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A Data-Driven Approach to Analyse the Status of Commons in India: A Case Study of Odisha

Shaurabh Anand[1] and Himani Sharma[2]

ABSTRACT

Commons, a broad set of material and non-material resources shared and managed collectively by communities, are vital for rural households in India. However, in recent years, commons have undergone degradation and depletion due to demographic, economic, ecological, and institutional factors. The conservation and sustainable management of commons require a thorough, grounded assessment of their status. While micro-studies demonstrate the social embeddedness and relationalities of common resources, they often face limitations in scaling up to larger geographies. The management of commons is essentially a community-level activity. Therefore, there is a need for a methodological framework to analyse the status of these resources at a scale at which they are used and managed (typically village) and aggregate it up to a scale at which policies are formulated and implemented (typically state). This study develops an operational, data-driven framework to evaluate the status of terrestrial commons in Odisha over a two-decade period (2001–2022) at the village level. The study uses annual MODIS land-cover data and the Census of India Village Directory to build an analysis framework. We analysed the spatial and temporal change in total area under commons at the village level. We also computed a transition dynamism index that captures the magnitude of changes at a district level. The results of our study show a modest overall increase of 4.5 per cent in the total area under commons at the state level. District-level dynamism exhibits high volatility in the central–southern, forested, and mining-affected districts, whereas coastal districts remain comparatively stable. There is a large heterogeneity in the performance of commons at the village level. The changes remained concentrated in a small percentage of villages under study: 11.1 per cent (4858) of villages recorded a decrease in area, while 14.8 per cent (6445) of villages recorded an increase in area. The area of commons remained the same in 32314 villages (74.1% of the total studied villages). Our results emphasise the importance of scaling the mapping from the village to the state. By rendering commons legible at the village scale and aggregating to the policy-relevant geographies, the study framework provides a much-needed approach for prioritising co-management, restoration, and monitoring.

Keywords: Commons mapping, remote sensing and GIS, land use dynamics, community resource governance, Odisha

JEL codes: O13, Q15, Q56, Q57, R14

I

INTRODUCTION

Common Property Resources (CPRs) or commons refer to natural resources, including pastures, forests, ponds, rivers, and watershed drainages. In terms of usage rights, they are shared and managed collectively by communities (Jodha, 1995; NSSO, 1999).

Rural households collect a variety of fuelwood, fodder, and forest produce from CPRs. The material collected can account for up to 6 per cent of total household consumption (Down to Earth, 2024; Beck & Ghosh, 2000; Jodha, 1990; FES, 2014). Produce from commons is essential for self-consumption, ensuring food and nutritional security (Nayak, 2024). Commons can also be a reliable income source,

[1]School of Development, Azim Premji University, Bengaluru; [2]Foundation for Ecological Security, Anand

specifically for women (Down to Earth, 2023). A regular income stream from commons can bring financial independence to women and increase their autonomy. Socio-ecological knowledge related to commons management is culturally embedded, and regular harvest practices help maintain the cultural identity of communities. The importance of commons extends beyond humans; they are critical for the healthy functioning of ecosystems through various essential ecosystem functions, including soil fertility, groundwater recharge, and biodiversity preservation.

Therefore, the healthy status of commons becomes an undeniable part of communities and individuals who are heavily dependent on nature and natural resources for their survival. These include landless, tribal communities, and women. Consequently, the degradation of common resources disproportionately affects these groups, increasing their vulnerabilities. For a community with commons at the centre of its cultural identity, the degradation erodes the intricate interactions between people, places, and practice.

In recent years, commons have faced misappropriation, depletion, and degradation for several reasons. One of the primary reasons for misappropriation of commons is the classification of these landscapes as 'wasteland' in India's revenue records (Baka, 2013; Singh, 2013). Originating from a rigid, productivity perspective, this categorisation does not recognise local communities' customary rights and usage patterns (Singh, 2013; Baka, 2013), paving the way for its diversion to industrial and infrastructural projects. In recent years, several attempts have made these landscapes 'productive' by doing large-scale plantations (Baka, 2013). Our insatiable needs for land resources, fueled by rapid population growth and urban expansion, have significantly contributed to the degradation of the commons.

