile regions approach is providing a new perspective for the assessment of environmental resources, sustainable development. This framework focuses on various aspects of the region such as environmental quality, develop a sound and appealing evidence base, emphasizing inclusive public involvement in planning, evaluating wide range of alternatives (Ramachandra et al., 2018b). The mapping of ecological fragile zones will lend guidance to responsible agencies to ensure a balance between ecological preservation and development. Geo-visualisation of hotspots of biodiversity at local level and prioritisation of ecological fragile regions helps in evolving appropriate conservation strategies for the implementation of sustainable developmental through the involvement of local stakeholders (Ramachandra et al., 2018c). The prioritisation and strategies framed will help in prudent use of natural resources, while realizing the vision of Biodiversity act, 2002, towards empowering Biodiversity Management Committees at village level. In this regard, the objectives of the current research are

(i) Quantification of spatio temporal land use changes from 1973 to 2018.
(ii) Visulaisng likely changes in the Kodagu considering the deforestation trend
(iii) Identification of ecological fragile zones for effective conservation and management.

STUDY AREA

Kodagu (Coorg) district in Karnataka is also known as "Kashmir of south" and "Switzerland of India" surrounded by Hassan district in the north, Mysore district in the east, Dakshina Kannada on the west and Kerala State to the south (Figure 1) with an area of 4,102 km^2 (2.4% of Karnataka's geographical area) having population of 5,54,762 as per 2011 census. The population density shows 135 persons per sq.km. The elevation ranges from 900 to 1750 m above mean sea level and mean temperature range from 20°-24°C in with an average rainfall of 4000 mm. Madikeri, a hill town is the head quarter and located 252 km away from Bengaluru (Karnataka's capital). The region is home to endangered Myristica swamps having Critically Endangered *Syzigium travancoricum* and *Gymnacranthera canarica* (Vulnerable) are amongst many other species. Realizing the rates of degradation Union government has proposed to protect natural ecosystems by considering as conservation units such as protected areas (PA) and district has 3 WLS namely Pushpagiri, Talacauvery, Bramhagiri and one NP i.e. Nagaraholé.

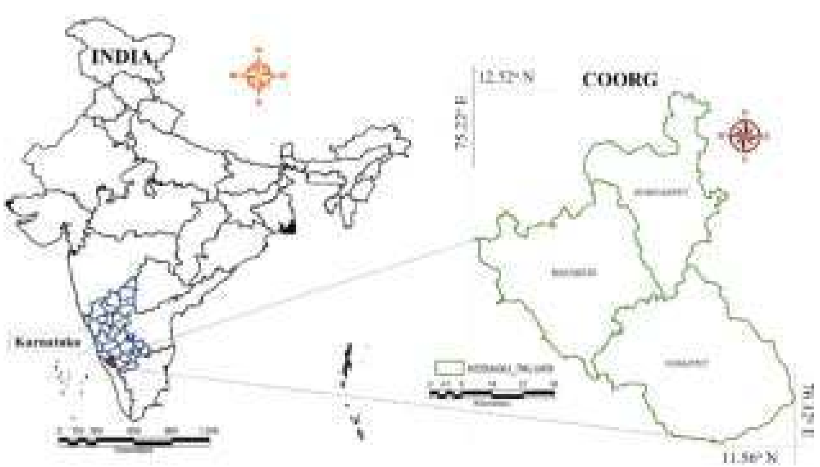

Figure 1: Kodagu district, Karnataka state.

METHOD

Figure 2 outlines the overall method adopted for the analysis. The process of land use classification, modelling likely changes and identifying ecological fragile zones are carried out in five phases i) Classification (ii) Modelling (iii) Computing weightage metric score for prioritisation.

(i) Land use classification: Land use analyses involved (a) generation of False Color Composite (FCC) of remote sensing data (bands–green, red and NIR), (b) selection of training polygons by covering 15% of the study area (polygons are uniformly distributed over the entire study area) (c) loading these training polygons co-ordinates into pre-calibrated GPS, collection of the corresponding attribute data (land use types) for these polygons from the field, (d) supplementing this information with Google Earth and (e) 60% of the training data has been used for classification, while the balance is used for validation or accuracy assessment. The land use analysis was done using supervised classification technique based on Gaussian maximum likelihood algorithm with training data. GRASS GIS (Geographical Resources Analysis Support System, http://ces.iisc.ernet.in/grass) a free and open source software with the robust support for processing both vector and raster data has been used for analyzing RS data.

