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PARK IN THE PERIPHERY: LAND USE AND LAND COVER CHANGE AND FOREST FRAGMENTATION IN AND AROUND YANGOUPOKPI LOKCHAO WILDLIFE SANCTUARY, MANIPUR, INDIA

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Abstract

This study documents the spatio-temporal land use and land cover dynamics of Yangoupokpi Lokchao Wildlife Sanctuary (YLWLS) in Manipur, India. Landsat imageries at three points of time spanning 38 years (1978, 2000 and 2016) were taken into account. Supervised image classification techniques were employed. Fragstats software was used to derive five landscape metrics, namely, class area (*CA*), number of patches (*NP*), largest patch index (*LPI*), percentage of landscape (PLAND) and mean patch size (MPS), to quantitatively assess the level of landscape fragmentation in the YLWLS. Dense and moderately dense forests decreased markedly during 1978-2000 from 46.5% to 40% and 38% to 28% of the total geographical area, respectively. However, between 2000 and 2016, the sanctuary managed to gain 840 ha of dense forest through various afforestation activities. The overall change in YLWLS during 1978-2016 indicates a substantial transition of dense and moderately dense forests.

Key words

land use • land cover • fragmentation • wildlife sanctuary • buffer • Manipur • India

Introduction

Anthropogenic land use change drivers pose mammoth challenges to biodiversity losses (Kobayashi, Okada, & Mori, 2019; Dale, 1997) and are an urgent challenge for human society to proactively address (Tilman et al., 2017; Kobayashi et al., 2019). The magnitude and impact of human land use on earth's environment are poised to increase this century, as population and associated demands for food, fibre, and energy spiral (Walelign, Nielsen, & Jacobsen, 2019). "Despite existing environmental protections and management strategies, increased human land use is likely to further isolate protected areas" (Wilson, Sleeter, Sleeter, & Soulard, 2014), inhibiting landscape and biological connectivity (Fischer, 2007) and diminishing habitat quality (Sharma, 2019).

Land use and land cover change (LULCC), a major issue of global environment change, is particularly important in many of the world's mountain regions (Korner & Ohsawa, 2005). The processes that drive LULCC in mountain regions are complex, occur at various temporal and spatial scales and often require multiple method analysis to understand their drivers and impacts on the environment, landscapes and rural societies (Lambin & Meyfroidt, 2010).

Of all the human impacts on biodiversity, land use change has been singled out as the greatest immediate threat to terrestrial biodiversity because it results in fragmentation and loss of habitats (Vitousek, Mooney, Lubchenco, & Melillo, 1997; Sala et al., 2000; Jetz, Wilcove, & Dobson, 2007). This anthropogenic activity has variously led to the degradation of natural forest by altering forest landscape patterns, including forest patches (Onojeghuo & Blackburn, 2011), fragmentation of into small sizes (Tang, Wang, & Yao, 2008; Coops, White, & Scott 2004; Sharma, Robeson, Thapa, & Saikia, 2017) and the isolation of forest areas (Sharma & Roy, 2007).

Forest fragmentation is a dynamic process in which contiguous forest tracks are progressively subdivided into smaller isolated patches (Gibson, Collins, & Good, 1988), reduces intact forest cover areas, increases forest edges and isolates remaining patches in a forested landscape (Carranza, Hoyos, Frate, Acosta, & Cabido, 2015). It negatively affects ecosystems worldwide (Forman & Godron, 1986; Reed, Johnson-Barnard, & Baker, 1996; McGarigal, Cushman, & Ene, 2012), and therefore, is a matter of global concern in safeguarding valuable forest resources upon which the health and well-being of the entire planet depends (Rodrigues et al., 2004).

Today PAs face critical management challenges because of changing land use and land cover (LULC) types and variability of landscape contexts within and adjacent to park boundaries (Wang, Mitchell, Nugranad-Marzilli, Bonynge, Zhou, & Shriver, 2009). LULC change monitoring is difficult in several contexts and such equations are all the more challenging in certain contexts in peripheral locations and less accessible enclaves in north east India. Often border areas and hill areas are remote and inaccessible. Many interior areas of India, such as Arunachal Pradesh and Manipur suffer in terms of accessibility and are hardly monitored. Several border areas, abutting international borders that Indian states share with China, Bhutan and Myanmar present a difficult set of problems in the protection of biodiversity resources. The Yangoupokpi Lokchao Wildlife Sanctuary (YLWLS) is one such case. The YLWLS is located in the hill region bordering Myanmar. Such a location at the periphery of India has favoured it as a suitable hideout for groups of local militant outfits or undergrounds (UGs). This study analyses the spatial and temporal patterns of LULC in the YLWLS in India's north eastern state of Manipur.

