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Ecologically Sensitive Regions in the Western Ghats, a Biodiversity Hotspot

Ecological sensitivity or fragility refers to the permanent and irreparable loss of extant life forms or significant damage to the natural processes of evolution and speciation with the alterations in the ecological integrity of a region. The comprehensive knowledge of the ecological fragility of a region is quintessential for evolving strategies for conserving the area, which entails identifying factors responsible for ecological sensitiveness, including landscape dynamics, and visualizing future transitions to mitigate the problems of haphazard and uncontrolled development approaches. Analyses of ecologically sensitive regions in the Western Ghats, one among 36 global biodiversity hotspots using temporal remote sensing data, highlight serious concerns about the status of forests and conservation measures. Ecological sensitive region (ESR) delineation considers abiotic, biotic, and socio/anthropological factors, reflecting the current status of the fragile landscape and their significance in maintaining ecosystem equilibrium. ESR analyses depict 63,148 km^2 area under significantly higher ecological fragility, 27,646 km^2 under high ecological fragility, 48,490 km^2 as moderate, and 20,716 km^2 as low ecological fragility. Integrating ESRs in the sustainable development policy framework would aid in regulating unplanned developmental activities, which aid in ensuring ecological security with the continuance of the essential ecosystem services to sustain the livelihood of people.

Key words: Biodiversity, Conservation, Cluster-based development, Ecological fragility, Endemic species, Sustainable development

Analyses of ecologically sensitive regions in the Western Ghats, one among 36 global biodiversity hotspots using temporal remote sensing data, highlight serious concerns about the status of forests and urgent need of conservation measures.

Introduction

Tropical forests, with rich biodiversity, constitute vital livelihood-supporting ecosystems across the globe. Forest ecosystems worldwide are the most threatened ecosystems with unplanned developmental activities leading to land cover changes and over-exploitation of natural resources due to industrialization during the last century and globalization in the recent past (Nayak *et al.*, 2020; Ramachandra *et al.*, 2020a; Brinck *et al.*, 2017, Aldieri et al., 2019). This necessitates to minimise anthropogenic pressures to avoid crossing planetary boundaries from climate change through large-scale land cover changes.

Land use land cover (LULC) changes in a forest landscape have been posing severe challenges for conservation due to the fragmentation of native forests, and rapid degradation resulting in deforestation with a sustained burden on the ecosystem (Ramachandra *et al.*, 2016 a,b,c; Langlois *et al.*, 2017; Ramachandra *et al.*, 2019a; Ewers and Banks-Leite, 2013; Chaplin-Kramer *et al.*, 2015; Hunter *et al.*, 2015; Latimer and Zuckerberg, 2017; Andronache *et al.*, 2019; Ramachandra and Bharath, 2021). Unregulated exploitation of forest resources and LULC changes have led to the degradation of the unique ecological units, evident from barren hilltops and fragmented forest patches (Ramachandra and Bharath, 2019c), affecting hydrological services such as the conversion of perennial streams to intermittent ones, and loss of groundwater recharge potential, loss of livelihood opportunities (Banerjee and Madhurima,

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2013), reduction in productivity (Nayak *et al.*, 2012), alteration in surface and ambient temperature, etc. (Bharath *et al.*, 2013; Bharath *et al.*, 2021; Koschke *et al.*, 2012; Ramachandra *et al.*, 2017a; Ramachandra *et al.*, 2018b; Ramachandra *et al.*, 2019b).

Integrated analyses considering the demographic, ecological, climatic, economic, market, and institutional factors help formulate prudent natural resources management strategies. Forest land management policies incorporating the perceptions of all stakeholders would aid in understanding driving forces, impacts, and remedial measures for improved livelihood strategies (Ramchandra and Bhrath, 2018).

Conservation planning approaches to protect the regions of ecological significance require appropriate technologies, an understanding of social-ecological systems, and opportunity costs of economic relevance. Considering the ecological system is crucial for sustainable development to support human activities with social and economic development, as per tenets of the Sustainable Development Goals (SDGs) (United Nations, 2015; Brinck *et al.*, 2017; Bharath and Ramachandra, 2021). Identifying landscape elements or regions of distinct characteristics that have low resilience and, if disturbed by external influences, either anthropogenic or natural, will be difficult to restore to their natural state (Gadgil *et al.*, 2011) is crucial. These identified regions at disaggregated levels are known as Ecologically Sensitive Regions/Areas/Zones (ESR/ESA/ESZ) or ecologically fragile regions (EFR). Hence, ESR or EFR constitutes the regions of diverse landforms, vegetation, geology, and rich biodiversity characterized by their sensitivity and economically significant for providing services. Conservation of ESR is vital for the long-term sustenance of biological diversity, soil, water, or other natural resources in the landscape/region. ESR framework prioritizes the inherent significance of a region, trade-offs involved due to conservation actions and in forms of consequences in the current management activities (Ramachandra *et al.*, 2017b). ESR supports comprehensive ecological conservation by conserving the most ecologically valuable and fragile ecosystems and guiding nature conservation. ESR identification accounts for the dynamic interactions among biodiversity, geo-climatic and social processes. The Ministry of Environment Forest and Climate Change (MoEFCC), the Government of India, is empowered to frame the conservation and environmental protection policies under section 3 of the Environmental Protection Act 1986 (EPA). The Ministry has the legal capabilities to prohibit environmentally hazardous or polluting industries as per section 5 of EPA. MoEFCC in 2000 constituted an expert committee (Pronab Sen committee: 2000) to provide guidelines to identify regions based on their ecological significance (MoEF, 2000). In this regard, the Western Ghats Ecology Experts Panel constituted by MoEFCC (in 2011) prescribed conservation and management measures in the ecologically 'salient' regions at the taluk (tehsil- a local administrative unit) level. High-Level Working Group, formed in 2013, demarcated ESA (Ecologically Sensitive Areas) through geospatial analysis but failed to account for the social dynamics and the role of local ecology in sustaining the ecosystem services. However, both reports have not been implemented yet.

Objectives

Policies for conserving biodiversity in the hottest hotspot regions, such as the Western Ghats (WG) require the demarcation of critical ecological, hydrological, and social regions by integrating a technologically advanced approach, considering ecologically or economically significant and sensitive variables, coupled with multi-criteria analysis. In this regard, the objectives of the current research are (i) assessment of the spatial extent of ecosystems, (ii) elucidation of ecosystem conditions through the understanding of LULC dynamics with the extent of fragmentation of forests; (iii) integrating bio-geo-climatic and social variables at disaggregated levels and (iv) demarcation of ecologically fragile regions or ecologically sensitive regions (ESR) at disaggregated levels through effective integration of bio-geo-climatic, hydrological, ecological and, social dynamics. ESR aids as an effective policy instrument in the decision-making (through BMC: Biodiversity Management Committees) at decentralized levels (panchayat) to sustain water, food, and fodder with sustainable development and support the livelihood of all stakeholders.