(ii) Modelling and visualization: Likely land uses in 2026 is generated considering (1) Markov Chain transition of base land uses, (2) evaluating the driving factors and constraints, (3) weightage metric score by fuzzy AHP based estimation and site suitability maps generation by MCE, (4) simulation and future prediction of land use by MC-CA algorithms. Land use maps of 2010, 2018 were evaluated by MC analysis to compute the transition probability. The driving forces of land use changes and constraints were identified based on the land use history, review of literature and policy reports. Major drivers of landscape transitions are slopes, major highways, industries, core residential areas. Constraints perceived are water bodies, river coarse, protected areas and reserve forest. The contributing factors for different land uses were normalized between 0 and 255 through fuzzification- 255 indicates maximum probability of change, while 0 indicates of no changes (Figure 3). The pair wise comparison matrices were generated across three agro climatic regions and their relative weights as Eigen vectors were estimated using AHP (Bernasconi et al., 2010) to measure the degree of importance between criteria or factors i and j. A response matrix A= [a_{ij}] is generated to measure the relative dominance of item i over item j. A is constructed with the decision maker's assessments a_{ij}, as pairwise comparisons that follow a uniform probability distribution. Validation was carried out based on the simulated land use, comparing the simulated land use map as against the actual land use map using Kappa Statistics. Model was calibrated by varying the input variables in order to achieve higher accuracy. Calibrated model was used to predict and visualize the land use change pattern for the year 2026.

(iii) Identifying ecological fragility: The study area is divided into 5'× 5' equal area grids (75) covering approximately 9 km^2. The data of various themes were collected based on literature, unpublished datasets, and ground-based surveys. The weightage metric score has been computed to captures the priorities associated with various themes. The approach has chosen a framework proposed by Beinat, 1997 for weightaging ecological fragile zones because it provides an objective and transparent system for combining multiple data sets together to infer the significance. The weightage is defined as,

$$Weighatge = \sum_{i=1}^{n} W_i V_i \quad \ldots (1)$$

Where n is the number of data sets, V_i is the value associated with criterion i, and W_i is the weight associated with 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. In particular, the weightages, which is based on an individual proxy and draws extensively on GIS techniques, stands out as the most effective method. The final ecological fragility zone map might help as a guide for the conservation of most sensitive regions.

RESULTS

The spatio temporal land use analysis: The land use analysis highlights the loss of forest cover due to uncontrolled expansion of coffee plantations and other driving forces. The region has under gone tremendous changes in its forest cover due to the pressures such as tourism and plantations. Figure 3 and Table 1 depicts the change across each land use categories. The major cover of evergreen forest (40.47 to 27.14%) has lost due to expansion of coffee plantations in across the district. The interventions in terms of road, built-up areas and other changes have led to loss of forest cover.

Around 66,892 ha of pristine forest cover was lost due to un-interrupted exploitation. The Kushalnagara and Madikere taluks have lost major chunk of forests due to innumerable homestays, villas construction. The regularizing encroachments till 1991 under various schemes has also caused tremendous changes in land use pattern of the district through increase in coffee extent, rubber plantations etc.

Modelling and visualization of LU: Simulation of 2018 and 2026 has been performed by accounting transition from 2010-2018. The consistency ratio of less than 0.1 has been achieved with multi criteria evaluation of factors. Land use modeling for the year 2026 shows the likely loss of the forest cover to 45.18%. The major LUchanges are noticed in the regions of Bhagamandala, Titimatti, Makutta and closer to major city centers where in forests are converted to horticulture, forest plantation. Horticulture would increase to 38.63% and agriculture to 10.31% which mostly towards the transition zones and plain region of Kushalnagara and north, Bhagamandala, Virajpet, Gonikoppa, Ponnampet and surroundings (Figure 4, Table 2).

