Conservation effectiveness across state and community forests: the case of Jaintia Hills, Meghalaya, India

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Despite decades of concerted global conservation efforts, biodiversity loss continues unabated, making it important to assess the effectiveness of conservation approaches. Using forest cover as a proxy for conservation effectiveness, we analysed land-use and land-cover changes across a community and a state forest of Jaintia Hills, Meghalaya, India. Forest losses in the community lands (77.94 sq. km) were higher compared to the state forest (11.48 sq. km) between 1994 and 2014, and were driven by mining, industry, plantations and agriculture. We examined the role of policies and institutional arrangements as larger drivers of forest change within the context of conservation effectiveness.

Keywords: Community forest, conservation effectiveness, forest change, protected areas.

ASSESSING the success of conservation efforts is becoming increasingly vital because species extinction rates are reaching alarming levels and funding for conservation is limited. The global response to arrest biodiversity loss has been either through creating state-led protected areas (PAs)[1], or by partnering with local communities and linking their livelihoods to conservation goals under community-based conservation (CBC) approaches[2]. While PAs have been largely successful in meeting their primary goal of preventing habitat and species loss[3], the multiplicity of goals in CBC makes its evaluation difficult[4]. However, the decentralized model of CBC has been found to reduce management cost[5], ensure social justice as well as improve livelihood and income of the communities[6]. Yet, the fate of forest habitat and biodiversity within community forests is not clear[7]. Given that PAs occupy a small proportion of the forest areas but have received disproportionate conservation attention[3], it is critical to understand how forests beyond PAs change over time. However, landscape-scale studies on forest change across different conservation and management regimes are few[8], particularly for the hilly regions of northeast India where 50–90% of the forests are under direct or indirect management of the communities[9].

In Meghalaya, a Sixth Schedule state in NE India, over 90% of the forests are under direct or de-facto control of the communities[10]. They are managed by 'traditional institutions' (TIs), organized at village level and recognized by the Indian Constitution[11]. The forests provide livelihood and are also culturally important for the communities[12]. During the last three decades Meghalaya has experienced a sudden increase in mining and industrialization, even within the forest areas[13]. Therefore, it is critical to evaluate the impact of such developmental changes on the forests, since their depletion can severely endanger biodiversity[14].

Although several studies have looked at the influence of industrial expansion on land-use and land-cover (LULC) change[13,15], little is known about their impact on forests across management and ownership regimes[16]. Using forest cover as a proxy for conservation effectiveness[17], we (1) examine the patterns, rates and drivers of LULC change, particularly forest cover, across a state and a community forest over 20 years and (2) discuss the role of forest management institutions and policies in mediating LULC changes across forest management regimes.

Study area and methods

Study area

The study was conducted in the Jaintia Hills Autonomous District Council (JHADC) (25.173781–26.129416°N, 89.808117–92.842091°E), Meghalaya, India (Figure 1). A total of 2546 sq. km forest area has been recorded in the JHADC[9], of which 311.22 sq. km (~12%) declared as Reserve Forests, is under the state management. The remaining 2234.78 sq. km area (~88%) of forests is under the control of the communities and is administered at two levels: *elaka* (cluster of villages) headed by a *doloi* and *chnong* (village) headed by *waheh chnong*.