Study Area

The YLWLS situated in Manipur belongs to the Indo-Malayan biodiversity region at the confluence of two major geographical zones, i.e. India and Myanmar (Fig. 1). The sanctuary was formally declared a Protected Area by the Government of India on 21st March 1989. The sanctuary is located in Tengnoupal sub-division under Chandel District of Manipur between 24°13′51″ N to 24°26′N latitude and 94°13′51″E to 94°23′51″E longitude at an altitude between 276 and 888 m. The total geographical area of the sanctuary is about 177 km^2 and it includes 14 forest villages that were allowed to remain within it by the State Forest Department. The people in the forest villages belong to different ethnic groups. The temperature of the sanctuary ranges from 4°C in January to 40°C in June with humidity ranging from 35% (during winter) to 80% (during the monsoon season).

The average annual temperature is 24.3°C., while the rainfall averages 2263 mm (2011-12). The forest types found within the sanctuary is mostly of Teak-Gurjan and tropical moist deciduous forest. The vegetation of the sanctuary is a combination of riverine and terrestrial ecosystems. The sanctuary is an abode of various flora and fauna which consist of seasonal migratory elephants from Myanmar and Hoolock-Gibbon, the only ape species found in India. The sanctuary supports 40 species of mammals, 65 species of birds, 27 species of reptiles, 6 species of amphibian, and 65 species of fishes. The population of important wild animals during 2012-2013 (Forest Department, Government