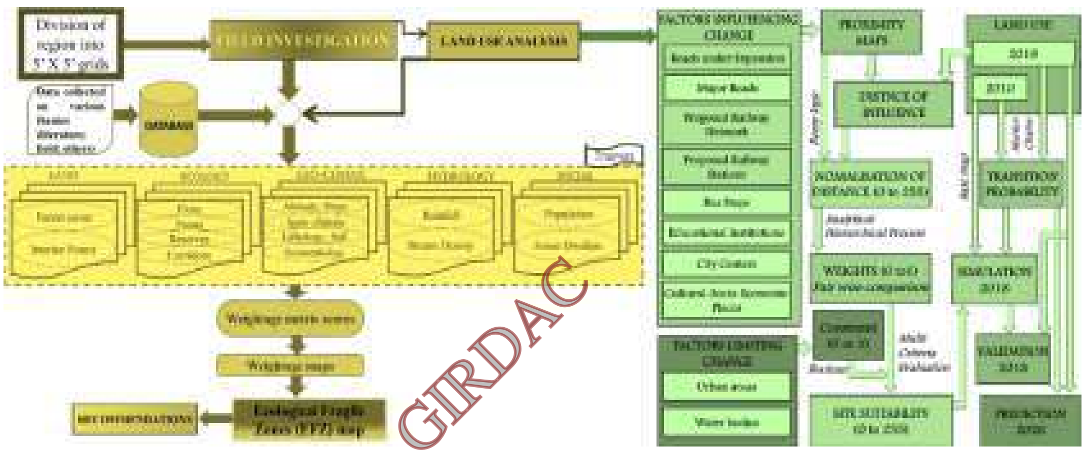

Figure 2: Method used for the analysis.

Table 1: Land use analysis of Kodagu

Year	**1973**		**2010**		**2018**		LOSS/GAIN COVER (1973-2018)
Category	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**
Evergreen Forest	166,025.49	40.47	109,143.82	26.61	99,133.41	24.17	-66,892.08
Semi-evergreen to Moist deciduous Forest	25,736.74	6.27	41,133.93	10.03	42,050.11	10.25	16,313.37
Dry deciduous Forest	10,169.36	2.48	22,436.83	5.47	24,104.94	5.88	13,935.58
Scrub/Grass land	8,796.68	2.14	11,586.05	2.82	15,185.03	3.70	6,388.35
Forest Plantations	6,004.35	1.46	8,327.78	2.03	8,179.73	1.99	2,175.38
Coffee Plantations	126,476.01	30.83	153,464.90	37.41	152,108.3	37.08	25,632.28
Agriculture	43,911.33	10.70	32,047.90	7.81	33,915.15	8.27	-9,996.18
Built-up	1,739.25	0.42	6,812.01	1.66	9,579.15	2.34	7,839.90
Water	1,950.03	0.48	4,367.53	1.06	4,183.56	1.02	2,233.53
Open spaces	19,390.76	4.73	20,879.25	5.09	21,760.63	5.30	2,369.87
Total Area	**410,200.00**						

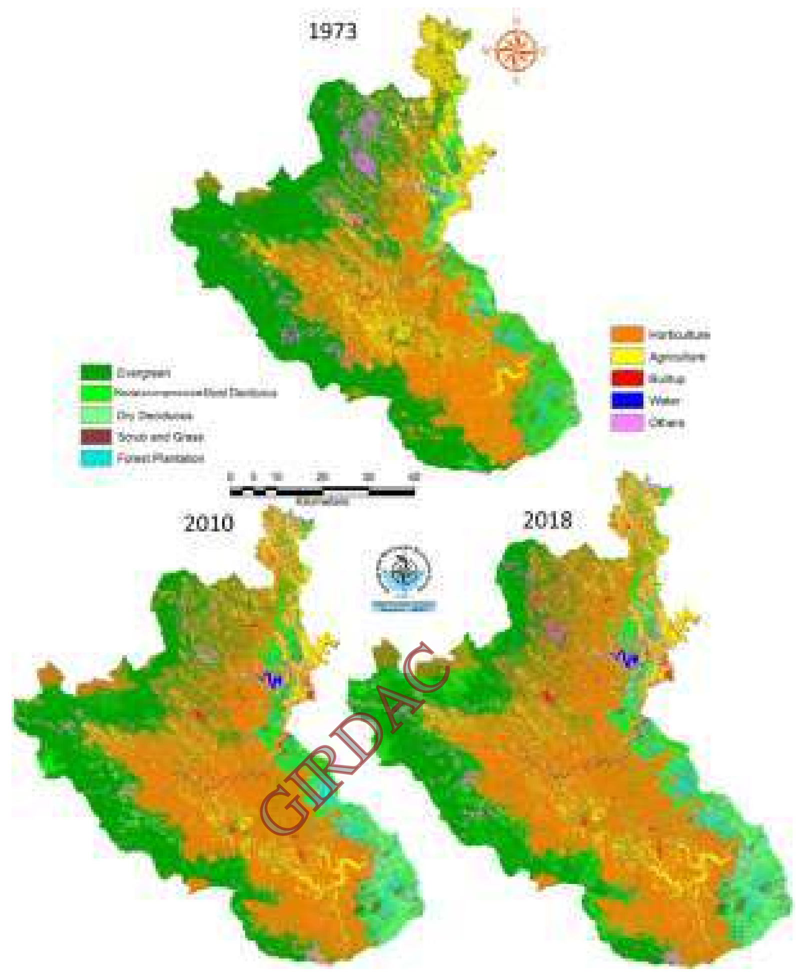

Figure 3: Land use analysis from 1973-2018.