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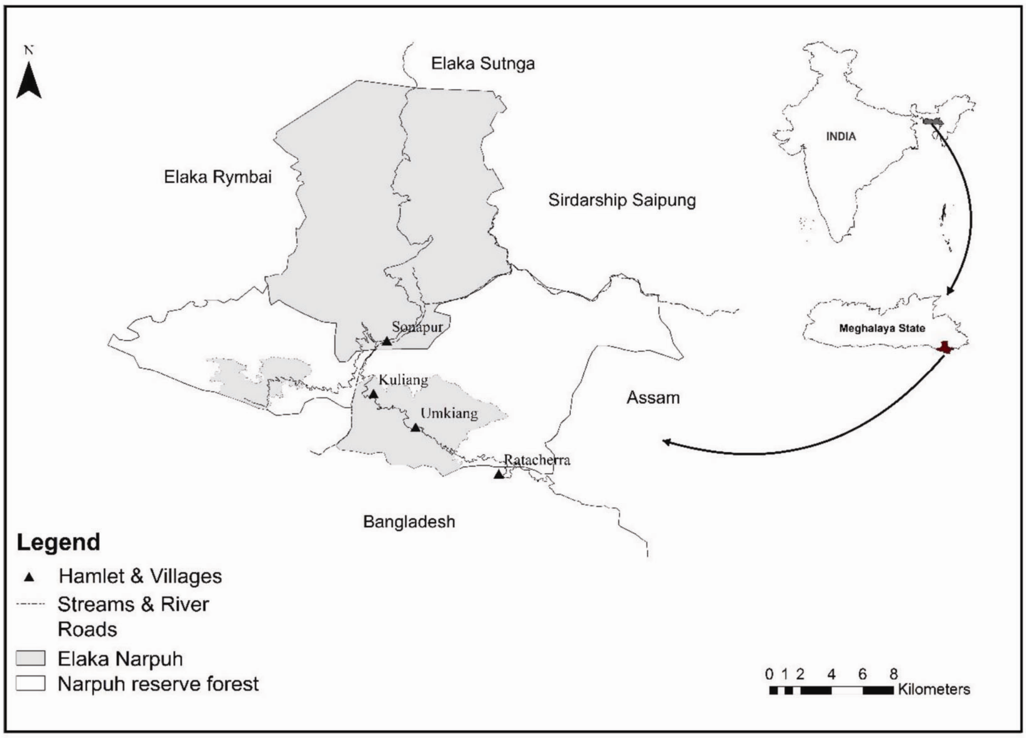

Figure 1. Map of the study area.

There are 18 *elakas* in JHADC, and their size and the number of villages governed within each *elaka* vary greatly.

The LULC study was carried out across 231.82 sq. km of community-controlled *elaka* Narpuh (henceforth *elaka*) spread across 25 villages and three localities (smaller than a revenue village) and 169.64 sq. km of state-controlled Narpuh Reserve Forest (henceforth reserve). Both the *elaka* and the reserve are situated on the southern escarpment of the Meghalaya plateau, which extends from east to west, and are located within similar altitudinal, soil, physiography, vegetation and forest characteristics. Culturally, both the sites are dominated by the Pnar (also known as Jaintia) tribal community. The altitude of the area spans roughly from 20 to 750 m with a warm and wet summer (April–October) and cold and dry winter (November–March). Bulk of the precipitation occurs between April and September, when it receives 5000–8000 mm of rain. The *elaka* and reserve, which include some of the last remaining low-elevation dense evergreen forest patches of Meghalaya, are rich in floral and faunal biodiversity[18]. The forests are also critical watersheds for many important rivers of Meghalaya and Assam in India, and Bangladesh.

Land-use and land-cover classification

Three multispectral remotely sensed images from Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) sensors dated 7 January 1994, 18 January 2003 and 19 February 2014 respectively, were acquired. January and February are the driest periods in the landscape and thus provide maximum contrast between the vegetation types. The red, blue, green, near infrared and short-wave infrared bands used in this study have a narrow wavelength in the OLI data of Landsat 8 compared to data from TM and ETM+ sensors of previous Landsat series. However, in an extensive review of the potential and capabilities of the OLI sensors of Landsat 8, authors have concluded that both the OLI spectral bands remain broadly comparable to the Landsat 7 ETM+ bands[19–21]. Therefore, many recent studies[22–24] have used data from OLI, ETM+ and TM sensors to monitor and study land-cover change across space and time, adopting methods similar to this study.

We did not carry out any atmospheric correction because of the following reasons: (1) We used the maximum likelihood classifier for image classification, whereby training samples were obtained from the same image[25]. (2) We followed the 'post-classification' technique for change detection[26], whereby we compared the resulting maps from the three images, each classified individually, to identify the changes[27]. The images were geometrically corrected using ground control points (GCPs).

