

Mitigation of Carbon Footprint

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India has committed at the Paris Climate Change Agreement to reduce its emissions by 33-35% by 2030, which necessitates immediate implementation of carbon capture with afforestation of degraded landscapes with native species, regulations of land use land cover (LULC) changes and de-carbonisation through large-scale implementation of renewable and sustainable energy alternatives. This article studies in-depth on the issue taking a case of ecologically-sensitive Western Ghats region.

Global warming with the burgeoning anthropogenic greenhouse gas (GHG) emissions (400 parts per million from 280 ppm CO₂ emissions of pre-industrial era) has been altering the climate, eroding the ecosystem productivity and sustenance of water, thus affecting the livelihood of people. The anthropogenic activities such as burning fossil fuel, power generation, agriculture, industry, polluting water bodies, and urban activities are responsible for increasing GHG footprint of which 72% constitute CO₂. GHG footprint needs to be in balance with sequestration of carbon to sustain ecosystem functions. Forests are the major carbon sinks (about 45%) that aid in mitigating global warming.^{1,2}

The land use land cover (LULC) dynamics leading to deforestation and land degradation is the prime driver of global warming due to the loss of carbon sequestration potential as well as emissions. The Western Ghats (WG), Fig. 1 are one among 36 global

biodiversity hotspots and forests in this region sequestering atmospheric carbon, which aid in moderating the global climate. The region is endowed with 4,600+ species of flowering plants (38% endemics), 330 butterflies

(11% endemics), 156 reptiles (62% endemics), 508 birds (4% endemics), 120 mammals (12% endemics), 289 fishes (41% endemics), and 135 amphibians (75% endemics). It covers an area of approximately 160,000



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sq. km. It is considered as a water tower of India due to numerous streams originating and draining millions of hectares. The rivers of WG ensure water and food security of 245+ million people in the peninsular Indian States. The region has tropical evergreen forests, moist deciduous forests, scrub jungles, sholas, and savannas including the high rainfall savannas of which 10% of the forest area is under legal protection.

The land use (LU) dynamics was assessed using temporal remote sensing data of Landsat 8 Operational Land Imager (OLI-30 m resolution) 2018 data integrated with field estimations and decadal land use (1985, 1995, 2005-100m resolution) available from International Geosphere-Biosphere Programme (IGBP). The collateral data included the vegetation maps developed by French Institute of Puducherry, topographic maps (the Survey of India) and virtual earth data (Google Earth, Bhuvan). The carbon sequestration potential of forest ecosystems was assessed on (i) published literature based on the standard biomass experiments and (ii) field-based measurements collected across the forests of WG of Karnataka using transect-based quadrat sampling techniques.^{1,2}

The spatiotemporal LU analyses presented in Fig. 2, highlights the loss of forest cover due to anthropogenic pressure. The region had 16.21% evergreen forest cover in 1985, which is reduced to 11.3% in 2018. It has 17.92%, 37.53%, 4.88% under plantations, agriculture, mining and built-up, respectively. The increase in monoculture plantations such as acacia, eucalyptus, teak and rubber, developmental projects, and agriculture expansions are the major drivers of LU changes. The region has lost 12% of interior (contiguous) forest cover during 1985 to 2018 with an increase of non-forest cover (11%). The interior forests (25% in 2018) are confined to major protected areas; edge forests are becoming more prominent due to sustained anthropogenic pressure (Fig. 3). Goa has experienced loss of large tracts of interior forest cover due to the indiscriminate rampant mining activities. The projected LU of 2031 (Fig. 4) highlights likely loss of evergreen forest with increases in agriculture cover (39%) and built-up area (5%).¹ The large scale changes of agriculture and built-up cover are noticed as per Fig. 4, in the eastern Kerala, Tamil Nadu, and Maharashtra States of WG. The evergreen forest cover will only be 10% of the WG by 2031, which would threaten the sustenance of water and other natural resources,^{3,4} affecting the food security and livelihood of people in the peninsular India.

Carbon Sequestration

The carbon sequestration potential of WG has been quantified, which confirms that the forests of WG are incredible reservoirs of biomass and carbon stock,^{1,5,6} highlighting the critical role of forests in lowering atmospheric carbon (emitted due to anthropogenic