The consequences of commons degradation are multifaceted. As the harvest from the commons decreases, households become more dependent on goods purchased from markets. This increased dependence reduces food sovereignty and increases economic vulnerability. The collapse of the commons leads to dispossession, accelerating outmigration, and ecological declines. Recognising the heterogeneity of commons and the diverse ways they live rural lives would be the first step in arresting this vicious cycle of dispossession and decline. A proper governance structure is essential for the long-term sustainability of commons resources (Meinzen-Dick et al., 2023). Commons remain vulnerable without supportive institutions, clear rights, and community participation. Top-down governance structures often push the most vulnerable groups, especially women and tribal groups, to the margins. Protecting commons starts with recognising them as essential for ecosystem health and communities' well-being, not just as leftover spaces.

Despite a rich body of work on common property resources (CPRs) in India, a significant gap persists in bridging micro-level insights with macro-level assessments. Most studies focus on village-specific dynamics, such as community forest governance and livelihood dependence, or aggregate spatial and economic patterns, but rarely attempt to integrate both (Springate-Baginski & Blaikie, 2007; Chopra & Dasgupta, 2007). Therefore, there is a need for a methodological framework to analyse the status of these resources at a scale at which they are used and managed (typically village) and aggregate it up to a scale at which policies are formulated and implemented (typically state). In this context, the current study builds a case for examining the status of commons by leveraging the large-scale secondary data available in the public domain. We conducted this study in the state of Odisha, specifically addressing how commons in Odisha have evolved in space.

1.1 Study area

Odisha lies on India’s eastern coast, covers about 4.7 per cent of the national land area, and has a population of roughly 42 million. Commons in Odisha comprise community forests, grazing lands, wetlands, mangroves, coasts, water bodies, and hillocks. For tribal and marginalised communities, commons contribute a substantial share of income (up to 40%) and support nutrition, seasonal risk buffering, local knowledge, and cultural identity (Beck & Ghosh, 2000; Jodha, 1990; FES, 2014). Forests, pastures, and uncultivated spaces form a routine part of household survival strategies across the state. However, commons in Odisha are facing various threats. Mining, infrastructure development, and land conversion for agriculture and plantations have reduced the extent and quality of commons (FES, 2014; Sahoo, 2015; Rout, 2023; Sahoo & Swain, 2013). Out-migration caused by agrarian distress has exacerbated the gendered costs of shrinking access (Pathak et al., 2018). Institutional arrangements compound these ecological trends. Community-used lands are frequently mislabeled and diverted without recognising customary use. Fragmented mandates across forest, revenue, and panchayat departments, as well as uneven implementation of the Forest Rights Act, limit community stewardship and blur accountability (Sahoo & Swain, 2013). A high degree of dependence, multiple threats, and institutional mismanagement make Odisha a suitable case for examining the commons.

II

METHODOLOGY

This study adopted a secondary data-driven design to quantify long-term changes in Odisha’s land commons. We operationalised commons as forest and grassland/pasture systems and measured changes over 2001-2022 at the village scale. We used two complementary datasets for the analysis workflow. First, the MODIS annual land-cover product (The International Geosphere–Biosphere Programme (IGBP), 17 land use/land cover classes; 500 m resolution) provided consistent land use land cover from 2001 onward (Friedl & Sulla-Menashe, 2022). Second, the Census Village Directory for 2001 and 2011 offered village-level land-use statistics, which were used for cross-checking, validation, and variable mapping. The census village directory is the only systematically compiled data source for land categorisation at the village level. Together, these sources enabled harmonised measurement of commons in a setting where "commons" is not explicitly recognised within official land-use classifications.