In order to prepare the LULC maps, seven LULC classes were identified, based on extensive ground survey of the landscape. They were: (1) dense forest (old-growth late successional evergreen forests with canopy cover >50%); (2) degraded forest (secondary forests at various stages of succession with canopy cover between 20% and 50%); (3) plantation and agriculture (PAG) (swidden farms, betel-nut plantations and orchards); (4) open areas (primarily active and abandoned open cast limestone mines along with granite quarries and land cleared for local use such as plantations, farming or building a house, etc. The latter two categories of land clearing happen at a much smaller scale); (5) Water; (6) settlements (built-up area) and (7) Industry (cement-manufacturing units). Field reference points to classify the present LULC classes were collected by the first author, who has been working in the field site since 2011 and has first hand knowledge about the landscape and landscape features.

Using these categories, supervised classification of the data using the 'maximum likelihood classifier' algorithm was carried out with ground-truthing points collected in the field during January–April 2013. Histograms of the training samples for each LULC category were plotted to check the normality of the data. All categories except 'water' were normally distributed.

All the data used in this study were cloud-free. Minor post-classification editing and recoding were carried out for the topographic shadows and confusion areas in order to improve the accuracy of the classification. The classification accuracy of the 2014 image was evaluated through confusion matrix[28] using 320 ground-truthed data covering the entire study area, collected with a global positioning system in 2013 and 2014. The 2014 classification along with field surveys about the past land use from the locals and from historical records of the State Forest Department were used in guiding the supervised classifications for the 1994 and 2003 images. LULC change analysis was prepared using post-classification change detection technique through the matrix tool available in ERDAS Imagine.

Forest boundaries and change analysis

The boundary of the reserve was sourced from the Meghalaya Forest Department. The *elaka* boundary, comprising mostly natural formations such as streams, rivers and ridges, was demarcated in consultation with the respective village and the *elaka* council members[29]. The area under each LULC class was extracted for the *elaka* and reserve for comparison. Relative proportions of each class with respect to the total area of the *elaka* and reserve were calculated for all the three years. Rate of change was calculated for the two time-periods across each class for the *elaka* and the reserve using the formula, $A2–A1/t2–t1$, where $A1$ and $A2$ are the areas for each class at time periods $t1$ and $t2$ respectively[30,31].

Results

The overall accuracy estimate of the classification was 85.63%, with a kappa statistic value of 0.83. The error matrix with the users' and producer's accuracies is presented in Table S1 (see Supplementary Material online). The area under degraded forest, open areas, PAG and industry recorded an increase, while dense forests decreased across both the reserve and *elaka* during 1994–2003 and 2003–14. Except water, which did not show much variation over the years (Figure 2), the magnitude of changes across all classes was higher in the *elaka*, particularly between 2003 and 2014, compared to the reserve.

Patterns of LULC change

The LULC patterns were similar across the *elaka* and reserve in 1994 and 2003, with dense forest occupying the highest proportion followed by degraded forests (Figure 3). In 2014, however, while the forests occupied

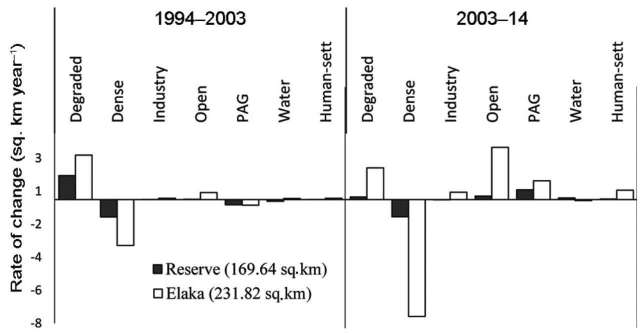

Figure 2. Rate of change in reserve and elaka between 1994–2003 and 2003–14 across the following classes: Degraded forest (degraded), dense forests (dense), industry, open areas (open), Plantation and agriculture (PAG), water and human settlement (human-sett). Negative trends indicate loss, while positive indicate gain.