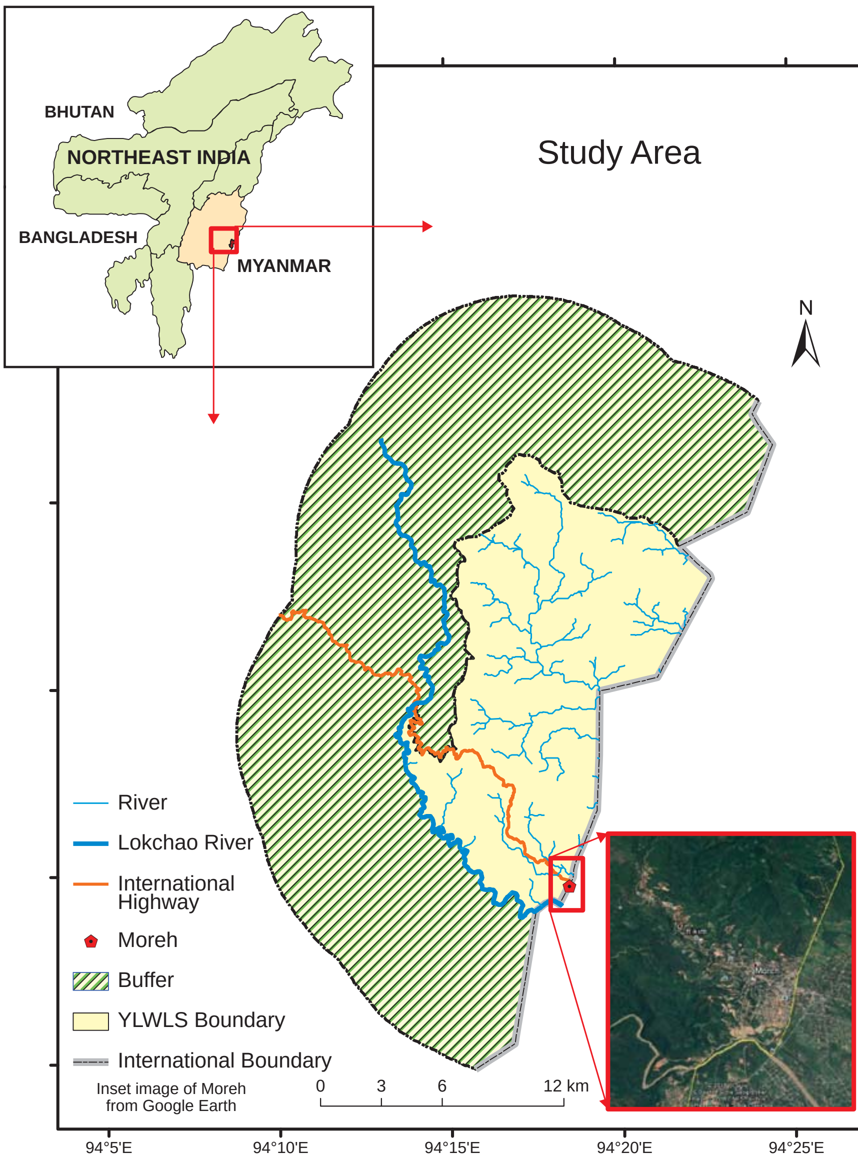

Figure 1. Study Area

of Manipur, Wildlife Wing, n.d.) included bears (10), Hoolock-Gibbon (51), Stump Tailed Macaque (20), Burmese Peafowl (20), Green Pigeon (164), Pangolin (102), wild boar (143), Sambar (10), leopard (10) and others.

The Government of India under the Environment Protection Rules 1986 notified an area of up to 7.8 km from the boundary of YLWLS in Manipur as the Yangoupokpi Lokchao Wildlife Sanctuary Eco-Sensitive Zone (ESZ). The extent of ESZ is 7.8 km from the boundary of YLWLS in all directions barring the east, as it shares the international boundary with Myanmar for 35 km in this direction. The area of the ESZ is 42,647 ha which serves as buffer area. The buffer area is an area of controlled and sustainable land use which separates the protected area from direct human pressure (Nepal & Weber, 1993). In this study the YLWLS and its buffer has been taken into consideration.

The YLWLS has been facing the problem of human interference. This can be attributed to the presence of settlements within the study area prior to its establishment as wildlife sanctuary. The local inhabitants are primarily dependent on the forest resources for sustenance and earning a living. They extract fuel-wood, pole-wood, charcoal and timber for domestic use as well as for commercial sale in the market. Shifting cultivation (locally known as *jhum* cultivation) is the only agricultural practice carried out by local inhabitants, wherein they cultivate rice for subsistence use (Tab. 1). The situation of settlements located within the protected area is hardly unique to Manipur and numerous forest villages in Assam (Sharma & Sarma, 2014) and scattered settlements in neighbouring Bhutan (Sharma et al., 2017) are located within PA boundaries.

Most of the villages located inside and in the fringe areas of YLWLS practice logging to generate income for their livelihood. Timber logging for commercial purposes and pole-wood extraction for domestic use were practiced well before the establishment of the sanctuary and still continues (Tab. 2).

Table 1. Households engaged in jhum cultivation in the forest villages.

Forest Villages			
Name of village	total households	jhuming households	percent
Satang	38	35	92.1
Kwatha	77	52	67.5
H.Mongjang	66	60	90.9
B.Bongjang	48	24	50.0
Govajang	35	22	62.9
Saikul	53	40	75.5
Nungkam	110	78	70.9

Table 2. Annual timber extraction by the forest villages (in cubic meters)

Forest village	Timber [m³]	Households engaged in logging [%]
S Khudengthabi	133	13.4
Kwatha Meitei	222	16.6
Langkhongching	85	37.5
Laibi Khunjao	437	28.0
Yangoupokpi	62	8.0
S. Moljhol	102	17.4
Govajang	176	27.3

Source: Field survey 2014-15. The timber is extracted from the YLWLS. Sample extractions were weighed using a hand held weighing scale and annual extraction was estimated based on discussions with the village respondents.

Data and Methods

The satellite images of Landsat MSS, ETM and OLI-TIRS covering YLWLS were obtained for 1978, 2000 and 2016 respectively from the United States Geological Survey (USGS). The cloud-free images between December and March were selected for the study (Tab. 3). The images were classified using supervised classification and the maximum likelihood algorithm in ERDAS Imagine 9.1. Four major land use land cover classes, namely, built-up, degraded forest, moderately dense forest and dense forest were identified to record the landscape characteristics of the study area (Tab. 4). Extensive ground truth verification using a handheld global positioning system (GPS) enabled the delineation of the various land use categories. The built-up class comprises of all cultural features whereas degraded forest includes abandoned jhum cultivation areas and barren lands. A household survey was conducted in the forest villages where information on jhum cultivation and timber extraction were collected during the field survey (2014-15) to supplement the LULC of the study area.

