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Elephant Reserves of India: Spatial Overlaps, Land Use Changes and Conservation Implications

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Abstract. 'Elephant Reserves' established under the 'Project Elephant' program, serve as the management unit for elephant landscapes in India. We examined the spatial overlap between Elephant Reserves and other conservation areas. We found that 33% of the area of Elephant Reserves overlapped with Protected Areas and Tiger Reserves, enhancing their conservation status. Land use changes from 1985 to 2015 in Elephant Reserve areas were analysed using pre-classified remote sensing data. Results revealed that 4.9% of forest cover in Elephant Reserves were transformed to other land-uses and that currently 72% of the area of Elephant Reserves was under forest cover, indicating that forest loss was minimal.

Introduction

The Asian elephant (*Elephas maximus*) is both a flagship and keystone species. Elephants contribute to tropical forest ecosystems, through seed dispersal, nutrient cycling and biomass removal (Poulsen *et al*. 2018). Asian elephants were once found from the Yangtze-Kiang River basin in China to the Tigris and Euphrates River basin in west Asia (Shoshani & Tassy 1996). However, they are now restricted to less than 7% of their former range (Pandey *et al*. 2024a). They occur in 13 countries in Asia as disjunct populations, with a global population of about 50,000 (Williams *et al*. 2020).

India harbours the world's largest population, with around 22,000 (Qureshi *et al*. 2025). Several factors such as cultural affinity, religious reverence, and nature-friendly attitudes among Indian societies, coupled with strong public support for elephant conservation, political commitment, enhanced institutional capacities and robust legal frameworks have contributed in securing the largest Asian elephant population in the world (Pandey *et al*. 2024b). Asian elephants are listed as 'endangered' in the IUCN Red List, included in Appendix I of CITES and listed under Schedule I of the Indian Wildlife Protection Act of 1972.

In India, elephants are distributed over 163,000 km^2, which is 52% of the global range, in the North-west, North-east, East-Central and Southern regions (Pandey *et al*. 2024a). In response to growing conservation challenges primarily stemming from ivory poaching and habitat threats, the Government of India launched 'Project Elephant' in 1992 as a centrally sponsored scheme to provide technical and financial assistance to elephant conservation. In order to strengthen the cultural bonds with elephants, the elephant was declared as a national heritage animal. Elephants have relatively large home ranges that often include areas outside Protected Areas (PA) (Sukumar 2003). In India, PAs consist of lands designated under the Wildlife (Protection) Act of 1972. Such areas encompass ~178,640 km^2 or 5.4% of the country and consists of 106 National Parks, 574 Wildlife Sanctuaries, 309 Community Reserves, and 145 Conservation Reserves (ENVIS Centre on Wildlife & Protected Areas 2025). Another category of conservation areas in India are Tiger Reserves (TR). Since the inception of 'Project Tiger' in 1973, 53 TRs have been declared, cov-