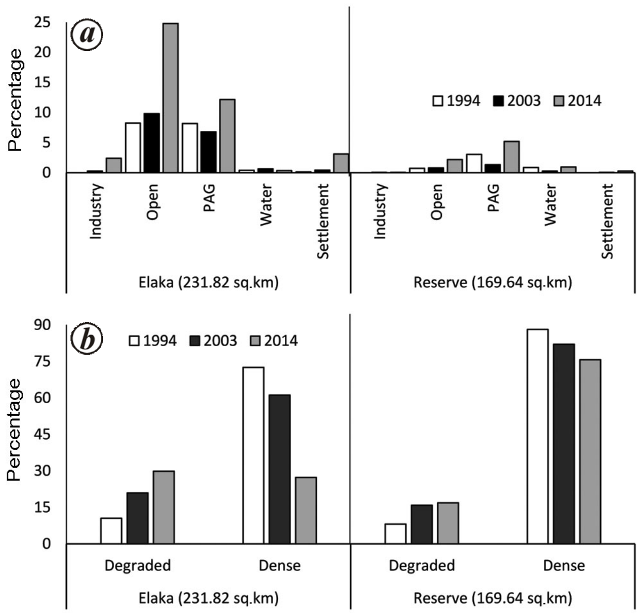

Figure 3. Relative percentage of (***a***) non-forest classes (industry, open areas (open), plantation and agriculture (PAG), water and human settlement (settlement)) and (***b***) Forest classes (degraded forest (degraded), dense forest (dense)) across *elaka* and reserve in 1994, 2003 and 2014.

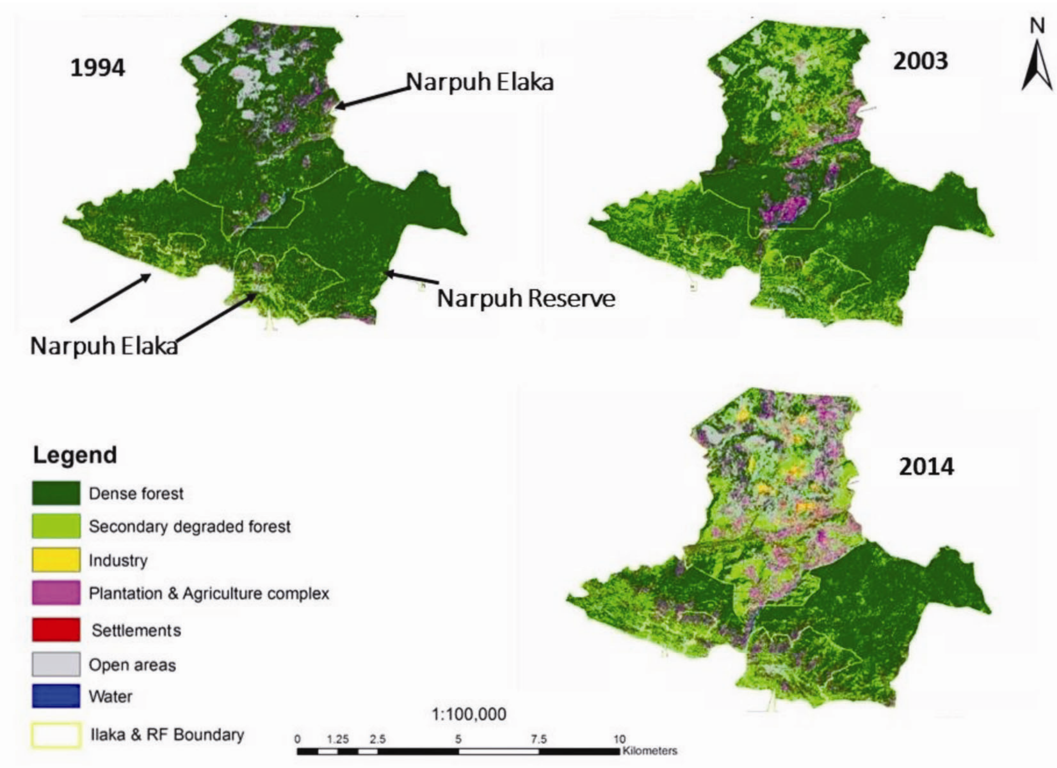

Figure 4. Supervised classification-based land-use and land-cover maps of 1994, 2003 and 2014.