An accuracy assessment was performed for all the classified images of three different time periods. The assessment results of Kappa statistics of 92% for 1978, 85% for 2000 and 84% for 2016 and overall producer's and user's accuracies of land cover classification were satisfactory (Tab. 5).

The scheme of image processing and classification is shown as a flow chart (Fig. 2).

Fragstats 4.2 (http://www.umass.edu/landeco/research/fragstats/fragstats.html) was run to describe the characteristics of landscape and components of landscape mosaic of the study area. To analyze the level of fragmentation, Mean Patch Area (AREA *MN*), Largest Patch Index (*LPI*), Total Class Area (*CA*), Number of Patches (*NP*) and Percentage of Landscape (PLAND) metrices were used (Tab. 6).

Table 3. Landsat imageries used in the study

Path/Row	Acquired Date	Spacecraft	Sensor	Resolution [m]
145/43	13 December,1978	LANDSAT-3	MSS	60
135/43	17 March,2000	LANDSAT-7	ETM	30
135/43	18 February,2016	LANDSAT-8	OLI-TIRS	30

Source: United States Geological Survey (http://earthexplorer.usgs.gov/)

Table 4: Scheme of LULC classification used in the study

Sl. No.	Class	Description
1	Dense Forest	Includes forest with cover of more than 40% of canopy density
2	Moderate Forest	Includes forest with tree cover between 10 to 40% of canopy density
3	Degraded Forest	Includes forest with poor tree growth of mainly small and stunted trees with less than 10% canopy density. It also includes abandoned jhum fields
4	Built-up	It includes human-made surroundings including settlements

Based on the Forest Survey of India (FSI) classification scheme.

Table 5. Accuracy assessment of classifications

Classification	Overall accuracy	Producer's accuracy	User's accuracy	Kappa statistics
1978	92.03	85.30	87.00	0.88
2000	85.26	72.90	76.90	0.79
2016	84.06	72.25	77.15	0.77