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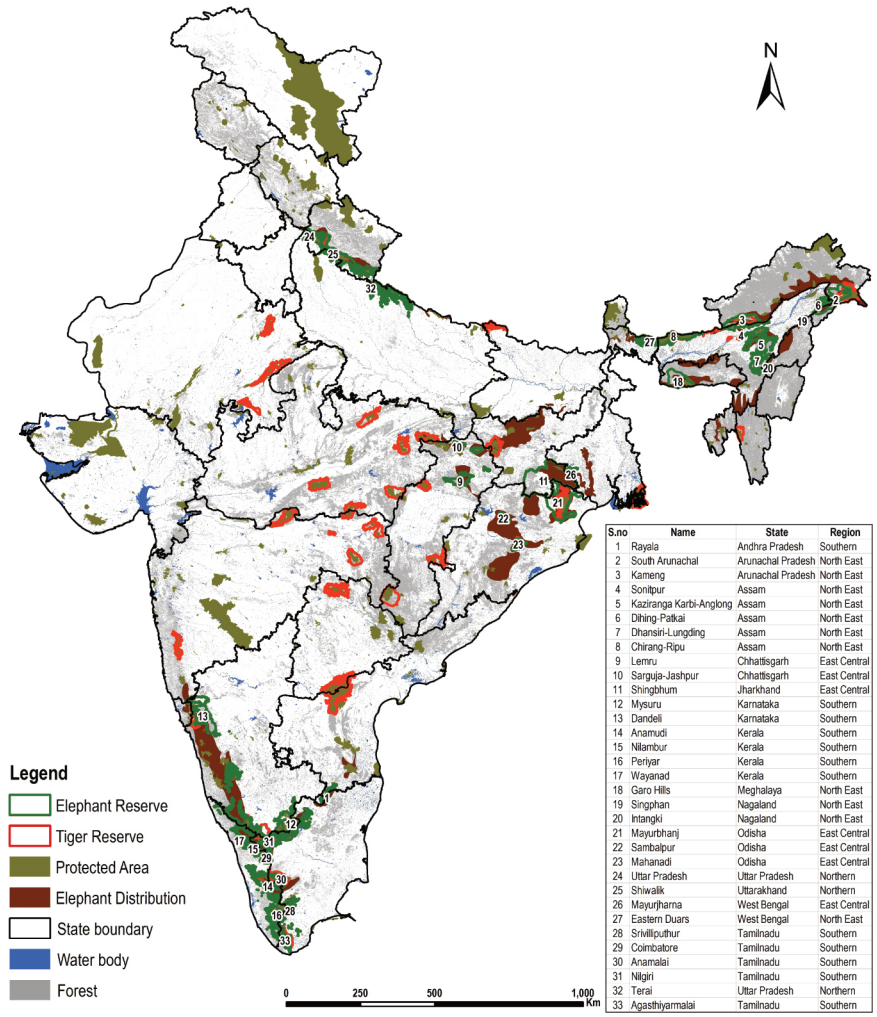
ering ~76,000 km² across 18 states (Nautiyal *et al*. 2023). PAs and TRs in India do not cover all elephant habitats and therefore are inadequate for management of elephants (Bist 2002). Therefore 'Project Elephant' prioritises a landscape approach to elephant conservation, by identifying Elephant Reserves (ER) and focusing on holistic and integrated management of areas identified as elephant habitat.

ERs may include Reserve Forests, PAs, TRs and multiple-use forest areas such as revenue lands and revenue forests, and human-use areas. While ER provides a conceptual framework for effective landscape management for elephants, it is not a legal entity as land-holding is not vested with the Forest Department. PAs and TRs are typically notified in areas that are inherently wildlife-rich and productive. ERs have been declared taking into consideration the elephants' large mobility and thus includes areas of human-elephant interface and corridors that provide permeability between landscapes. Thus, in comparison to the size of PAs (mean 221.5 km²) and TRs (mean 1433.4 km²), ERs are much larger (mean 4809.1 km²). Project Elephant conservation funding is primarily for ERs to support activities such as habitat improvement, mitigation of human-elephant conflicts, and the maintenance of critical movement corridors.

The number of notified ERs increased from five in 2001 to 33 by 2023 across 14 states (Fig. 1) covering a total area of 80,777 km², which constitutes about 2.5% of the country's landmass. They are spread across all four regions of elephant distribution. The southern region has 12 ERs covering 30,364.4 km², northeast 11 ERs encompassing 19,520 km², east-central 7 ERs covering 21,671.4 km², and the northern region 3 ERs covering 9,222.4 km². The sizes of ERs vary significantly with the smallest being Singphan in Nagaland at 23.5 km², and the largest being Singhbhum in Jharkhand at 13,440 km² (Pandey *et al*. 2024b).



S.no	Name	State	Region
1	Rayala	Andhra Pradesh	Southern
2	South Arunachal	Arunachal Pradesh	North East
3	Kameng	Arunachal Pradesh	North East
4	Sonitpur	Assam	North East
5	Kaziranga Karbi-Anglong	Assam	North East
6	Dihing-Patkai	Assam	North East
7	Dhansiri-Lungding	Assam	North East
8	Chirang-Ripu	Assam	North East
9	Lemru	Chhattisgarh	East Central
10	Sarguja-Jashpur	Chhattisgarh	East Central
11	Shingbhum	Jharkhand	East Central
12	Mysuru	Karnataka	Southern
13	Dandeli	Karnataka	Southern
14	Anamudi	Kerala	Southern
15	Nilambur	Kerala	Southern
16	Periyar	Kerala	Southern
17	Wayanad	Kerala	Southern
18	Garo Hills	Meghalaya	North East
19	Singphan	Nagaland	North East
20	Intangki	Nagaland	North East
21	Mayurbhanj	Odisha	East Central
22	Sambalpur	Odisha	East Central
23	Mahanadi	Odisha	East Central
24	Uttar Pradesh	Uttar Pradesh	Northern
25	Shiwalik	Uttarakhand	Northern
26	Mayurjharna	West Bengal	East Central
27	Eastern Duars	West Bengal	North East
28	Srivilliputhur	Tamilnadu	Southern
29	Coimbatore	Tamilnadu	Southern
30	Anamalai	Tamilnadu	Southern
31	Nilgiri	Tamilnadu	Southern
32	Terai	Uttar Pradesh	Northern
33	Agasthiyarmalai	Tamilnadu	Southern