Material and Methods

Study Area

The Western Ghats (Sahyadri), extending from 8° N to 21° N latitudes and 73° E to 77° E longitudes (Fig. 1), is one among 36 global biodiversity hotspots (Myers *et al.*, 2000), one among the eight unique 'hottest hotspots' of biological diversity, and also one of the primaries of the 200 globally most important ecoregions (Olson *et al.*, 2001). It is a continuous escarpment spreading from Gujarat to Kerala states covering an area of 160000 km^2 (constitutes only 5% of India's geographical extent) and a length of 1600 km with an exceptionally small break in

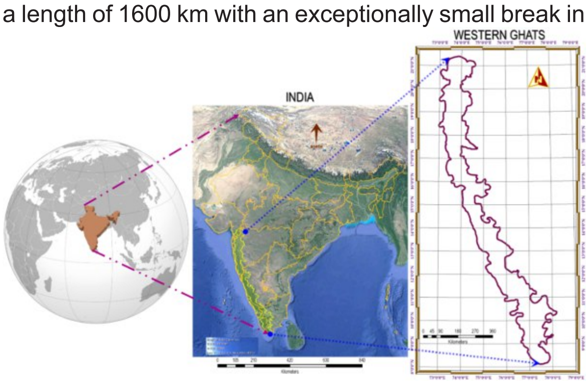

Fig. 1: Study region - the Western Ghats of India

the far south called 'Palghat gap' between Nilgirihills and Annamalai ranges. It is one of the oldest mountain chains, retaining the original Gondwanaland geology. It has elevation ranges from 300-2700 meters, spread across six states (*i.e.*, Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, Kerala) and a union territory (Dadra and Nagar Haveli) of India, with a mean annual rainfall of 2500 mm. The forest landscape, due to variability in precipitation and topographic diversity, comprises a wide variety of eco-zones ranging from wet evergreen and semi-evergreen forests at high altitudes, moist deciduous forests in the medium altitudes, and dry deciduous forests, scrub type on the eastern slopes and lowlands (Champion and Seth, 1968). The Western Ghats are endowed with perennial river networks and function as a water tower for peninsular India, ensuring water and food security, and sustaining the livelihood of millions of dependent populations.

Forest ecosystems support various life forms, providing goods and services and acting as a lifeline for the dependent population. The diverse agriculture and horticulture sectors are being supported by perennial water flows across the region. The presence of patch forests with relics highlights the lineage of primeval forests. Large-scale anthropogenic activities across the Western Ghats have accentuated land degradation leading to deforestation. The presence of close canopies, magnificent trees, large herds of elephant movements, troops of lion-tailed macaques in southern rain forests, and herds of jumping deer across the various forest types highlight the scope for conservation through sustainable management approaches to maintain the ecological integrity of the serene landscape.

Method

Identification and delineation of ESRs in the Westerns Ghats have been carried out as outlined in Fig. 2.

Quantification of spatiotemporal changes in LU

Temporal remote sensing (RS) data from 1985 to 2020 has been analysed with the help of field data, and collateral data such as vegetation maps of the French institute Puducherry (Pascal, 1986), topographic maps from the Survey of India (https://onlinemaps.surveyofindia.gov.in/Home.aspx), biodiversity information from the biodiversity portal(http://indiabiodiversity.org/), and LU attribute information from the virtual spatial data portals such as Google Earth (http://earth.google.com), Bhuvan (http://bhuvan.nrsc.gov.in). RS data of 1985 (100 m resolution resampled to 30 m) is procured from International Geosphere-Biosphere Programme (IGBP), and Landsat 8 OLI (Operational Land Imager –

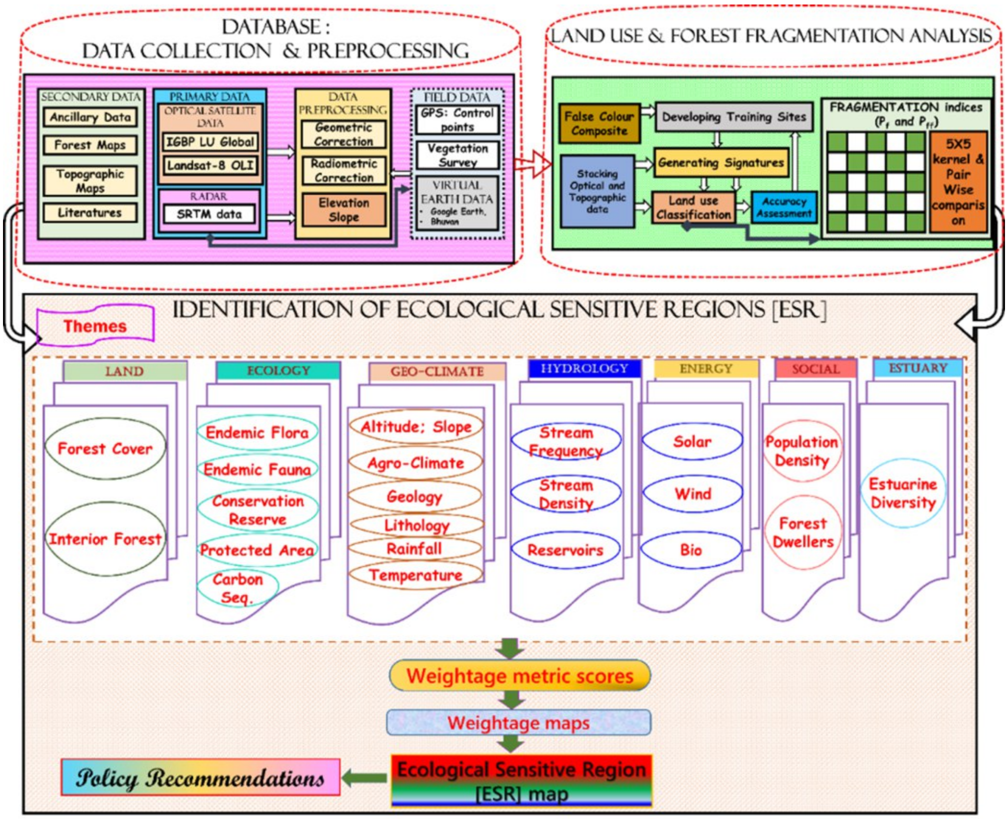

Fig. 2: The protocol employed for the delineation of ESR regions at disaggregated levels

30 m) for 2020 was pre-processed for geometric (geo-referencing) and radiometric corrections. Field surveys across forest types have been carried out to collect training data for LU analysis and attribute data pertaining to species composition. Remote sensing data has been classified through the supervised classifier based on the Gaussian maximum likelihood algorithm (Otukei and Blaschke, 2010; Ramachandra *et al.*, 2019a). Land use classification using remote sensing data involved (i) the creation of False Colour Composite (FCC) to identify heterogeneous features; (ii) the selection of training sites by integrating secondary data with field data (60%), covering at least 15% of the scene area and training polygons uniformly distributed across the study region; (iii) LU analysis through supervised classification technique to differentiate eight distinct LU categories using GRASS GIS (Geographical Analysis Support System); (iv) accuracy assessment to validate the classification based on rest (40%) of field samples (Lilles and *et al.*, 2014). LU analysis has aided in evaluating the condition of forests through fragmentation matrices, as per equations 1, and 2 (Riitters *et al.*, 2002; Kuèas *et al.*, 2011; Ramachandra *et al.*, 2016b). Indices Pf and Pff were computed through a moving kernel/window of 5×5 pixels over the study area map. The analysis has categorized forests into five distinct fragmentation groups (Ramachandra *et al.*, 2016b). Lakes, streams, or river courses were excluded, which aid as a natural corridor of non-fragmenting features. At the same time, anthropogenic landscape elements (such as paved surfaces-buildings, roads; agricultural fields; horticulture; and barren land) were combined as non-forest cover types.

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

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

Identification of Ecological Sensitive Regions (ESR)

ESR mapping has been carried out by considering the significant descriptive variables covering various themes. The study area is divided into 5'× 5' equal-area grids (2329) corresponding to a grid (5'×5'), covering approximately 9×9 km^2 of the 1:50000 scale of the Survey of India topographic maps. The data of various themes were collected through field surveys, review of literature, online information portals, and unpublished datasets. A comprehensive database of all features ranging from land to the socio-economic system has been created.