The spatial unit of analysis was the village. We used village polygons from the Socioeconomic High-resolution Rural-Urban Geographic Platform for India (SHRUG) database. The final selection of villages for analysis proceeded by reconciling village identifiers across the 2001 and 2011 Census village directories, followed by intersecting these with SHRUG polygons and MODIS pixel footprints. Of 51,349 villages listed in 2001 and 51,313 in 2011, 51,082 had matched records across both Census years. After overlaying with SHRUG polygons (46,548 villages) and retaining villages with at least one MODIS pixel intersecting the footprint, 44,433 villages met the multi-source match criterion. A final set of 43,617 villages was obtained after removing outliers (decided based on area). The final set of villages corresponded to 96,875-99,136 km² of analysable area, depending on whether the SHRUG or Census area is used as the reference. These steps create a longitudinal, village-level panel for change detection and validation (Table 1).

TABLE 1. SELECTION OF VILLAGE FOR ANALYSIS

Parameter	Number	Area (Sq. Km)
Number of villages in 2001 as per the census village directory	51,349	116064 (77.30%)
Number of villages in 2011 as per the census village directory	51,313	115738 (77.08%)
Number of villages with matching data from both 2011 and 2001 as per the census village directory	51,082	115101 (76.66%)
Number of villages as per SHRUG database polygons	46,548	112758 (75.10%)
Number of villages with complete matching records of census data, SHRUG data, and MODIS data (Matching criteria for MODIS: Number of pixels ≥ 1 pixel)	44,433	108876 (72.51%) - SHRUG 109268 (72.77%) – Census
Number of villages after removal of outliers	43,617	96875 (64.51%) - SHRUG 99136 (66.02%) - Census

Commons categories were derived through an explicit crosswalk from both the Census and MODIS schemes. "Forest commons" were mapped to census forest area and, in MODIS, to IGBP classes 4 (deciduous broadleaf, canopy > 2 m, cover > 60%), 5 (mixed deciduous/evergreen, canopy > 2 m, cover > 60%), and 8 (woody savanna, canopy > 2 m, cover 30–60%). "Grazing/grassland commons" were mapped to Census culturable waste plus permanent pasture/other grazing land, and in MODIS, to classes 9 (savanna, canopy > 2 m, cover 10–30%) and 10 (grassland). We added the area under 'Forest commons' and 'Grazing/grassland commons' to calculate the total area under commons in a village. This dual-source mapping provides parallel estimates suitable for cross-validation and for triangulating temporal trends, while keeping the focus on forest and grassland commons as the most policy-relevant categories for Odisha (Table 2).

TABLE 2. VARIABLE MAPPING ACROSS CENSUS VILLAGE DIRECTORY AND MODIS LAND USE /LAND COVER DATA

Unified category	Variables from the census village directory 2011	Variables from the census village directory 2001	Variable from MODIS land use land cover data
Forest	Forest area	Forest area	Class 4 (deciduous broadleaf, canopy > 2 m, cover > 60%) + Class 5 (mixed deciduous/evergreen, canopy > 2 m, cover > 60%)+ Class 8 (woody savanna, canopy > 2 m, cover 30–60%)
Grazing and pastureland	Culturable Waste Land Area + Permanent Pastures and Other Grazing Land Area	Culturable waste (including *gauchar* and groves) area	Class 9 (savanna, canopy > 2 m, cover 10–30%) + Class 10 (Grassland)

Data processing followed a consistent annual pipeline for each village: select villages that met the multi-source match; extract yearly MODIS land-cover data; compute class-wise pixel area; convert class areas to the two unified commons categories using the crosswalk; and assemble a time series of commons area per village. Temporal analysis estimates within-village and within-district trends and inflection points across 2001–2022, while spatial analysis characterises the geography of gains and losses. Validation leverages Census aggregates at two anchors (2001 and 2011) to benchmark MODIS-derived areas. At the state level, MODIS forest area is lower than Census in 2001 (−39%) and closer in 2011 (−11%), whereas MODIS grassland area is higher than Census in 2001 (+38%) and modestly higher in 2011 (+11%). These divergences were expected, given definitional and sensor differences, and are used diagnostically, not normatively, to gauge directionally consistent change rather than to impose absolute agreement (Table 3).