Figure 1. PAs, TRs, elephant distribution range and ERs. ERs are numbered in the map and listed in the table.

Integrating ER management with PAs and TRs

Three essential constituents considered for managing elephant landscapes are (i) protecting intact forest habitats (ii) identifying and protecting corridors that connect otherwise discrete forest habitats and (iii) effectively managing human-elephant conflict. Project Elephant has developed a "Framework for Preparation of Elephant Conservation Plans" (ECP) (PE-WII-MoEFCC 2024), to provide a comprehensive approach for the management of ERs. The ECP provides a landscape-level approach to elephant conservation including corridors and takes into consideration other management plans for ER areas that also have other designations. To gauge the effectiveness of ERs, management effectiveness evaluations are conducted to assess the implementation of policies, and impacts on elephant populations and habitats.

Here, we assess the spatial overlap between ERs, PAs and TRs and the landscape dynamics in ERs.

Methodology

The boundaries of the ERs were obtained from State Forest Departments and official gazette notifications. The boundaries of PAs and TRs were obtained from the National Tiger Conservation Authority and the Wildlife Institute of India's National Wildlife Database.

To assess Land Use Land Cover changes (LULC), classification products at 100-m resolution for 1985, 1995 and 2005 were acquired from Oak Ridge National Laboratory Distributed Active Archive Center (Roy *et al*. 2015). Data were derived from Landsat 4 and 5 Thematic Mapper, Enhanced Thematic Mapper Plus, Multispectral data, India Remote Sensing satellites, Resourcesat Linear Imaging Self-Scanning Sensor-1 or III data, ground truth surveys, and visual interpretation. Further, the LULC data for 2015 was acquired from the BHUVAN – Thematic Services website at the scale of 1:50,000 derived from Resourcesat-2 Satellite Linear Imaging Self Scanning Sensor – III data

Table 1. Land-use and land-cover classification scheme used in the study.

Land cover type	Land use type with IGBP Classification (Roy *et al*. 2015) for 1985, 1995 and 2005	Land use type with NRC LULC50K Mapping Project (NRSC 2019) for 2015
Agriculture	Crop land	Crop land
	Fallow land	Fallow land
	Plantations	Plantations
	-	Current shifting cultivation
Forest	Evergreen needle forest	Evergreen / Semi evergreen
	Evergreen broad leaf forest	Deciduous
	Deciduous needle forest	Forest plantation
	Deciduous broad leaf forest	Scrub forest
	Mixed forest	NA
	Savanna/woodland (including woody scattered trees)	NA
	Mangrove forest	Swamp / Mangroves
Barren land	Barren land	Salt affected land
	Waste land	Gullied / Ravinous land
	NA	Scrub land
	NA	Sandy area
	NA	Barren rocky
	NA	Rann
Built up	Built up (urban and rural)	Urban
	NA	Rural
	NA	Mining
Water body	Water bodies	Inland wetland
	Permanent wetland	Coastal wetland
	NA	River / Stream / Canals
	NA	Water bodies
	NA	Snow

(NRSC 2019). These layers follow the IGBP (International Geosphere Biosphere Programme) LULC classification scheme (Loveland & Belward 1997). The Bhuvan LULC database defines 'forest' as land with a tree canopy cover exceeding 10% and an area of more than 0.5 hectares, with trees capable of reaching a height of 5 m and Roy *et al*. (2015), as canopy cover of over 60% and vegetation height exceeding 2 m.

The two classifications of LULC were merged and five major LULC classes were used to assess LULC change (Table 1). Vectorisation of the raster subset was executed to estimate the area of various classes. Spatial analyses were performed in ArcGIS 10.6.1.