The process of categorizing ESR at disaggregated levels comprised of the following steps: (i) considering the significant descriptive variables covering various themes which elucidate ecological conditions (Liu *et al.*, 2015); (ii) evaluating and generating spatial maps based on the environmental sensitiveness of each land unit (extent and condition); (iii) developing an aggregated weight by linking individual factor weights, which assist in dividing/prioritizing the region based on aggregated weight into broad classes of sensitivity such as "exceptionally sensitive, high sensitive, moderately sensitive, marginally sensitive, and not sensitive" (Leman *et al.*, 2016; Ramachandra *et al.*, 2018a, c); (iv) exploring the prepared ESR map, offering detailed recommendations for aiding in sustainable developmental prospects and enriching the existing forest cover (Gadgil *et al.*, 2011; Ramachandra *et al.*, 2020a). The preliminary analysis has resulted in a series of weight maps pertaining to various themes. The weightage metric score has been computed to capture the priorities associated with each theme (based on the extent and condition),which assists in combining knowledge from a wide array of disciplines (Beinat, 1997; Termorshuizen and Opdam, 2009). The weights are assigned as per Equation 3,

$$Weighatge = \sum_{i=1}^{n} W_i V_i \quad (3)$$

where n is the number of data sets, Vi is the value associated with criterion i, and Wi is the weight associated with that criterion. Each theme is described by a group of mapped factors normalized between 10 and 2. Grids were assigned a value of 10 for high-priority conservation, whereas 2 is for lowest priority. The values 8, 6, and 4 correspond to high, moderate, and low levels of conservation based on the input factor values (Ramachandra *et al.*, 2018a). Weights computed for each variable are aggregated for each grid. Grids are grouped into four categories based on the aggregate score as ESR 1, ESR 2, ESR 3, and ESR 4 (ESR 1: aggregated scores > μ+2σ (μ indicates average value and σ indicates the standard deviation), ESR 2 (for grids within μ+2σ and μ+σ), ESR 3 (for grids with μ+σ and μ) and ESR 4 (grids with values < μ)). In particular, the weights are based on an individual proxy and depend extensively on GIS techniques, which is the most effective method.

Results and Discussion

Understanding LU dynamics

The reliable spatial data available at regular intervals from space borne sensors have helped to understand forest cover dynamics and underlying anthropogenic pressures. LU analysis highlights the loss of evergreen forest cover of 5% with an increase of built-up cover (4.5%), and agriculture area (9%) due to anthropogenic pressures (Fig. 3). The evergreen forest cover has reduced from 16% (in 1985) to 11% (in 2018). The decline in native forests is due to unplanned anthropogenic activities involving the construction of a series of hydroelectric projects, indiscriminate mining, and unscientific afforestation of monoculture plantations (Acacia, Rubber, Eucalyptus, Teak), etc. Mining activities in the hilly and undulating terrains are disrupting the hydrologic regime, continuous forest patches, and ecological footprints beyond the physical

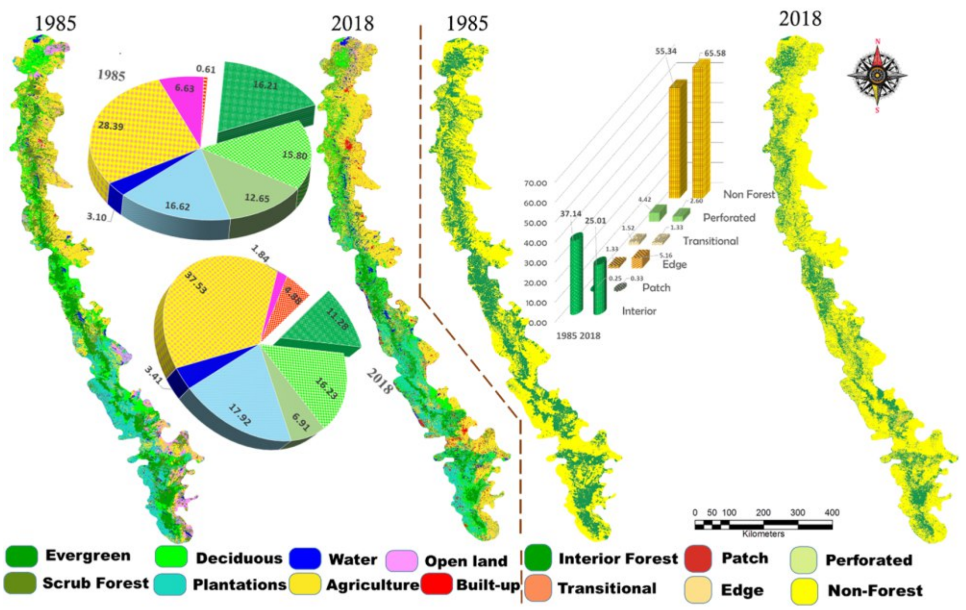

Fig. 3: LU dynamics of the Western Ghats

boundaries of mines. In the past two decades, recurring instances of floods and landslides were noticed due to abrupt LULC changes across the Ghats, especially in Kerala, and Karnataka states (Ramachandra *et al.*, 2021). The water-holding capacity is of the soil is affected by LULC changes, resulting in flash floods across the states. Fragmentation analyses highlight the status of forests in the Western Ghats. Over the past three decades, interior forest cover has reduced from 37.14 to 25.01%. The loss of interior cover (12.2%) with an increase of non-forest cover (11.3%) from 1985 to 2018 represents an escalation in fragmentation, which has affected local ecology, leading to habitat loss, and impacting many forest-dependent biotas. The interior forests are mainly situated in protected areas across the region. The decline of the contiguous interior forests affects endemic taxa and habitats, resulting in the loss of life and property with higher recurring instances of human-wildlife conflicts.

Prioritization of ESR and recommendations for conservation

ESR is prioritized at disaggregated levels based on the extent and condition of an ecosystem by integrating bio, geo-climatic, land cover, condition of ecosystems (fragmentation), ecological, hydrological, and social variables with the assignment of weights.

Landscape status

The extent and condition (fragmentation) of forests depict the landscape status. Spatiotemporal analyses of LU indicate a significant loss in the forest cover across the states of Maharashtra, eastern parts of Tamil Nadu, western parts of Kerala and Goa. Current forest cover is confined to well-managed reserve forests, and protected areas (Pas) corresponding to the Western Ghats region in Karnataka and Kerala that have > 60% forest cover and contiguous or intact forests (>60% extent).

Species distribution across the latitudinal gradient highlights the higher occurrence of endemic trees and fauna species at 10-14° latitudes corresponding to the Kerala and Karnataka portions of the Western Ghats regions (Figs. 4 and 5). The spatial distribution of species across the latitudinal range signifies the necessity of conserving habitats of endemic species to avoid further degradation. The fragmentation of forests in the Western Ghats will adversely impact this unique genepool. The loss of continuity of forest animals tends to reside in small fragments, restrict movement to relatively narrow bands around the forest edges, and prefer inbreeding. The consequences of fragmentation on biodiversity include a lower growth rate of species

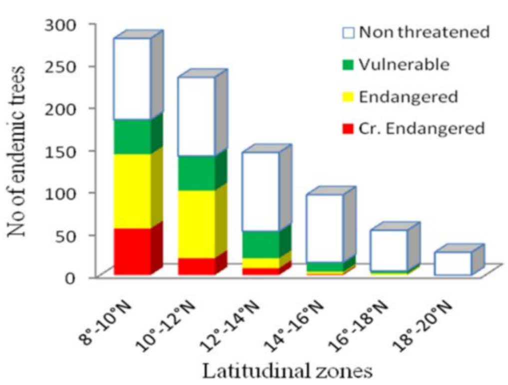

Fig. 4: Endemic species of flora across a latitudinal gradient in the Western Ghats

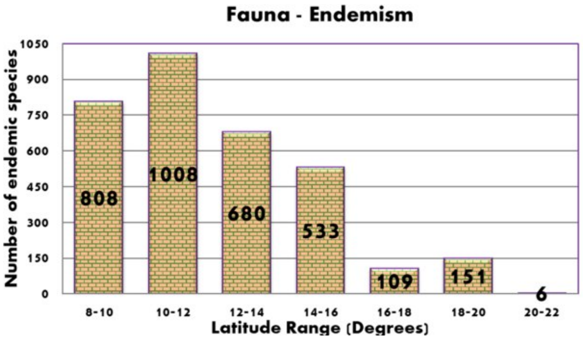

Fig. 5: Endemic species of fauna across a latitudinal gradient in the Western Ghats

due to resource shortage or dietary diversity, disruption of genetic exchanges amongst wildlife populations, and a significantly high mortality rate.