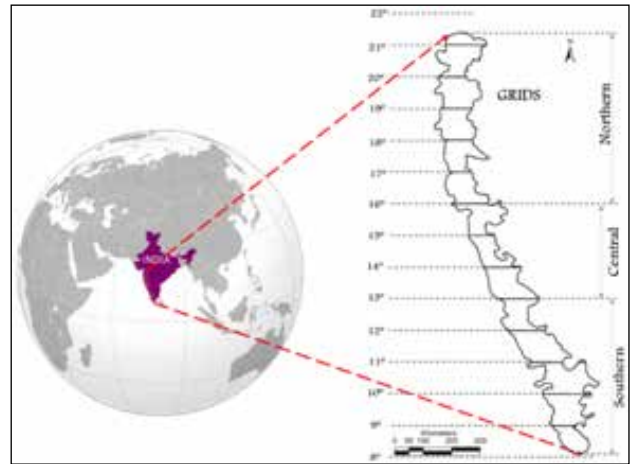


Fig. 1 Study Area-Western Ghats, India

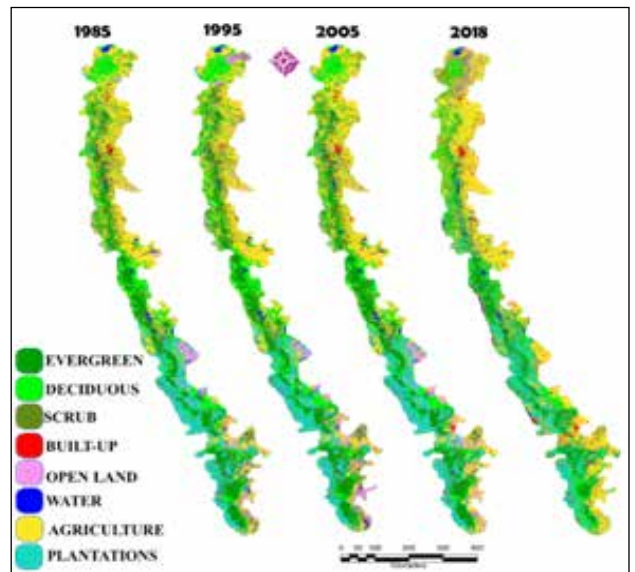


Fig. 2 LU Analyses of WG from 1985-2018

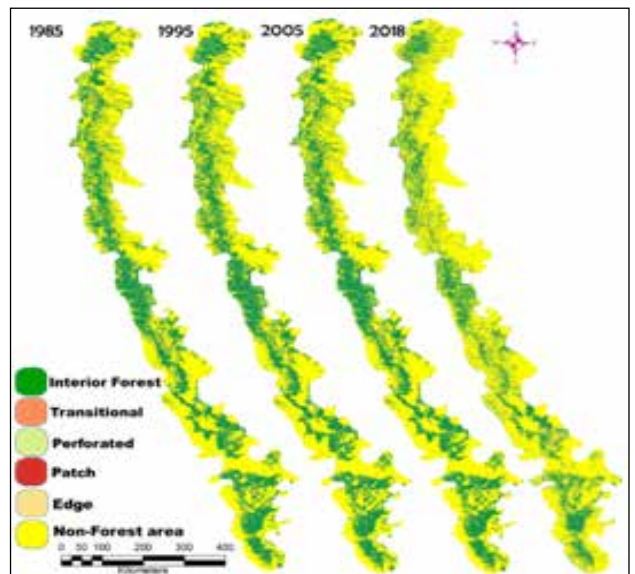


Fig. 3 Forest Fragmentation from 1985-2018

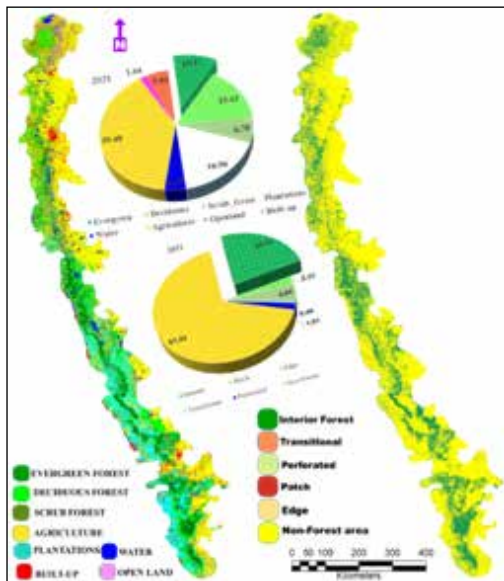


Fig. 4 Likely LU and Fragmentation of WG by 2031

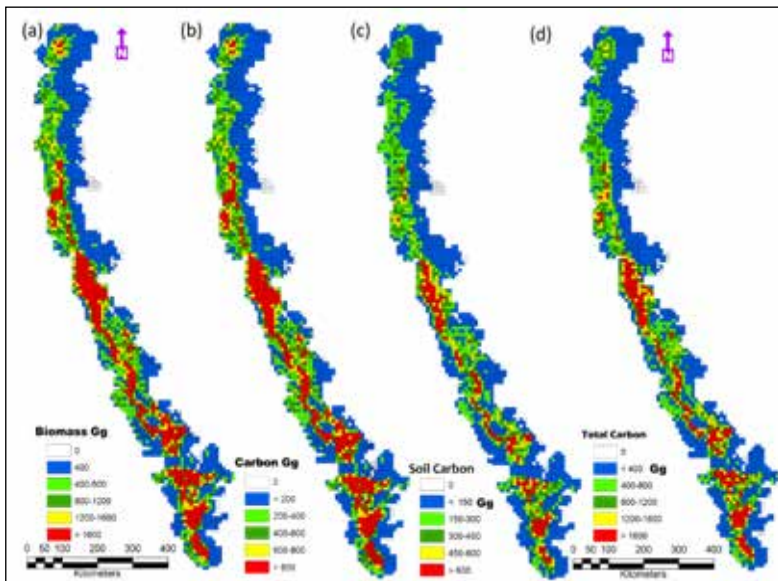


Fig. 5 Above Ground Biomass (Standing Biomass), Carbon, Soil Carbon Content and Total Carbon Stock of WG

activities) and mitigation of global warming (Fig 5a, 5b). The southern and central WG regions endowed with the rich native forests have soils rich in carbon (0.42 MGg), evident from Fig. 5c. Similar trend is noticed in the incremental carbon captured by soil 15120 Gg, and higher carbon content increment per year is noticed in Karnataka and Central Kerala parts of WG. The total incremental carbon excluding carbon loss through productivity is accounted to be 37507.3 Gg. The likely changes in carbon sequestration potential in the WG is estimated considering simulated

LU's (a) conservation scenario and (ii) business-as-usual scenario. The business-as usual-scenario (with the current trend of decline of forest cover due to LU changes) depicts the above ground biomass of 1.3 MGg with stored carbon of 0.65 MGg and soil carbon of 0.34 MGg.

Carbon Footprint

Carbon footprint is contributed by emissions from the energy sector (68%), agriculture (19.6%), industrial processes (6%), LU change (3.8%) and forestry (1.9%), respectively in India with CO₂ emissions of

about 3.1 MGg (2017) and the per capita CO₂ emissions of 2.56 metric tonnes. Carbon emissions from major metropolitan cities of India is about 1.3 MGg contributed by major cities such as Delhi (38633.20 Gg), Greater Mumbai (22783.08 Gg), Chennai (22090.55 Gg), Bengaluru (19796.6 Gg), Kolkata (14812.1 Gg), Hyderabad (13734.59 Gg), and Ahmedabad (6580.4 Gg) from energy, transportation, industrial sector, agriculture, livestock management and waste sectors per year.⁵