Results

Overlap of PAs with ERs

A total of 130 PAs overlapped with 30 ERs, with 61 PAs in the northeast overlapping with 10 ERs, 49 PAs in the southern region overlapping with 11 ERs, 11 PAs in the east-central region overlapping with 6 ERs, and 9 PAs in the northern region overlapping with 3 ERs (Fig. 2, Table 2).

Overlap of TRs and ERs

A total of 26,154. km^2 comprising 25 TRs overlapped with the 33 ERs, with 12 TRs in the southern region overlapping with 8 ERs, 7 TRs in the North East overlapping with 6 ERs, 4 TRs in the North overlapping with 2 ERs, and 2 TRs in East Central overlapping with 2 ERs. The area of overlap between TRs and ERs in the southern region was 13.4% of overall ER range in the country, in the northeastern region 9%, in the northern region 6%, and in the east-central region 4%.

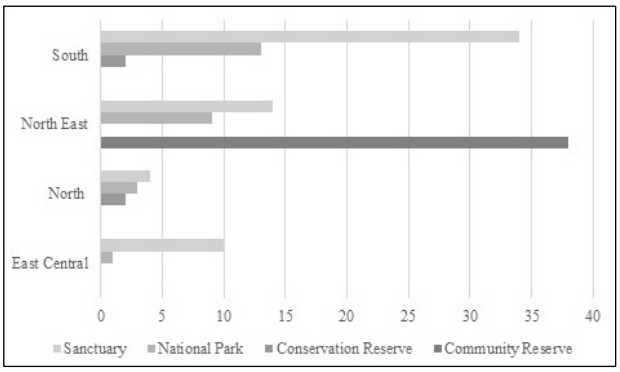


Figure 2. Region wise number of PAs overlapping with ERs.

Overlap of PAs, TRs and ERs

The total spatial overlap among PAs, TRs, and ERs was ~17,548 km^2 and in the southern region was 21% of the total area of ERs in the country and in Northeast 10%, in East Central 7% and in Northern region 5%.

Forest areas in ERs administrated by the Forest Department, that were not PAs or TRs but were mostly notified forests.

Land-use and land-cover in ERs

Around 72% of the area of the ERs were under forest cover in 2015 and the rest comprised of other land-uses. There were shifts in land use patterns in ERs in all four regions with increase in agriculture (Table 3 and Fig. 3).

Discussion

Spatial analysis indicated a substantial spatial overlap between the PAs, TRs, and ERs, with 15% of the area of PAs overlapping with ERs, 33% of ERs overlapping with PAs, 36% of the area of TRs overlapping with ERs, and 32% of ERs overlapping with TRs. Areas under PAs and TRs have management plans, which prioritise wildlife conservation. They also have stat-

Table 2. Extent of area of overlap between PAs and ERs (km^2).

Zone	Community Reserve	Conservation Reserve	National Park	Sanctuary	Total
East Central	-	-	1359.17	3601.87	4961.04
North	-	51.11	1978.61	1160.45	3190.17
North East	24.07	-	4523.84	2366.98	6914.89
South	-	78.15	3594.66	8428.16	12,100.97
Total	24.07	129.27	11,456.27	15,557.45	27,167.06

Table 3. Percentage wise LULC classification of the ERs.

Region	Year	Forest	Water	Agriculture	Barren land	Built up
East Central	1985	71.8	1.1	25.3	1.5	0.3
	1995	70.5	2.7	24.7	1.5	0.6
	2005	69.6	2.7	25.8	1.3	0.6
	2015	68.4	1.6	27.4	1.9	0.6
North East	1985	75.8	3.0	19.6	1.2	0.4
	1995	74.7	3.6	20.0	1.2	0.5
	2005	73.5	3.6	21.3	1.1	0.5
	2015	71.4	1.8	25.6	0.7	0.5
North	1985	71.4	6.0	21.3	0.9	0.1
	1995	71.2	6.4	21.3	0.7	0.1
	2005	71.3	6.2	21.5	0.6	0.1
	2015	73.8	2.8	21.8	1.5	0.1
South	1985	76.1	2.6	19.6	1.3	0.4
	1995	75.1	3.1	20.1	1.2	0.5
	2005	74.0	3.1	21.3	1.1	0.5
	2015	71.8	1.7	25.4	0.6	0.5

utory protection under the Wildlife (Protection) Act, 1972. ERs that were notified forests, came under the Indian Forest Act, 1927, or under local laws, so also have statutory protection. Overlap of ERs with PAs and TRs increases legal protection, as unlike ERs, PAs and TRs are legally protected. Consequently, ~33% of the overall extent of ERs were legally protected.