The Western Ghats is the hottest hotspot of biodiversity and has been experiencing land degradation and deforestation due to higher loss of forest cover since independence with unplanned developmental activities and fragmented governance. Many carnivore taxa are now confined in small fragments leading to escalation in human-animal conflicts apart from the inbreeding pressure and extirpation of the viable gene (Ramachandra and Bharath, 2019c). Especially, endemic taxa such as Lion-Tailed Macaques are experiencing higher predation due to loss of contiguity in the canopy with the fragmentation of forests.

Ecology

Ecological status has been assessed by considering species endemism (flora, fauna), threat status of species, the spatial extent of protected areas, carbon sequestration potential (based on biomass and soil carbon), etc. Biodiversity in the ecologically fragile Western Ghats is accounted for through field investigations coupled with the data mining of published literature and- research papers published in peer-reviewed international journals, biodiversity portals (of the respective states), administration reports, and forest department management plans. The Western Ghats biodiversity database has 29047 records covering flora species across diverse forest types (https://wgbis.ces.iisc.ac.in/biodiversity/database_new/), which is compiled based on field investigation and the review of 450 literature. The fauna database has 13878 records covering multiple categories (taxa) collected through the literature review (400 literature). The data analyses reveal that the Western Ghats are endowed with rich biodiversity, evident from the occurrence of 5000+ species of flowering plants (38% endemics), 330 butterflies (11% endemics), 197 reptiles (62% endemics), 529 birds (4% endemics), 161 mammals (12% endemics), 335 fishes (41% endemics) and 248 amphibians (75% endemics). Hence, conserving ecologically sensitive regions is essential for sustaining diverse food and medicine. Endemism and IUCN (International Union for Conservation of Nature) conservation status is considered with respect to flora and fauna variables. Endemic flora includes *Hopea erosa, Vateria indica, Poeciloneuron pauciflorum, Memecylon sisparense, Actinodaphne campanulata, Actinodaphne lanata, Artocarpus hirsutus, Cinnamomum agasthyamalayanum, Cinnamomum malabatrum, Diospyros atrata, Litsea bourdillonii, Litsea hookeri, Symplocos anamallayana, Psychotria globicephala. Holigarna grahamii,* etc., which are mostly confined to the southern Western Ghats. Weights were assigned to grids based on the frequency distribution of endemic species considering mean (μ) and standard deviation (σ) as 10 for grids with endemic/threatened species >μ+2σ, 8 for grids with endemic/threatened species in the range μ+2σ and μ+σ, 6 for grids of endemic/ threatened species μ+σ and μ, 4 for grids with endemic/ threatened species < μ, and 2 for grids with the prevalence of only non-endemic species. The central and southern Western Ghats account for 227+ endemic trees belonging to 37 families. The dominant families of endemic flora include Rubiaceae, Lauraceae, Anacardiaceae, Meliaceae, etc. Critically endangered and vulnerable fauna includes *Gonoproktopterus thomassi, Horalabiosa arunachalami, Indiranagundia, Rhacophorus pseudomalabaricus, Fejervarya murthii, Philautus kaikatti, Ardeotis nigriceps, Cnemaspis sisparensis, Gyps indicus, Martes gwatkinsii, Macaca Silenus, Millardia kondana, Viverra civettina*, etc.

National Parks, Wildlife Sanctuaries, Conservation Reserves, etc., are intended to conserve the sensitive flora/fauna under the protected area (PA) network through a regulatory framework (Ramachandra *et al.*, 2018b). PAs have been notified under the provisions of the Wild Life (Protection) Act, 1972, and management is governed considering the anthropogenic pressure on wildlife and other threatened taxa by a set of environmental legislation such as the Indian Forest Act, 1927, Forest (Conservation) Act, 1980, Environment (Protection) Act, 1986 and Biological Diversity Act, 2002, the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, etc. PA network constitutes a protected corridor for wildlife, connecting two or more habitat patches previously connected but isolated due to forest fragmentation and anthropogenic activities. The Western Ghats region has about 7953 km^2 under PAs, constituting 5% of its geographical area, of which 39 are major PAs. They are safeguarding numerous species and shielding them from extinction. Nilgiri Biosphere Reserve (NBR) with a spatial extent of 5000 km^2 spread across the Western Ghats regions of three states (Kerala, Karnataka, and Tamil Nadu). NBR consists of the Western Ghat's highest mountain peaks and plateaus, with an elevation ranging from 1700-2600 m and 500-7000 mm rainfall. The mountain tops in these regions supporting a wide variety of biota are covered with grasslands of diverse species. Clumps of evergreen species with stunted trees, popularly known as “sholas,” are present in the valleys. NBR region alone has 3,300 angiosperm species, of which 132 are endemic, and 19 are listed in the IUCN Red List of threatened species.

Carbon sequestration is another key ecosystem variable that reveals an ecological process, quantified by considering above-ground and below-ground biomass across various forest ecosystems. Biomass was assessed based on (i) vegetation survey: through transect cum quadrat sampling techniques with the field-based measurements of GBH (girth at 130 cm) collected across the forests of the Western Ghats, (ii) published literature: based on the standard experiments covering aboveground biomass, below-ground biomass estimations. Field estimations were carried out across the diverse forest types covering around 300 transects in Uttara Kannada, Shimoga, Chikmagalur, Kodagu, Dakshina Kannada, and Udupi. Empirical equations used for biomass estimation across forest cover types are based on field experiments integrated with literature (Ramachandra and Bharath, 2019a). Carbon sequestration is accounted as 50% of the biomass.

Geo-Climate

Topography and climatic factors such as elevation, slope, lithology, geology, temperature, and rainfall play a crucial role in maintaining the moisture of a forest landscape and influencing species diversity. The Western Ghats have eight distinct soil groups of highly productive types that support diverse vegetation and agriculture activities. Regions with steep slopes and high altitudes are vulnerable, and large-scale land cover changes induce higher mudslides and landslides, likely to be eroded more easily through a trigger of high-intensity rainfall. Incidentally, these least resilient regions constitute a vital habitat to diverse biota (flora and fauna) and are ecologically fragile or environmentally sensitive.

Regional climatic conditions are expressed by rainfall and temperature variables, which can play a decisive role in determining community structure, functions, and species distributions (Peters *et al.*, 2012). Rainfall is considered a critical and limiting factor regarding forested landscapes in terms of the community composition and structure (Bell *et al.*, 2014). The average rainfall and temperature are assessed using Global databases (NCAR and Princeton University) and validated through comparison with the surface measurements of ground-based monitoring stations of the regional climate datasets (IMD, KSNDMC), which show 90% similarities. Temperature shows many variations across the grids, and rainfall analysis shows that the central Western Ghats receives an average rainfall of over 2500 mm and tends to decline to less than 1500 mm towards northern portions. Montane rain forests cover the southern regions, tropical and subtropical moist broadleaf forests at the western slopes, and rainfall ranges from 3500 mm to 7000 mm per year.