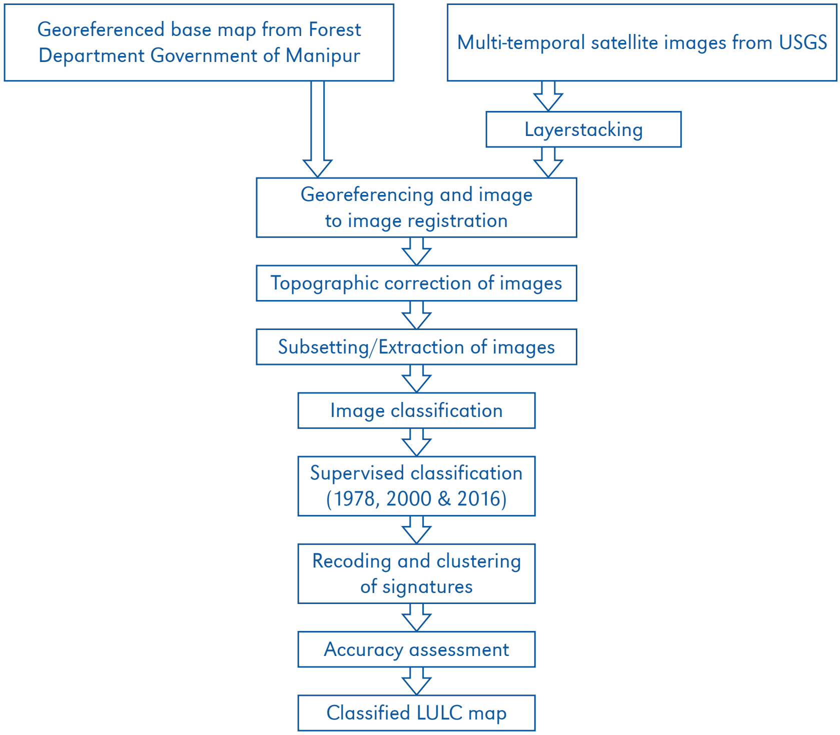

Figure 2. Schematic work-flow diagram

Table 6. Landscape metrics analyzed

Sl. No	Indicators	Formula	
1	Class Area (*CA*)	*CA* equals the sum of the area (m²) of all patches of the corresponding patch type divided by 10,000 to convert into hectares	$CA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{10.000}\right)$
2	Number of Patches (*NP*)	PN equals the total number of patches of corresponding patch type in landscape	$NP = ni$
3	Percentage of Landscape (PLAND)	PLAND is the percentage of landscape comprised of corresponding patch type denoted as *Pi*	$Pi = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$
4	Area Mean (AREA_*MN*)	Area Mean *MN* equals the sum, across all patches of the corresponding patch type, of the corresponding patch metrics values divided by the number of patches of the same type	$MN = \frac{\sum_{j=1}^{n} x_{ij}}{n_i}$
5	Largest Patch Index (*LPI*)	*LPI* equals the area (m²) of the largest patch in the landscape divided by total landscape area multiplied by 100	$LPI = \frac{\max(a_{ij})}{A}(100)$

Source: McGarigal et al., 2012

Results and discussion

The classified imagery clearly shows the status of land cover during the sanctuary's pre- and post-establishment years. The classified image shows the status of land cover of the ESZ or the buffer area of the sanctuary during 1978, 2000 and 2016 (Fig. 3).