Table 2: Likely LU of 2026 for Kodagu.

LU	2010		2018		2026	
	Ha	%	Ha	%	Ha	%
Forest	218120.80	53.17	206255.26	50.28	185346.50	**45.18**
Forest Plantation	7539.30	1.84	8169.39	1.99	9217.00	2.25
Horticulture	144762.78	35.29	150092.70	36.59	158463.60	**38.63**
Agriculture	28775.97	7.02	31914.36	7.78	42279.70	**10.31**
Built up	6812.01	1.66	9579.15	2.34	10704.10	**2.61**
Water	4189.14	1.02	4189.14	1.02	4189.10	1.02

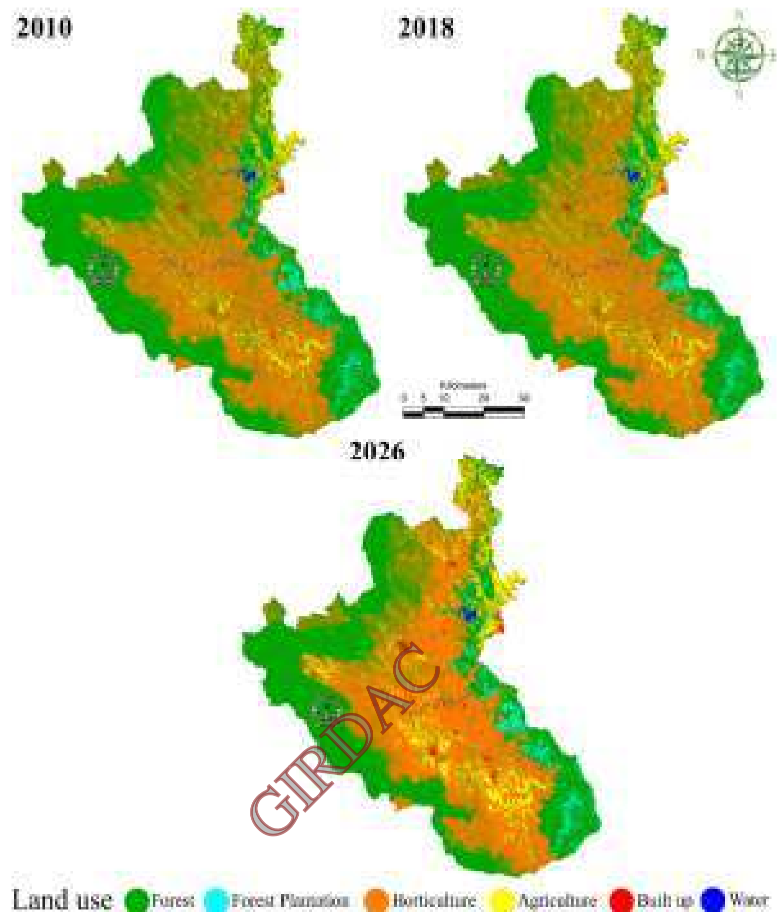

Figure 4: Simulated LU of Kodagu.

Identification of Ecological Fragile zones: Mapping of ecological fragile zones offers a comprehensive representation and prioritisation for conservation of Kodagu region based on various themes such as Land, Ecology, Geo-climatic, Hydrology, Social diversity. Each theme has set of representative factors, which are weighted based on their prominence at grid wise. The results have been analysed theme wise and aggregated weightage metric score has been computed. The greater forest cover (> 80%) is represented by grids of Talcauvery, Pushpagiri, Bramhagiri WLS region, which were assigned higher weightages. The protected areas of Kodagu and elephant migratory path are considered as another prime variables as large tracts of forest are being protected under Pushpagiri WLS, Bramhagiri WLS, Talacauvery WLS, Nagarhole NP. These grids were assigned higher weightages that covered in protected areas. Geo-climatic information of region has been analyzed to identify sensitive zones by considering altitude, slope, soil, geomorphology, lithology and agro-climatic zones. The weightages are assigned based on each variable specific characteristics to the respective grids. The population density of each grid is analyzed based on census data of 2011. The higher population density has considered as least priority weightages (1) and lower density regions are projected as higher conservation priority weightages (10). The forest-dwelling communities of the region are considered as one of the key variables in prioritization. The presence of tribes considered as higher weightages and absence is assigned least value. The aggregated weightage metric score associated with each theme has been computed and it resulted in ecological fragile zones of 1, 2, 3 and 4. The categories of 1 is considered as high ecological fragile zone (36 grids), 2 as moderate (24 grids), 3 &4 as fragile zones of medium 1 and 2 (6, 4 grids). High and moderate constitute 95% of the Kodagu signifies its importance for conservation. The further degradation should not be allowed in this regions. The village wise analysis highlight high ecological fragile zones of 117 villages and moderate covers 143 villages, medium 1, 2 covers 35, 3 villages respectively.