Hydrology

Forest landscapes with native species of vegetation in the Western Ghats aid as hydrological reserves catering to the ecological and societal water demand of Peninsular India. The sustained anthropogenic pressure on the fragile ecosystems in the Western Ghats affects the physical integrity, biota, hydrological regimes, bio-geo-chemical relationships, etc., resulting in water and food security affecting people's livelihood. With the relatively higher forest cover, the Ghats (hilly) region of the Western Ghats is endowed with perennial streams and rivers. In contrast, the eastern portions, the transition zone of Ghats, and plain lands dominated by monoculture plantations are with intermittent and seasonal streams of 4 to 6 months water availability (Ramachandra *et al.*, 2020b). The absence of intact or contiguous native forests and the prevalence of patch and edge forests (with fragmentation) in the socially active regions (increased unplanned developmental activities with urbanization, industries, etc.) have altered the hydrologic regime evident from the decline of rainfall and sustenance of water (perennial to seasonal or intermittent).The streams are perennial when their catchment is dominated by vegetation (> 60%) of native species, mainly due to infiltration or percolation in the catchment, as the soil is porous with native species. Diverse microorganisms interact with plant roots and soil, which helps transfer nutrients from the soil to plants, and the soil is porous or permeable. Analyses of soil samples from the catchment of perennial and intermittent streams reveal that soil in the perennial stream's catchment has the highest moisture content (61.47 to 61.57%), and higher nutrients (C, N, and K), lower bulk density (0.50 to 0.57 g/cc). In a catchment of intermittent and seasonal streams, the soil had a higher bulk density (0.87 – 1.53 g/cc) and relatively lower nutrients (Ramachandra *et al.*, 2020b).

The major peninsular rivers like the Godavari, Krishna, and Cauvery originate in the Western Ghats and flow across the country along with their numerous tributaries and finally discharge into the Bay of Bengal. The west-flowing rivers are equally productive and support the rich biota (flora, fauna), agriculture (croplands and horticulture) activities, and finally, discharge into the Arabian Sea. The numerous streams in the mountainous parts of the Western Ghats draw a large quantum of water to the main rivers. The stream frequency, *i.e.*, the number of stream segments per unit drainage area (usually per square kilometer), is assessed to understand the density of the streams across the grids, which also indicates the water availability and condition of the basin. Higher stream frequency with rich native vegetation increases permeability and infiltration capacity.

A comparative assessment of people's livelihood has been made with soil water properties and water availability in the respective catchment across four river basins in the central Western Ghats (Ramachandra *et al.*, 2020b). The result shows that streams are perennial when the catchment is covered with > 60% vegetation of native species, which have higher soil moisture and groundwater than catchments (of seasonal streams) during dry spells. The higher soil moisture due to water availability during all seasons facilitates the farming of commercial crops with higher economic returns to the farmers, unlike the farmers who face water crises during the lean season. The study emphasizes the need for conservation endeavour on maintaining native vegetation in the catchment, highlighting its potential to support people's livelihood with water conservation at local and regional levels. Both plantation and agricultural crops are considered for the valuation in the select catchments of perennial and seasonal streams. Plantation crops (*viz*. areca nut, coconut, banana, beetle leaf, and pepper) are the major income-generating products in the catchment of perennial streams. A total amount of ₹ 3,11,701 ha^{-1} $yr.^{-1}$ (year 2009-10) gross average income was generated from the plantation crops against an average expenditure of ₹ 37,043 ha^{-1} $yr.^{-1}$, (mainly for plantation maintenance), yielding a net profit of ₹ 2,74,658 ha^{-1} $yr.^{-1}$. On the contrary, for the catchment of seasonal streams (where both plantation and rice fields were considered for income calculation),the average gross income generated was ₹ 1,50,679 ha^{-1} $yr.^{-1}$ against the expenditure of ₹ 6474.10 $ha^{-1}yr.^{-1}$ for plantation maintenance and field preparation (Ramachandra *et al.*, 2020b).

Energy

The Western Ghats region's energy prospects have been analyzed for renewable energy potentials such as solar, wind, and bioenergy. Global data signifying solar and photovoltaic PV power potential has been collected using consistent high-resolution data layers from the ESMAP portal (ESMAP, 2020). The long-term energy availability of solar resource potential has been estimated from global horizontal irradiation (GHI) for the region. GHI integrates direct and diffuse irradiation components received by a horizontal surface in kilowatt-hours per square meter (kWh/m^2).The entire Western Ghats region has good solar potential (>5 kWh/m^2), except for some of the grids of Kerala (Kottayam, Idukki, Ernakulam) high-altitude regions (Ramachandra *et al.*, 2016a). Wind energy is a cost-effective and clean fuel source and another form of solar energy. The wind energy potential was analysed from the global wind atlas database based on high-quality and high-resolution average wind speed data measured at m/s-meters per second (available at 10 m, 50 m, 100 m, 200 m). The data shows the region's eastern part has higher potential (>3.5 m/s), and the central and southern parts depict moderate potential. Bioenergy includes many potential feed stocks, conversion processes, and energy applications, easily integrated with existing infrastructure. It associates strongly with the agriculture, forestry, and waste management sectors, and its prospects are linked to the growth of a broader bio-economy. Bioenergy can be supplied and used sustainably, contributing to climate change mitigation (Ramachandra *et al.*, 2014). Bioenergy potential was assessed to reduce or remove the impact of GHG-intensive fuels on the environment. The northern Western Ghats region grids have more potential than the southern Western Ghats.

Social aspects

Uncontrolled population growth in forest landscapes induces the exploitation of forest natural resources for numerous purposes, which will have irreversible changes on forest structure, causing an imbalance in the carrying capacity of forest resources (Misra *et al.*, 2014). The rapid population growth will force forest degradation, increase resource consumption inequality, and intensify waste production, emissions, and pollution (Mote *et al.*, 2020). The population density for the Western Ghats region has been analysed. The Western Ghats regions in Maharashtra and Kerala depict higher population pressure than the central Western Ghats (Karnataka). Tribal communities are primitive traits having distinctive culture, and geographical isolation, which play a critical role in forest protection. Tribal groups like the Soligas, Kunubis, Gowlis, etc., are native to the Western Ghats forests.

Estuary

Estuaries are highly dynamic and productive ecosystems in the transition between freshwater with the tidal influence generating salinity gradients. These ecosystems are endowed with a variety of habitats, and the open coast has diverse ecological communities of plants and animals. The ecological importance and services of the estuaries formed by west-flowing rivers were assessed based on the ongoing research in the West Coast and literature review (Nakhawa *et al.*, 2017; Ramachandra *et al.*, 2019c; Karthik *et al.*, 2020).