PA and TR overlap of ERs provided other indirect benefits as well, as financial resources allocated for PAs and TRs are utilized for anti-poaching measures, habitat management, scientific monitoring, rapid response mechanisms and community development programs, which also benefit elephants.

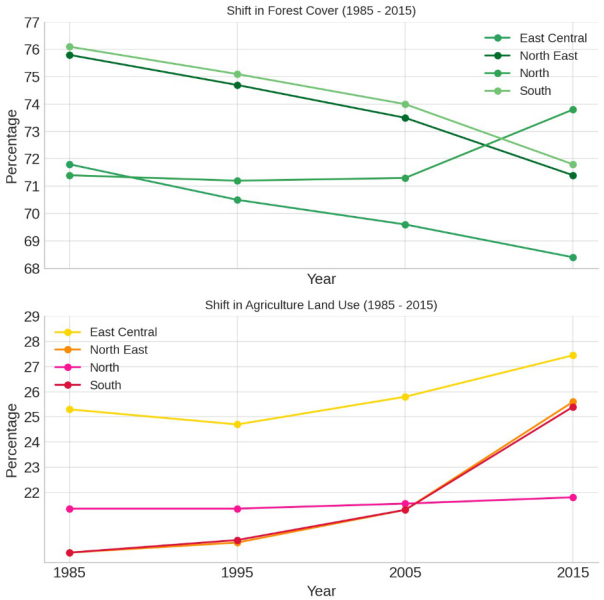


Figure 3. Forest cover and agriculture land use (1985–2015) in ERs.

Land-use and land-cover in ERs

As 72% of the area of ERs was under forest cover, forest loss was minimal. A major challenge in the management of ERs is addressing the 28% of areas with non-forest land-uses, as they are not under administrative control of the Forest Department. Here land-use is driven by economic and development aspirations. Therefore, multi-sectoral engagement to promote wildlife friendly land use is a priority. Thus, our findings highlight the importance of integrating participatory approaches and multi-sectoral coordination with local communities, revenue departments, and other stakeholders, for the effective management of ERs.

The forest cover of ERs in the north-east, southern and east-central region regions declined by 4.4% and 4.3% and 3.4% respectively over 30 years. Forest loss occurring in southern and north-eastern elephant distribution regions was also observed, by Padalia *et al*. (2019). In the north-east region, jhum cultivation and illegal logging exerted substantial pressure on forest cover (Mahapatra *et al*. 2025). Forest cover in the southern region was more affected by population expansion, cropland conversion, mining,

rail and road network connectivity (Menon & Bawa 1997). A relatively high level of fragmentation leading to isolation of patches of forests, that can severely impact the movement patterns of elephants resulting in negative interactions with humans was observed in the east-central region (Padalia *et al*. 2019). In recent times, Jharkhand, Chhattisgarh, Odisha, and South Bengal in the East Central region, have reported high levels of human-elephant conflict, which could be attributed to loss and fragmentation of elephant habitat due to LULC changes (Pandey *et al*. 2024b).

The slight observed increase in forest cover and decrease in water bodies in the northern region may not represent actual change but could be due to classification issues in LULC mapping. Babu *et al*. (2019) assessed the landscape dynamics in elephant habitat of the northern region and concluded that the forest area is relatively less affected and nearly stable, which is consistent with our findings.

Overall, the shifts in forest cover in ERs in India have been relatively minimal. Agricultural land use within ERs increased in all regions, indicating intensification of agriculture during the last few decades. The evolving LULC pattern has fragmented elephant habitats, forcing elephants into close proximity with human settlements and influencing their movement due to obstruction of migratory pathways (Billah *et al*. 2021), which may also affect the ranging behaviour of dispersing elephants and result in the emergence of new human-elephant conflict zones.

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Figure 4. Elephants in Terai Elephant Reserve, Dudhwa, Uttar Pradesh. Photo by Surendra Kumar.