TABLE 3. DATA VALIDATION ACROSS CENSUS VILLAGE DIRECTORY AND MODIS

Year	Commons category	Census Area (sq. Km)	MODIS Area (sq. Km)	Percentage difference (compared to census)
2001	Forest	13959	8467	-39
2001	Grassland	11376	15637	38
2011	Forest	14466	12809	-11
2011	Grassland	11841	13166	11

To summarise net landscape dynamism at policy-relevant scales, the study computed a district-level "dynamism index," defined as the ratio of total commons area transiting between categories (sum of gains and losses) to total district area over the study period (Equation 1). This scale-free indicator highlights districts where commons are most fluid—whether due to degradation, recovery, or reclassification dynamics—and supports prioritisation for further investigation and intervention. Trend and change products (village-level time series, district-level volatility maps) together provide an evidence base for routine monitoring of commons in a state where official records do not directly encode "common property" and where on-ground diversion or encroachment can outpace updates to administrative ledgers.

$$Dynamism\ Index\ = \frac{\Sigma\,(Area\ gained_{i} + Area\ lost_{i})\,from\ i{=}1\ to\ n}{Total\ district\ area} \quad \text{Equation-1}$$

The schematic workflow of data analysis is presented in Figure 1 below:

FIGURE 1. THE DATA ANALYSIS WORKFLOW

III

RESULTS

3.1 Total area under commons

The total area under commons for the state of Odisha showed a modest increase of 4.5 per cent (1,097.79 square kilometres) from 23,922.53 square kilometres in 2001 to 25,020.32 square kilometres in 2022 (Figure 2). The lowest area under commons was estimated in 2003 (23,335.11 square kilometres), resulting from the maximum year-on-year decrease of 3.2 per cent from 2002 (Figure 3). The total area rose through the next decade to a peak in 2014 (26,337.30 square kilometres) before easing and settling near the 2022 level. The maximum year-on-year increase of 3.4 per cent was observed in 2008 (Figure 3). Overall, the total area under commons in Odisha has recorded a long-term increase, punctuated by short-term fluctuations.