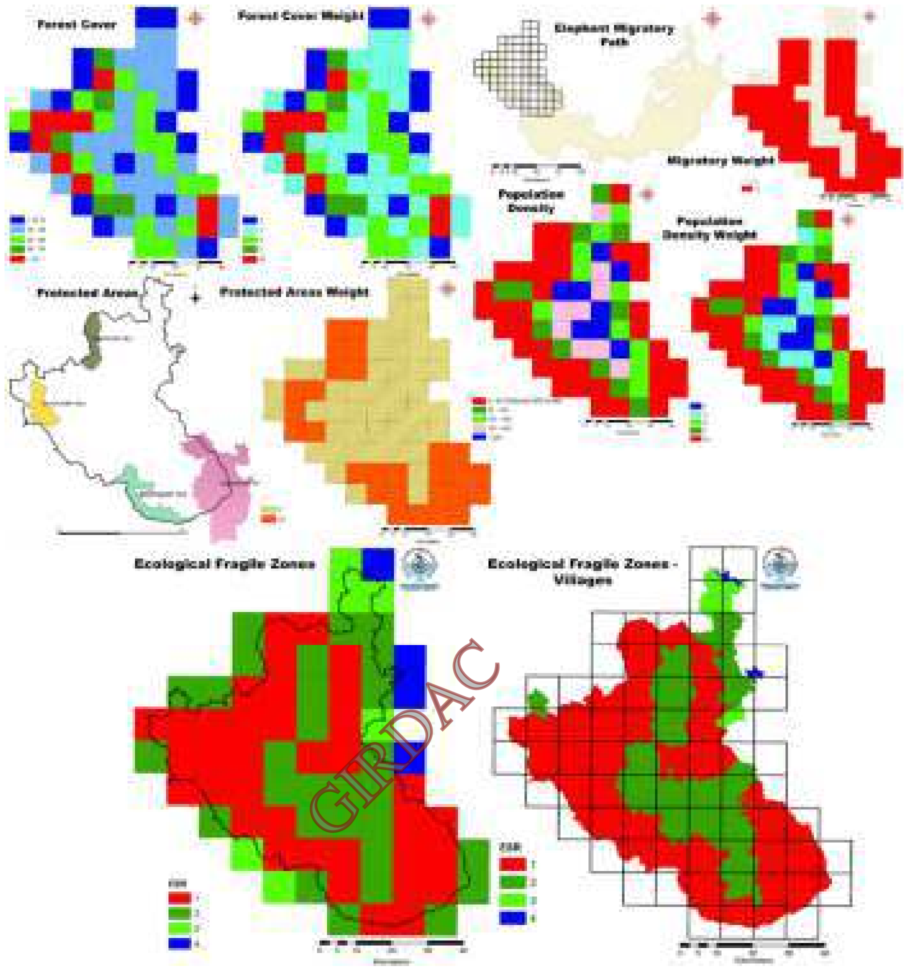

Figure 5: Variables, weightages and Ecological Fragile Zones.

CONCLUSION AND RECOMMENDATIONS

The LU analysis shows loss of evergreen cover from 40.47 to 27.14% (1973-2018). The simulated LU shows deforestation will be further aggravated and result in 5% loss of forest cover. The abrupt LULC changes in the high forested regions will result in imbalance of ecosystem and threatens the resources availability. The temporal remote sensing data in conjunction with other supporting attribute data, influential factors used for simulation of likely LU in 2026. The ecological fragile zones identification prioritises region as high ecological fragile zone (36 grids), moderate (24 grids), fragile zones of medium 1 and 2 (6, 4 grids). The village wise analysis highlight high ecological fragile zones of 117 villages and moderate covers 143 villages, medium 1, 2 covers 35, 3 villages respectively. Considering ecological fragility of the region it is recommended that no new major/ expansion of roads, railway lines are allowed, as 90% district falls under high category. Forest Rights Act to be implemented in its true spirit by reaching out to people. Monoculture plantations should not be allowed, existing exotics should be replaced by planting endemic species. Incentives should be provided to encourage farmers for maintain native species cover in coffee plantation. Promote decentralized electricity, use of renewable energy sources such as (solar, wind power). 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. Tourism Master Plan should be based on MoEFCC regulations (after taking into account social and environmental costs).

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