Ecologically fragile WG has been playing the pivotal role of mitigating

Table 1. Carbon Emission Across the States of WG

State/UT	Emission (Gg) per year			Total (Gg)	Carbon storage in WG (Gg) per year	% Removal
	CH ₄ (CO ₂ equivalent)	CO (CO ₂ equivalent)	CO ₂			
Goa	233	337	3881	4451	872	20
Gujarat	15546	14498	79138	109182	1947	2
Karnataka	15662	15239	54337	85237	10401	12
Kerala	3167	6108	26047	35321	7617	22
Maharashtra	23129	26497	105260	154886	11020	7
Tamil Nadu	15761	19190	71107	106058	5375	5
Dadra and Nagar Haveli	46	63	1458	1567	601	38
Total Emission (Gg)				496703	37833	8

carbon footprint with the potential to sequester carbon emission of all southern Indian cities and 1.62% of the total CO₂ emissions from India. The total emissions from WG states accounted to be 352922.3 Gg (Table 1) and forests of WG have the ability to sequester 11% of the emissions, which highlights vital carbon mitigation role and in moderating climate. India has committed at the Paris Climate Change Agreement to reduce its the emissions by 33-35% by 2030, which necessitates immediate implementation of carbon capture (with afforestation of degraded landscapes with native species, regulations of LULC changes) and de-carbonisation (through large-scale implementation of renewable and sustainable energy alternatives) through stringent norms towards (i) protection of ecologically fragile regions, (ii) dis-incentives for continued higher emissions based on 'polluter pays' principle, (iii) adoption of cluster-based decentralised developmental approaches, and (iv) incentives for reduced emission. The carbon trading has demonstrated the potential in monetary values across the globe of Indian forests in capturing carbon and the forest ecosystems in the WG are worth Rs. 100 billion (\$1.4 billion) at \$30 per tonne. The carbon

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credit mechanism and streamlining stakeholder's active participations would dramatically reduce the abuse of forests and encourage farmers to grow trees and converting the land to its next best use.¹⁻⁴