Ecological significance and the need for conservation

Ecological sensitivity at disaggregated levels is assessed grid-wise by aggregating weights of various themes. Grids are grouped into four distinct groups based on the frequency distribution of aggregated scores: ESR 1 (aggregated scores > $\mu+2\sigma$), ESR 2 (for grids within $\mu+2\sigma$ and $\mu+\sigma$), ESR 3 (for grids with $\mu+\sigma$ and μ), and ESR 4 (grids with values < μ). The analysis highlights that the 755 grids covering an area of 32.4% are under ESR-1, 373 grids covering 16% are in ESR-2, and 789 grids (34% spatial extent) in ESR-3,412 grids covering 17.7% area are in ESR-4. Regions or Grids corresponding to ESR-1 and 2 represent ecologically fragile regions with the highest degrees of vulnerability and are endowed with rich natural resources and higher biodiversity that sustains people's livelihood. ESR-3 depicts moderate sensitivity, whereas ESR-4 demarcates the grids of the least ecological significance with the least resource availability. State-wise analyses highlight that Southern states such as Kerala, and Karnataka, located in the latitudinal gradient of 8 -14° of the Western Ghats with the higher composition of endemic and threatened taxa, cover a wider spatial extent in ESR-1, and 2 regions. The major part of Maharashtra and Tamil Nadu state landscapes are in ESR-3, and 4. Fig. 6 depicts ESRs at the village level. State-wise, village-level ESR analyses presented in Table 1 and Fig. 7 indicate that there are (i)345 ecologically vulnerable villages (of 1037 villages) in Gujarat state, (ii) 2311, and 2900 villages under ESR-1, and 2 in Maharashtra State, (iii)771, and 1111 villages (of 4911 villages) under ESR-1 and ESR-2 in Karnataka, (iv) 163, and 49 villages (of 841 villages in the Western Ghats) under ESR-1, 2 in Kerala, 261, and (v) 144 villages (of 1407 villages) under ESR-1, and 2 in Tamil Nadu.

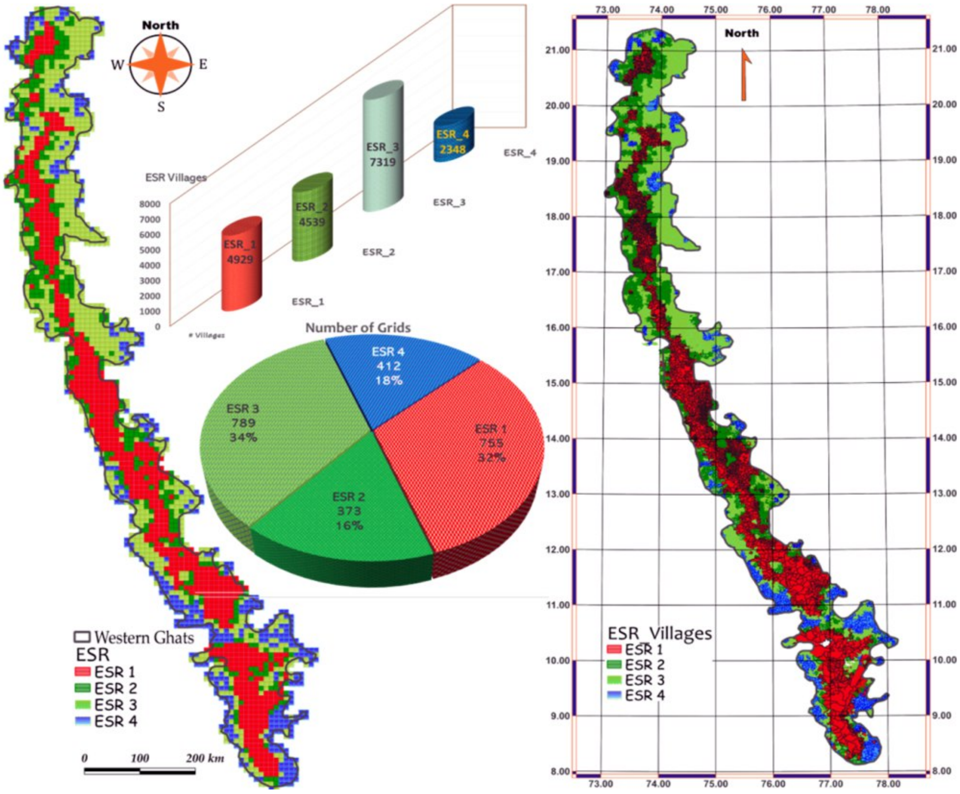

Fig. 6: Grid wise and village wise ESRs of the Western Ghats

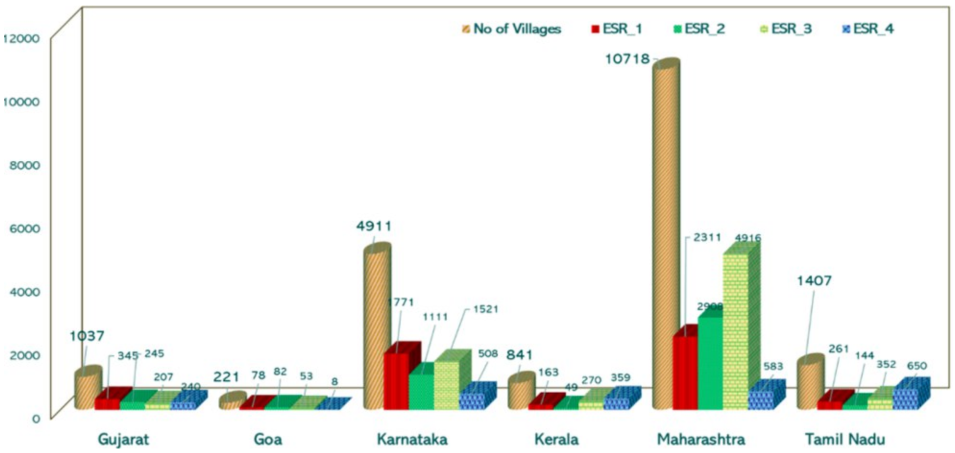

Fig. 7: State-wise ESR distribution of villages that are part of the Western Ghats

Table 1: State-wise distribution of ESRs

State name	Total Area Km^2	ESR-1		ESR-2		ESR-3		ESR-4	
		Km^2	%	Km^2	%	Km^2	%	Km^2	%
Gujarat	6045	2160	36	1552	26	1126	19	1208	20
Goa	2409	1267	53	686	28	410	17	47	2
Karnataka	42021	23277	55	7123	17	8779	21	2842	7
Kerala	26240	13401	51	1483	6	5453	21	5904	23
Maharashtra	60323	12958	21	14668	24	28710	48	3987	7
Tamil Nadu	22961	10085	44	2135	9	4013	17	6728	29
	160000	63148	39	27646	17	48490	30	20716	13

ESR-1 and 2 signify highly vulnerable and fragile region with a high degree of ecological sensitivity and are endowed with rich ecology (evident from the distribution of endemic and threatened species of biodiversity), hydrological regime (occurrence of perennial streams supporting agriculture and horticulture with higher productivity) and an array of ecosystem services including the provision of diverse food and medicine sustains people's livelihood. ESR-3 depicts moderate sensitivity, ESR-4 with the least sensitivity, and cluster-based developmental projects based on the natural resources available in the region are to be implemented to benefit local people. ESR-1 and 2 are ecologically susceptible regions with higher ecological fragility; hence, the region's ecological integrity needs to be preserved without anthropogenic interventions. These regions have demonstrated their utility by (i) supporting the livelihood of people through the sustenance of water (due to the presence of perennial streams), (ii) the presence of diverse pollinators resulting in efficient pollination leading to higher crop productivity, (iii) lower instances of mudslides, and landslides (as roots of diverse vegetation provide binding of soil) and hence ESR1 and ESR 2 are to be considered as restricted (no-go) areas for any large scale developmental activities. Only environmentally friendly initiatives, listed in Table 2 that benefit local people be taken up.

The ESR framework proposed here forms a foundation for conservation and facilitates addressing the various developmental issues through an established scientific basis. Western Ghats Spatial Decision Support System (WGSDSS) has been designed and implemented (Fig. 8, https://wgbis.ces.iisc.ac.in/sdss/wgsdss/index.php).