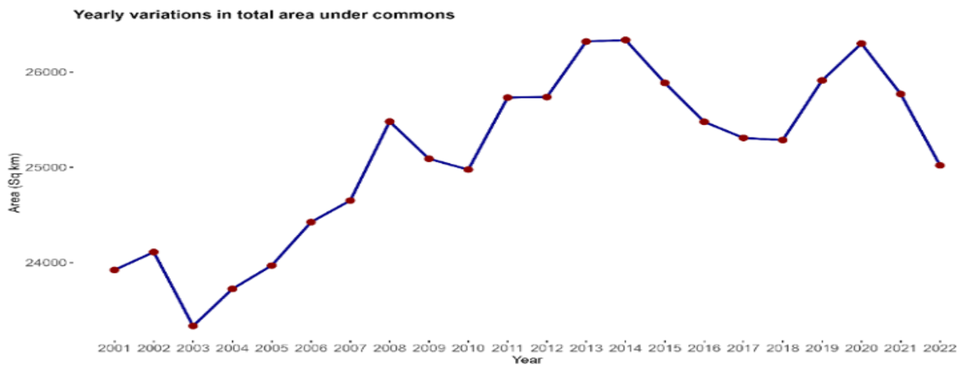

FIGURE 2. YEARLY VARIATIONS IN TOTAL AREA UNDER COMMONS

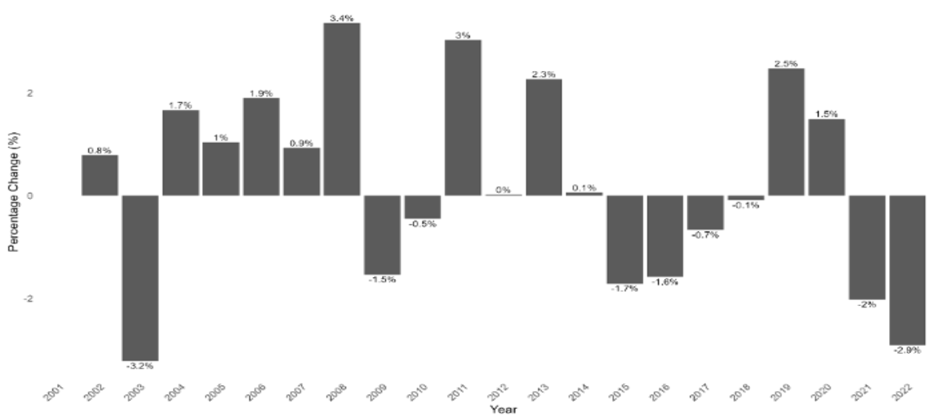

FIGURE 3. PERCENTAGE YEAR-ON-YEAR VARIATIONS IN TOTAL AREA UNDER COMMONS

3.2 District-level dynamism

Across Odisha's 30 districts, the commons dynamism index showed major heterogeneity (Figure 4). The value of the index ranged from 0.0048 in Jagatsinghpur to 0.320 in Kandhamal (mean ± SD = 0.099 ± 0.084). The distribution is right-skewed with a small set of districts exhibiting very high dynamism, while many others cluster at low to moderate levels. The upper quartile (≥0.141) is dominated by the forest- and highland belt: Kandhamal (0.320), Rayagada (0.295), Gajapati (0.246), Baudh (0.186), Anugul (0.183), Malkangiri (0.179), Debagarh (0.158), and Sundargarh (0.141) with a typical (median) value around 0.185. In contrast, the lower quartile (≤0.0398) is concentrated in the coastal and intensively settled plains, Subarnapur (0.039), Jajapur (0.027), Cuttack (0.026), Bargarh (0.024), Baleshwar (0.017), Bhadrak (0.0147), Kendrapara (0.0125), and Jagatsinghpur (0.0048) with a typical value near 0.021. Our analysis showed that dynamism is highest in the central-southern, forested, and mining-affected districts, and lowest along the coastal plain and in stabilised agrarian districts.

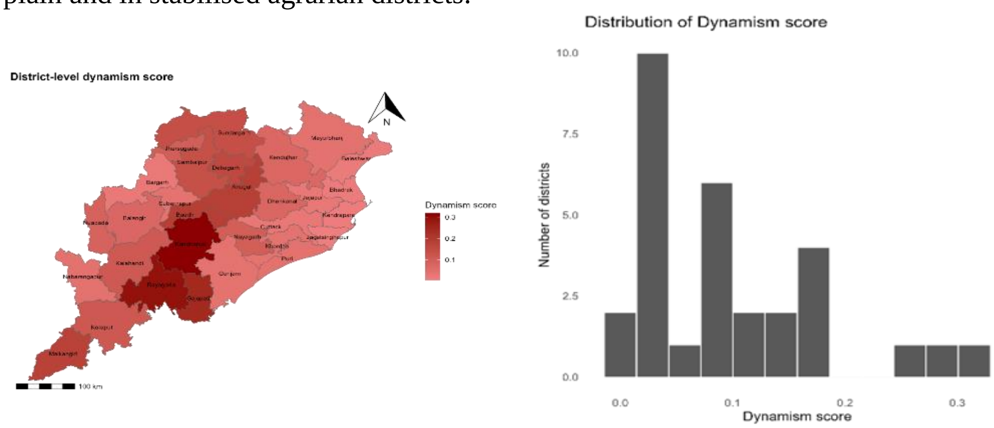

FIGURE 4. DISTRICT-LEVEL DYNAMISM SCORE FOR TOTAL CHANGE IN AREA UNDER COMMONS. A: SPATIAL SPREAD, B: DISTRIBUTION

3.3 Village-level changes in area under commons

Our analysis of village-level changes in total area under commons showed that the area decreased in 4858 (11.1 per cent of the total studied villages), increased in 6445 (14.8% of the total studied villages), and remained the same in 32314 (74.1% of the total studied villages). The spatial spread of these changes mirrored the patterns observed in the dynamism score. Rayagada district had the highest share of villages showing a change in area, with 34.1 per cent increasing and 5.43 per cent decreasing (Figures 5 and 6).