Table 1. Net gain and loss in the key land-use and land-cover (LULC) categories in the *elaka* between 1994 and 2014

	Net gain/loss	
LULC class	*Elaka* (231.82 sq. km)	Reserve (169.64 sq. km)
Dense forest	–102.6	–20.9
Degraded forest	45.3	14.7
Open areas	38.6	2.4
Industry	5.5	0.0
Plantation and agriculture	9.5	3.6
Human settlement	5.4	0.1

All values in sq. km. Negative values indicate loss and positive values gain. Figures in parenthesis indicate the total extent of *elaka* and reserve respectively.

over 80% (155.26 sq. km) of the reserve, the proportion of forests within the *elaka* was reduced to 57.21% (132.62 sq. km). The remaining area was occupied by industries, mining, PAG and human settlement (Figure 4). 'Human settlement' class in the *elaka*, which recorded a marginal increase of 0.70 sq. km between 1994 and 2003, added 6.25 sq. km between 2003 and 2014, a 7.5 times increase compared to 2003. Such a rise in human-settlement area corresponds to the exponential increase (3 and 9 times respectively) in the open and the industrial classes between 2003 and 2014 (Table 1).

Between 1994 and 2014 the reserve lost 20.92 sq. km of dense forest, while the degraded forests more than doubled from 13.62 (8.12%) to 28.33 sq. km (16.9%). The class PAG, however, initially fell from 5.10 sq. km (3.04%) in 1994 to 2.21 sq. km (1.31%) in 2003, but recorded a steep rise to 8.70 sq. km (5.19%) in 2014. There was not much change seen in the human settlement area in the last 20 years in the reserve (Table 1).

Rate of LULC change across state and community areas

The rate of LULC change was higher in the *elaka* compared to the reserve across all classes during both 1994–2003 and 2003–14. In the *elaka*, with the exception of the 'degraded forest', the rate of change across all the LULC classes was higher in 2003–14 compared to 1994–2003 (Figure 2). Similarly, in the reserve, the rate of change was higher during 2003–14 for all classes, except the degraded and dense forests, which did not show much change. This indicates that the changes in landscape have intensified during the last 11 years and have affected the *elaka* more than the reserve.

Drivers of change across state and community forests

The change matrix analysis (Tables 2 and 3) shows that large areas of dense and degraded forests have been

Table 2. Transition matrix for Narpuh *elaka* across 2003–14 (all values in sq. km)

LULC class	Water body	Industry	Settlements	Open areas	Plantation and agriculture	Degraded forest	Dense forest	Total 2003
Water body	0.09	0.25	0.10	0.93	0.00	0.10	0.03	1.51
Industry	0.00	0.23	0.17	0.65	0.11	0.23	0.09	1.47
Settlements	0.01	0.08	0.22	0.39	0.02	0.17	0.07	0.96
Open areas	0.11	1.52	1.37	11.84	1.47	5.00	1.39	22.69
Plantation and agriculture	0.01	0.26	0.39	3.19	4.95	5.78	1.12	15.70
Degraded forest	0.22	**1.32**	**1.27**	**13.55**	8.12	15.07	8.71	48.26
Dense forest	0.36	**1.89**	**3.68**	**26.92**	**13.51**	**42.99**	51.87	141.22
Total 2014	0.80	5.54	7.21	57.47	28.17	69.34	63.28	231.82

Changes in the dense and degraded forest classes to other classes are shown in bold.

Table 3. LULC transition matrix for Narpuh Reserve Forest across 2003–14 (all values in sq. km)

LULC class	Water body	Industry	Settlements	Open areas	Plantation and agriculture	Degraded forest	Dense forest	Total 2003
Water body	0.23	0.00	0.03	0.15	0.00	0.06	0.02	0.49
Industry	0.03	0.00	0.01	0.02	0.00	0.01	0.01	0.07
Settlements	0.00	0.00	0.00	0.02	0.00	0.03	0.01	0.06
Open areas	0.08	0.01	0.05	0.44	0.05	0.55	0.18	1.35
Plantation and agriculture	0.01	0.00	0.01	0.03	0.77	0.73	0.68	2.22
Degraded forest	0.60	**0.00**	**0.16**	**1.19**	1.79	8.89	14.16	26.79
Dense forest	0.64	**0.00**	**0.20**	**1.78**	**6.10**	**18.07**	111.88	138.66
Total 2014	1.59	0.01	0.45	3.63	8.70	28.33	126.93	169.64

Changes in the dense and degraded forest classes to other classes are shown in bold.

converted to non-forest use in the *elaka* between 2003 and 2014. A total of 40.5 sq. km of forest (27 sq. km dense and 13.5 sq. km degraded) was converted to open class as a result of land clearing carried out for open-cast limestone mining, swidden cultivation, cash crop and horticulture plantations in the *elaka*. During the same period (2003–14), about 22 sq. km of forest (13.51 sq. km dense and 8.12 sq. km degraded) was converted to PAG.