WGSDSS helps in (i) visualizing regions based on eco-sensitiveness, (ii) visualizing variables used for

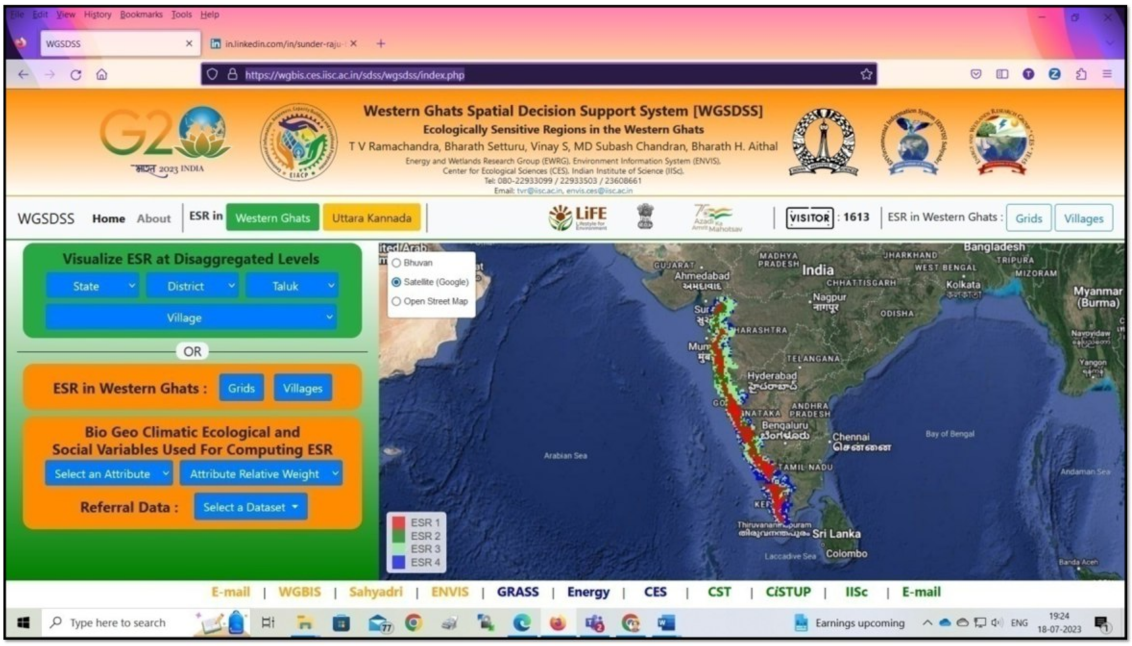

Fig. 8: Western ghats spatial decision support system for visualizing ESRs at village level

computing eco-sensitiveness at grid level (5'x5' or 9 km x 9 km) and village levels and (ii) aids in decision making at decentralized levels (BMC, local forest department, etc.). Understanding ecological sensitiveness at disaggregated levels aids in evolving sustainable developmental plans with minimal unplanned developmental activities, which helps in conserving ecologically susceptible regions.

Table 2: Activities that could be allowed and restricted across ESRs

Sl.	Activities	Ecological sensitive regions			
		ESR-1	ESR-2	ESR-3	ESR-4
1	**ENERGY**				
	a) Solar (Rooftop)	✓	✓	✓	✓
	b) Wind power	×	✓	✓	✓
	c) Bioenergy	×	✓	✓	✓
	d) Coal-based (Thermal power)	×	×	×	×
	e) Gas or liquid fuel-based	×	×	×	✓
	f) Hydropower (Major)	×	×	×	×
	g) Hydropower (Micro)	×	×	×	✓
	h) Nuclear power	×	×	×	×
2	**FORESTS**				
	a) Land-use changes (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)	✓	✓	✓
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 and P) fertilizers	×	×	×	✓Dosage as prescribed by Agriculture department
	c) Endosulfan	×	×	×	×
	d) Pesticide	×	×	×	✓
	e) Watermelon and Muskmelon farming	×	✓	✓	✓
	f) Ginger cultivation	×	✓	✓	✓
5	**INDUSTRIES (Large scale)**				
	a) Agro-processing	✓	✓	✓	✓

Sl.	Activities	Ecological sensitive regions			
		ESR-1	ESR-2	ESR-3	ESR-4
	b) Information Technology (IT)	×	×	✓	✓
	c) Red category (Polluting)	×	×	×	×
	d) Garment	×	×	✓	✓
	e) New establishment	×	×	×	✓(Allowed only after critical review by local stakeholders and experts)
	f) Nonpolluting (Green)	×	×	✓	✓
6	**INDUSTRIES (Small scale)**				
	i. Garment	×	✓	✓	✓
	ii. Domestic (Home-based)	✓	✓	✓	✓
	a. Papad				
	b. Mango processing	✓	✓	✓	✓
	c. Areca nut processing and Coir	×	✓	✓	✓
	d. Milk products and processing	✓	✓	✓	✓
	e. Dry fruits and 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	×	✓	✓	✓
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	×	×	×	×

Sl.	Activities	Ecological sensitive regions			
		ESR-1	ESR-2	ESR-3	ESR-4
	c) Bauxite	×	×	×	×
	b) Manganese	×	×	×	×
	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 with the strict regulation and social audit**			
	c) Up-gradation of existing infrastructure	×	×	✓(Subject to EIAs, strict regulation and social audit)	✓

Remarks

ESR-1 regions are ecologically susceptible, representing a zone of highest conservation, and maintain ecological integrity with no further degradation be allowed. ESR-2 has the potential to become ESR-1 provided with strict regulations and improved forests and their environs with more protection. Also, a small change in ESR-2 will have more adverse effects in ESR1.

Linear (new major/ expansion of roads and railway lines) be allowed across the ESR-1 and 2 due to their ecological sensitivity. Essential expansion activities should be subjected to the Environmental Impact Assessment (EIA) and strict monitoring based on the social audit.

Public utilities involving the construction of schools, hospitals, government offices, libraries, and other public amenities (large/small scale) be allowed and subject to strict monitoring with the social audit.

Forest Rights Act to be implemented in its true spirit to support the genuine forest-dwelling communities.

Monoculture plantations should not be allowed, and existing exotics should be replaced by planting endemic species. Fast-growing native trees such as *Madhuca longifolia* (Mahua), *Madhuca latifolia, Melia dubia, Azadirachta* indica (Neem), *Terminalia arjuna*, etc., could be used, which not only aid in the eco-restoration but help in meeting the local timber requirements in ESR regions.

Monoculture exotic species should be restricted even in coffee plantations of ESR-1.

Promote decentralized electricity generation through location-specific renewable energy sources such as solar, wind, biomass, etc.

Farmers need to be encouraged with incentives for practicing organic farming, agroforestry, beekeeping, etc.

Fruit-yielding tree saplings to be distributed to farmers through decentralized forest nurseries, which would aid as an alternate income source.

The local bio resource-based industry should be promoted. All should be strictly regulated and be subject to social audits.

Adapt environment-friendly development projects and involve local community members in decision-making and ecological monitoring.

The tourism Master Plan should be based on MoEFCC regulations (after considering social and environmental costs). The ban should be imposed on large resort construction and new tourism establishments in ESR-1.

Controlled activities are permitted based on socio-economic importance, and activities such as depriving wetlands and natural forests and introducing alien invasive species are not allowed.

Tribes and indigenous communities should be engaged in the conservation and protection of forests. Tribal women should be employed in the nurseries across the ESRs.

The Western Ghats biodiversity information centers should be established at all the district headquarters of the region to sensitize students and citizens on conservation measures and issues. These centers work towards implementing a comprehensive plan for the protection of fragile ecosystems and livelihoods.

Public hearings and timely consultations with all the stakeholders must be made mandatory for all the largescale/medium-scale projects, including liner projects, to have a collective decision, which will also gain people's opinion, and help in stemming the impacts with alternatives.