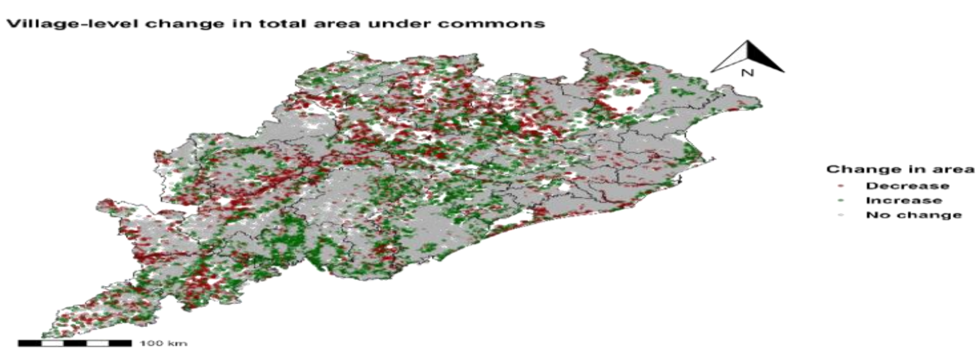

FIGURE 5. VILLAGE-LEVEL STATUS OF COMMONS FROM 2001 TO 2022

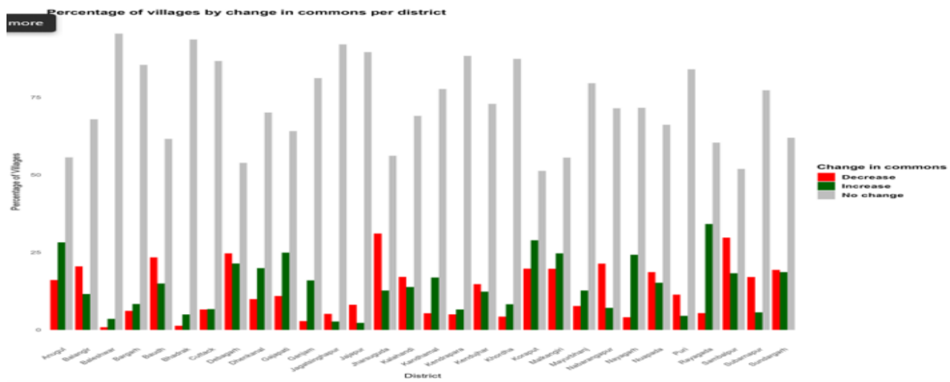

FIGURE 6. PERCENTAGES OF VILLAGE WITH INCREASE, DECREASE, OR NO CHANGES IN THE AREA UNDER COMMONS

IV

DISCUSSION

Our study develops a one-of-a-kind methodological workflow for the granular mapping of the status of common areas. Using remote sensing data products rooted in biophysical characterisation and administratively collected records of land categorisation, the workflow can track the status of ecological commons at the village, district, and state levels. The granular mapping highlights the significant spatial heterogeneity that exists throughout the state in the performance of commons. This study's major contribution lies in demonstrating how village-level, longitudinal mapping can generate actionable insights for conservation and management. The village-level estimates build upon prior state- or district-level estimates, demonstrating the feasibility of aggregating data from villages to the state level. The enhanced granularity can enable both within-village change detection and systematic cross-validation at the village and district levels.