In comparison, the reserve lost 7.89 sq. km of forest (6.1 sq. km dense and 1.79 sq. km degraded) to PAG, while 2.97 sq. km (1.78 sq. km dense and 1.19 sq. km degraded) was converted to open areas between 2003 and 2014.

Discussion and conclusion

The LULC change analysis carried out over 20 years in Jaintia Hills showed that large areas of forests were lost to open limestone mining areas, industries and PAG in the *elaka*, with bulk of such loss occurring in the last 11 years. Comparatively, forest loss in the reserve was much lower, implying that in terms of preserving forest cover and preventing diversion of forest to non-forest use, the state-owned reserve might be more effective than the community-owned *elaka*. We discuss the local and large-scale drivers of high forest loss and LULC transformation across the state and community areas, and contextualize the results within the larger debate of conservation effectiveness.

Local drivers of forest loss

PAG was among the most important local drivers of forest loss in the landscape. A careful study of the change matrix (Tables 2 and 3) indicates a clear shift in the nature and dynamics of forest loss vis-à-vis PAG in the last 20 years. During 1994–2003, the rate of loss of dense forest was almost equal to the rate of increase in degraded forest. However during 2003–2014, across both the *elaka* and the reserve, the rate of dense forest loss was much higher than the rate of increase of degraded forest (Figure 2), indicating the irreversible nature of forest loss. Although unprecedented limestone mining and industrialization were the main drivers of such irreversible forest loss, PAG contributed to a loss of 7.89 sq. km of reserve and 21.63 sq. km of *elaka* forest (Tables 2 and 3) between 2003 and 2014. The traditional form of agriculture in the hilly landscape of Meghalaya is jhum (shifting) cultivation with an average fallow cycle of 7–11 years in Jaintia Hills (R. Goswami, unpublished data). According to Metzger[32], a slash-and-burn landscape is sustainable if the conversion of forest to agricultural may be compensated by forest regeneration in a way that primary and secondary forest reserves can be maintained over time.

During 1994–2003, the PAG growth rates were almost zero while the rates of dense forest loss and increase in degraded forest were identical, indicating maintenance of equilibrium in terms of the overall forest acreage. This indicates that the predominant jhum cultivation, carried out with longer fallow periods, was sustainable in nature which helped maintain the landscape in a 'steady-state condition'[33]. However, during the last decade, a rapid shift in the landscape from jhum to permanent cash crops, chiefly of areca nut (*Areca catechu*), might have driven the high growth rates in PAG. Areca nut, which has high demand in local and international market, is maintained as monoculture stands for 30–50 years, translating to irreversible loss of forests. This might be the reason for the increasing gap between rates of dense forest loss and degraded forest gains. Shift from food to cash crops has also been reported from other parts of Meghalaya during the last decade owing to increasing demands, better linkages to market, improvement in supply-chain networks and surface-transport infrastructure[34].

Meta-drivers of forest loss

The highest forest loss was driven by limestone mining and industries. The southern slopes of the Meghalaya plateau, where the study area is situated, contain rich reserves of high-grade limestone, ideal for cement manufacturing. However, the key trigger for the exponential increase in cement-based industries and limestone mining during the last decade was the North East Industrial Investment Promotion Policy (NEIIPP), passed and adopted in 1997 (Patricia Mukhim, pers. commun.)[35]. This policy eased regulations, created subsidies and provided tax benefits in order to promote industrial growth in NE India, which was perceived to be an underdeveloped region. Within the next decade seven large factories were set up in the *elaka*, thereby driving an exponential increase in the limestone demand which triggered large-scale mining (Figure 5). Such mining activities which destroy forests[16], and pollute the environment[36] not only affect species diversity and abundances[37] but are also known to impact biological processes such as dispersal, migration[38] and predation[39] by creating inhospitable habitat matrix within the remaining forest patches[40].