Water and Food Security towards Sustainable and Healthy Living

Ecologically fragile Western Ghats through perennial streams and rivers has been ensuring water and food security in the peninsular India. Alterations of landscape structure in the catchment areas influence the hydrological regime leading to variations in the hydrological status,

which is evident from the occurrence of perennial streams compared to the intermittent or seasonal streams in the catchment dominated by degraded forest patches in the Western Ghats. The streams are perennial when its catchment is dominated by vegetation (>60%) of native species. This is mainly due to infiltration or percolation in the catchment as the soil is porous with the presence of native species. Diverse microorganisms interact with plant roots and soil helps in the transfer of nutrients from the soil to plants and the soil is porous. Analyses of soil sample from the catchments of perennial, intermittent streams reveal that soils in the perennial streams catchment has the highest moisture content (61.47 to 61.57%), higher nutrients (C, N and K), and lower bulk density (0.50 to 0.57 g/cc). Compared to this, catchment of intermittent and seasonal streams had higher bulk density (0.87 – 1.53 g/cc) and relatively lower nutrients [3]. The analyses provide insights of the role of forests with native species in maintaining the hydrological regime while sustaining the local demand, which is useful in the watershed (catchment/basin) management by the respective government agencies. Fragmented governance and the deteriorating ecological ethics with the lack of vision among the decision makers are the principal reasons of deforestation and land degradation.

A comparative assessment of people's livelihood with soil water properties and availability of water reveals that streams with its catchment dominated by native species vegetation (>60%) have higher soil moisture and groundwater in comparison to the catchment (of seasonal stream) during dry spell of the year. The higher soil moisture due to the availability of water during all seasons facilitates farming of commercial crops with higher economic returns to the farmers, unlike the farmers who face water crisis during the lean season. This emphasises the need



for conservation endeavour towards maintaining native vegetation in the catchment, highlighting its potential to support people's livelihood with water conservation at local and regional levels. Plantation crops (viz. areca nut, coconut, banana, betel leaf, and pepper) are the major income generating products in the catchment of perennial streams. A total amount of Rs. 3,11,701/ha/yr (year 2009-10) gross average income was generated from the plantation crops against an average expenditure of Rs. 37,043/ha/yr, (mainly for plantation maintenance), yielding a net profit of Rs. 2,74,658/ha/yr. 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 Rs. 1,50,679/ha/yr against expenditure of Rs. 6474.10/ha/yr for maintenance and field preparation. This emphasises that sustenance of water in a river ensures the food security in the region which is dependent on the land use dynamics (forest vegetation cover) in its catchment. Thus, catchment integrity plays a decisive role in sustaining water for the societal and ecological needs, which is evident from the occurrence of perennial streams in the catchment dominated by native flora, highlighting the riverscape dynamics with the hydrological, ecological, social, and environmental dimensions linkages and water sustainability.^{3,4} This provides invaluable insights to the need for integrated approaches in the river basin management in an era dominated by mismanagement of river catchment with the enhanced deforestation process, inappropriate cropping and poor water efficiency. The premium should be on conservation of the remaining native forests, which are vital for the water security (perennial streams) and food security (sustenance of biodiversity). There still exists a chance to restore the lost natural forests through appropriate conservation and management

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practices. Current practices adopted by 20th century decision makers have been contributing to the erosion of water retention capability in the catchment with severe water scarcity, evident from 180 to 279 districts in the country reeling under droughts during the last three consecutive years. An increase of mean temperature by 0.5°C and decline of rainy days in the Western Ghats highlights of the imminent changes in the climate with the global warming due to the increase in carbon footprint with the deforestation or reduction in de-carbonisation mechanisms.

The Western Ghats with the spatial extent of 1,60,000 sq. km constitutes only 4.86% of India's geographical area (3,287,263 sq. km) and about 1.94% (64000 sq. km) in WG are ecologically sensitive, which plays a decisive role in sustaining the water for crop cultivation in 100 million hectares in the peninsular India. Recent unfortunate instances of floods and subsequent drought (drying up of water bodies) in Karnataka, Maharashtra, and Kerala is a pointer towards the mismanagement of forests in the region. The region witnessed higher quantum of precipitation in shorter duration and as the catchment had lost the capability to retain water (due to deforestation) through infiltration, most of the rainwater moved towards ocean as overland flow resulting in

scarcity of water immediately after the rainy days and also loss of life and property with the mudslides, etc. Hence, ecologically fragile regions such as Western Ghats needs to be conserved on priority to sustain the agriculture and horticulture in the peninsular India and support the economy to realise the status of developing country with the healthy citizen and \$5 trillion economy by 2025. Lopsided developmental approaches driven by land, wood, and water mafia will only drain the nation's economy with the recurring instances of floods and droughts. □

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