Conclusion

The comprehensive knowledge of the ecological fragility of a region assessed at disaggregated levels through integration of bio-geo-climatic, ecological and social variables representing dynamics of socio-ecological systems, impacts, and drivers has aided in evolving location-specific strategies for conservation. LU analyses using temporal remote sensing data highlight the loss of evergreen forest cover of 5% with an increase of 4.5% built-up cover, and 9% agriculture area due to anthropogenic pressures. Due to unplanned developmental activities, the evergreen forest cover has reduced from 16 to 11% from 1985 to 2018. The fragmentation analysis highlights the status of forests in the Western Ghats. Interior forest cover has reduced from 37.14 to 25.01% over the past three decades. The reduction of contiguous interior cover affects endemic taxa and habitats and results in higher instances of human-wildlife conflict. Endemic taxa such as Lion-tailed Macaques are experiencing higher predation due to loss of continuity in the canopy with the fragmentation of forests.

Mitigating frequent instances of human-animal conflicts requires addressing the fragmentation and conservation of native forests in the Western Ghats region. It is recommended to (i) enrich the dispersal corridors between the fragments patches using fruit trees to facilitate dietary diversity, (ii) maintain connectivity among canopy across linear corridors, (iii) arrest the deforestation by strict vigilance, protect fragments from further degradation, and developing forest species nurseries by involving local stakeholders (iv) enrich the degraded patches periodically with afforestation of native vegetation for long term conservation and (v) transparency in forest governance with mechanisms for accountability of forest officials for fragmentation and land degradation of forest landscape. The policies of maintaining forest contiguity would help sustain natural resources and address the recurring problem of human-animal conflicts due to habitat fragmentation.

Prioritization of ecologically sensitive (susceptible/vulnerable/fragile) regions (ESR/EVR/EFR) at disaggregated levels has been done by integrating bio-geo-climatic, land cover, condition of ecosystems (fragmentation), ecological, hydrological, and social variables with the assignment of weights based on the extent and condition of ecosystems. The study emphasizes the need for conservation to maintain native vegetation in the catchment, highlighting its potential to support people's livelihood with water conservation at local and regional levels. Based on the level of the ecological sensitivity of the region at disaggregated levels considering various themes (bio-geo-climatic, ecological, and social variables themes), grouped into four distinct groups: ESR 1, ESR 2, ESR 3, and ESR 4.

ESR analyses highlights 39% of the geographical area of the Western Ghats is demarcated as ESR-1, 17% as ESR-2, 30% as ESR-3, and 13% as ESR-4. State-wise, village-level ESR analyses indicate that there are ecologically vulnerable villages in there are 345 villages (of 1037 villages) in Gujarat state, 2311, and 2900 villages under ESR-1, and 2, in Maharashtra State 771, and 1111 villages (of 4911 villages) under ESR-1 and ESR-2 in Karnataka , 163, and 49 villages (of 841 villages in the Western Ghats) under ESR-1, 2 in Kerala, 261, and 144 villages (of 1407 villages) under ESR-1, and 2 in Tamil Nadu. ESR-1 and 2 are the ecologically susceptible region with higher ecological fragility, and hence the region's ecological integrity needs to be preserved without any anthropogenic interventions. These regions have demonstrated their utility in supporting the livelihood of people through (i) the sustenance of water (due to the presence of perennial streams), (ii) the presence of diverse pollinators resulting in the efficient pollination leading to higher crop productivity, (iii) lower instances of mudslides and landslides (as roots of diverse vegetation provide binding of soil). Hence these regions are considered restricted (no-go) areas for any large-scale developmental activities. Enriching the existing forests across the ESRs with the help of stakeholders would help in mitigating global warming and climate change. ESR 1 and 2 are to be treated as No Go areas for all developmental activities to protect the ecosystem integrity to sustain the livelihood and health of people. The ESR framework acts as a spatial decision support systems (SDSS) tool at decentralized levels in the systematic assessment, monitoring of changes, and formulation of appropriate forest protection policies.

End section statements

1. ***Data and accessibility:*** Data used in the analyses are compiled from the field. Data is anlysed and organized in the form of table, which are presented in the manuscript. Also, synthesized data are archived at http://wgbis.ces.iisc.ac.in/energy/water/paper/ researchpaper2.html#ce

   http://wgbis.ces.iisc.ac.in/biodiversity/
2. ***Competing interests:*** We have no competing interests either financial or non-financial
3. ***Research ethics:*** The publication is based on the original research and has not been submitted elsewhere for publication or web hosting.

पारिस्थितिक रूप से संवेदनशील क्षेत्र, पश्चिमी घाट, एक जैव विविधता केंद्र

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सारांश

पारिस्थितिक संवेदनशीलता से यह अभिप्राय है कि जब किसी क्षेत्र की पारिस्थितिकीय अखंडता में बदलाव के कारण उस क्षेत्र के जीव-जंतुओं की स्थायी एवं अपूरणीय क्षति अथवा प्राकृतिक प्रक्रियाओं का विकास और प्रजातियों की बड़े पैमाने पर क्षति हो। किसी क्षेत्र की पारिस्थितिक संवेदनशीलता का ज्ञान क्षेत्र के संरक्षण की रणनीति विकसित करने के लिए अत्यंत आवश्यक है, जिसमें पारिस्थितिक संवेदनशीलता के लिए जिम्मेदार कारकों की पहचान करना शामिल है, जिसके अंतर्गत परिदृश्य के परिवर्तन (landscape dynamics) एवं निकट भविष्य में दृश्यों के परिवर्तन द्वारा अव्यवस्थित और अनियंत्रित विकास को कम किया जा सके। पश्चिमी घाट जो 36 विश्व जैव विविधता केंद्रों में एक है, जिसके पारिस्थितिक रूप से संवेदनशील क्षेत्रों का विश्लेषण सुदूर संवेदन (Remote sensing) के आंकड़ों द्वारा वनों की स्थिति और संरक्षण पर गंभीर चिंताओं को उजागर करता है। पारिस्थितिक रूप से संवेदनशील क्षेत्र (प.स.क्ष. या ESR) का चित्रण जैविक, अजैविक और सामाजिक मानव विज्ञानीय कारकों पर विचार करता है, जो संवेदनशील परिदृश्य की वर्तमान स्थिति और पारिस्थितिकी तंत्र संतुलन बनाए रखने में उनके महत्व को दर्शाता है। प.स.क्ष. विश्लेषण से पता चलता है कि 63148 वर्ग कि.मी. क्षेत्र अत्यधिक पारिस्थितिक संवेदनशीलता (प.स.क्ष. -1) के अंतर्गत है, 27646 वर्ग कि.मी. अधिक पारिस्थितिक संवेदनशीलता (प.स.क्ष.- 2) के अंतर्गत है, 48490 वर्ग कि.मी. मध्यम (प.स.क्ष.- 3) और 20716 वर्ग कि.मी. न्यून पारिस्थितिक संवेदनशीलता (प.स.क्ष.- 4) के अंतर्गत है। सतत् विकास नीति तंत्र में प.स.क्ष. को एकीकृत करने से अनियोजित विकास गतिविधियों को विनियमित करने में मदद मिलेगी, जो लोगों की आजीविका को बनाए रखने के लिए आवश्यक पारिस्थितिकीय तंत्र सेवाओं की निरंतरता के साथ पारिस्थितिक सुरक्षा सुनिश्चित करने में सहायक होगा। पारिस्थितिक रूप से संवेदनशील पश्चिमी घाट के विवेक पूर्ण प्रबंधन के माध्यम से अगली पीढ़ी के लिए प्राकृतिक संसाधनों का संरक्षण सुनिश्चित करने की जिम्मेदारी हमारे कन्धों पर है और हमें मिलकर भावी पीढ़ी के लिए इस महत्वपूर्ण पारिस्थिति की तंत्र का संरक्षण सुनिश्चित करना होगा।

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