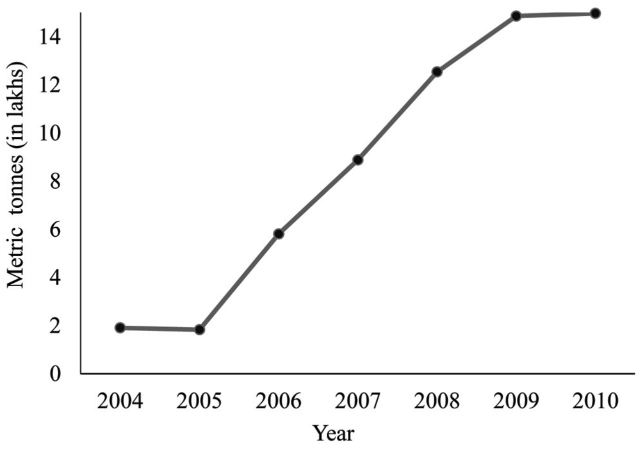

Figure 5. Limestone dispatched from Jaintia Hills between 2004 and 2010. (Source: Department of Mining & Geology, Government of Meghalaya.)

Forest loss and conservation effectiveness

Previous meta-analyses of forest cover-based conservation effectiveness report policy, market, remoteness of the area, human population density, developmental and economic pressures and institutional arrangements as key variables impacting the outcomes[8,16,41,42]. In this case variables such as remoteness, population density, market, developmental and economic pressures were equal across the *elaka* and the reserve, given that both are situated within the similar geopolitical landscape. However, since institutional arrangements (forest laws, regulations, forest management bodies and their interactions) varied across the *elaka* and the reserve, they need to be considered in order to explain the differences in forest loss and spread in mining.

In the reserve, in tune with the existing forest laws and regulations and local management priorities[18,43], the Forest Department has not permitted mining and industries within its boundaries but has allowed agricultural activities for the forest-dependent communities[44]. This explains the LULC patterns, changes and drivers within the reserve. In the *elaka*, however, the situation is more complex. Our preliminary observations from an ongoing study suggest confusion regarding the application of existing forest laws and regulations within the *elaka* and village forests. The retaining of JHADC, which maintains its own independent forest rules and regulations[45], even after attaining full statehood, adds another institutional layer to the prevailing confusion. Additionally, conflicts have been reported between the TIs, the Autonomous District Councils and the Forest Department regarding control and management of forests and its resources[46,47]. Such confusions, conflicts and presence of multiple institutions have been responsible for the poor management of community forests and might have facilitated the unregulated growth of mining and industries. Elsewhere in the NE too, political conflicts have been found to adversely impact management of forest resources and biodiversity conservation[48,49]. It is important to note that most of the mines and industries are set up through merely obtaining NOCs (no-objection certificates) from JHADC, *doloi* and waheh *chnongs* while bypassing mandatory forest and environmental clearances and regulatory checks[29]. A growth-friendly political dispensation along with the inability of the Forest Department to implement forest laws and regulations in the community forests might have aided and driven large-scale forest loss in the *elaka*.

The forest loss in the Narpuh landscape of Jaintia Hills is not an isolated case. Rather, it reflects the larger situation across Meghalaya as well as the entire tropics where high biodiversity overlaps with high natural wealth and poverty, where pressures and demand of rapid economic growth are often high. We suggest effective application of the existing forest regulations, acts and laws to all forest areas, irrespective of their tenure and ownership to arrest large-scale forest loss.

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ACKNOWLEDGEMENTS. The field work was supported by Rufford Small Grants and National Geographic Society. The first author thanks the Council for Scientific and Industrial Research, New Delhi for Senior Research Fellowship. We thank the Forest Department of Meghalaya, the *doloi* of the *elaka* Narpuh and village councils of Sonapyrdi, Umkiang and Lumshnong, Kong Patricia Mukhim, Arwat Challam and Bah H. H. Mohrmen for their help, advice and co-operation and Bah Roy Talang for assistance during the data collection. We also thank the two anonymous reviewers for their critical comments and inputs.

Received 26 January 2015; revised accepted 17 March 2016

doi: 10.18520/cs/v111/i2/380-387