Such granular mapping holds significance for two reasons. First, village-level estimates reveal heterogeneity masked in coarser aggregates. We identify three regimes: loss, gain, and stability. Most villages remained unchanged between 2001 and 2022; yet, a meaningful share registered losses, while a comparable share experienced gains. These shifts are spatially uneven, pointing to localised drivers and the value of sub-district monitoring. The spatial distribution of dynamism reveals heterogeneity that exists in terms of commons conservation and degradation. Districts such as Rayagada simultaneously host the highest shares of villages with increases and the highest shares with decreases, indicating spatial juxtaposition of recovery and decline. Such juxtaposition argues against one-size-fits-all prescriptions and underscores the need for micro-targeted strategies within the same administrative unit. Second, the approach makes it feasible to identify hotspots of "dynamism" where conservation or restoration returns are likely to be highest, while also flagging “cold spots” of persistent degradation that may require institutional rather than purely ecological remedies.

Methodologically, the study’s crosswalk, mapping “forest commons” to MODIS deciduous, mixed, and woody savanna classes and Census forest area, and “grazing/grassland commons” to MODIS savanna and grassland classes and Census pasture and culturable waste, aligns biophysical characterisation with legal-administrative categories. This harmonisation is essential because commons are rarely recognised as a distinct land-use class in official statistics; the crosswalk builds a workable bridge between ecological form and tenure function. The dual-source strategy, in turn, enables the triangulation of levels and trends, thereby increasing confidence in temporal inferences. The processing workflow provides a replicable template for other states.

The study findings support the idea that village commons are people-and-nature systems that function best when rules are tailored to local conditions and the community actively manages them (Ostrom, 1990; Delgado-Serrano and Ramos, 2015; Meinzen-Dick et al., 2023). Granular maps enable administrators and communities to tailor rules to local contexts, such as rotational grazing and seasonal closures in villages, targeted enrichment planting where woody cover is thinning, and protection of regenerating patches where gains are emerging. When paired with simple monitoring dashboards at the gram panchayat level, village-scale trajectories can be turned into routine “signals” for action, lowering the transaction costs of adaptive management.

The data also create a practical basis for aligning conservation with rights and livelihoods. Studies show that shrinking access to commons can disproportionately increase women’s time burdens and constrain participation in collective decision-making, revealing the gendered costs of commons decline (Sahoo and Swain, 2013). Village-level trajectories enable a focus on Forest Rights Act (FRA) implementation and community forest resource planning in areas where losses are recent and potentially reversible. In districts where mining has transformed landscapes, village-scale loss maps would help prioritise ecological restoration, compensation, and cumulative impact assessments (Rout, 2023). In western Odisha, where migration has intensified under agrarian stress, ecological interventions and social protection need to be co-designed (Pathak et al., 2018). These alignments are consistent with work emphasising the ecosystem services of forests for food security and welfare (Place et al., 2021) and with Indian debates on the contribution and crisis of rural common property resources (Jodha, 1990).

From a knowledge perspective, the central claim is not that medium-resolution remote sensing can perfectly identify tenure-defined “commons,” but that, with a rigorous crosswalk and validation anchors, it can identify ecologically equivalent spaces that typically coincide with community-used forests and grasslands in Odisha. This distinction is crucial for governance because many failures stem from the misclassification of community-used lands as “wastelands” or state property, thereby facilitating diversion and enclosure (Jodha, 1990; Lele et al., 2013). The present maps therefore serve as both a conservation instrument and a diagnostic of institutional fit: where ecological signals of commons persist but rights recognition is weak, tenure reform and rule-making are likely to be binding constraints; where rights are recognised but degradation advances, investment and rule enforcement are the priorities.

Finally, the distribution of gains and losses invites a conservation strategy that is both place-based and time-sensitive. In districts like Rayagada, where villages with increases cluster alongside villages with declines, coordinated landscape approaches could stabilise gains and buffer losses by focusing on ecological corridors, ridge–valley connectivity, and rules that manage extraction across village boundaries. Conversely, in districts with mostly stable commons, vigilance and low-cost monitoring may be more valuable than heavy interventions. The core management insight is that granular mapping turns “commons conservation” from an undifferentiated mandate into a portfolio of locally tailored, empirically justified actions.

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