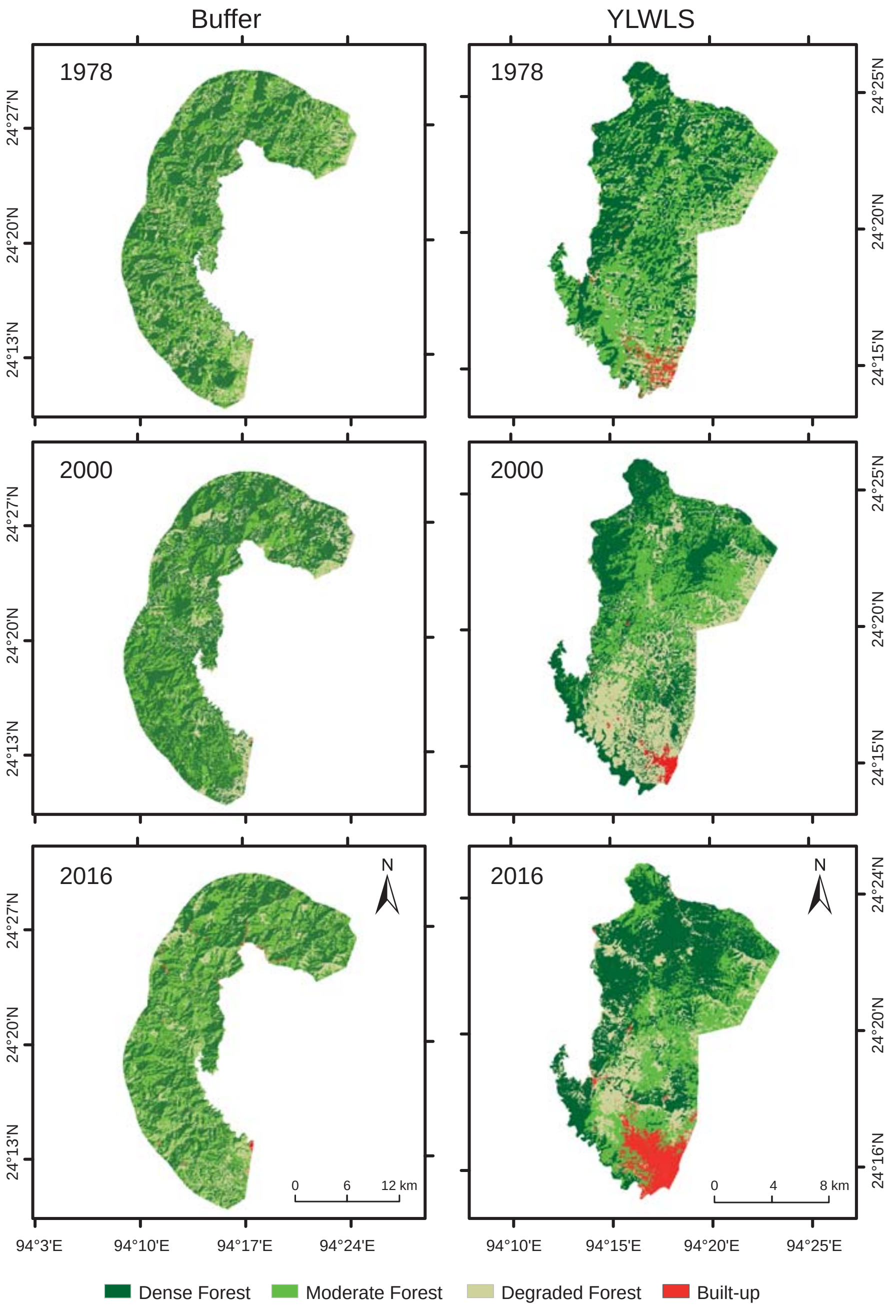

Figure 3. LULC of the YLWLS and its buffer

The classified images of YLWLS indicate that there were human disturbances in the sanctuary prior to its designation as a wildlife sanctuary in 1989. The dense forest was the most dominant land cover class in 1978 (8239.3 ha) followed by moderate forest (6732 ha) and degraded forest (2557.8 ha). The situation differed slightly in the buffer area, where dense forest remained the dominant land use category in all three periods. Built-up area was meagre in both cases, 180.3 ha in YLWLS and 45.7 ha in buffer area (Tab. 6). A gain of 3134.8 ha of dense forest in the buffer area between 1978 and 2000 accrued. On the other hand, there was a loss of 1015.6 ha of dense forest within the sanctuary (Tab. 7). This was mainly because of the introduction of an Eco-Sensitive Zone (ESZ) in 1986. A buffer was created around the sanctuary in order to minimise human activities in these areas. Confronted by the strict vigilance in the buffer zone, the people ceased their extractive activities in the area. Instead they shifted their activities from the buffer zone, to interior parts of YLWLS and this caused degradation within the park. Such extractive activities for about 15 years adversely affected the sanctuary.

Conditions in the YLWLS and its buffer improved partially during 2000-2016. Dense forests gained about 840 ha covering around 45% of the total area in 2016. This was, in all likelihood, the result of extensive afforestation efforts undertaken by the Forest Department (Sharma & Saikia, 2018; Sharma, 2019; Thong, Sahoo, Pebam, & Thangjam, 2019). 16 years is insufficient for dense forests to develop. Dense forest in this study refers to forests with 40% or more canopy cover (Tab. 2), based on the Forest Survey of India (FSI) classification scheme. Thus a change from moderate to dense forest implies only a slight improvement from a forest with a tree cover of 10-40% to one with > 40% tree cover. Tropical forests recover growth in a few decades, though species abundance never matches the old-growth forests (Rozendaal et al., 2019).

However, the increasing trend of built-up areas did not abate. The built-up area expanded almost four fold from 371.6 ha in 2000 to 1264.4 ha in 2016. The rise in built-up area occurred concurrently with a loss in degraded forest indicating that new built-up area occurred in hitherto degraded forest areas.

Timber extraction or logging is a widespread economic activity in the tropics (Alavalapati & Zarin, 2004). Harvesting of trees and its impact on the surrounding vegetation is known to affect animals also, particularly the medium and large-size vertebrates (Fredericksen & Fredericksen, 2002; Heydon & Bulloh, 1997). Most tree species in tropical rainforests require animals for seed dispersal (Ghazoul, 2005; Howe & Smallwood, 1982), the loss of animal vectors could exert significant effects on logged forests and forest undergrowth composition and diversity (Chapman & Chapman, 1995; Wright, 2003).

The local communities of the sanctuary depend mainly on jhum cultivation as their primary source of sustenance (Tab. 1). They cultivate mainly rice and vegetables like chilly, maize, pumpkin, etc. under jhum. The size of jhum land varies from family to family base on the size of family and also depending on the economic condition of the family. It is difficult to estimate the exact area of jhum land held by a family, since swidden is a dynamic land use practice wherein jhum plots change periodically (Padoch, Coffey, Mertz, Leisz, Fox, & Wadley, 2007; Saikia, 1998; Tawnenga, Shankar, & Tripathi, 1996). Thus, an average size of jhum land of a family is estimated based on their yields in case of rice production and by visual observation for other crops. Based on this estimation the average size of jhum land of a family in the YLWLS varied between 0.5 ha to 2 ha; in consonance with previous studies in neighbouring states of north east India (Tawnenga et al., 1996).

Increases in the duration of the rotational period of jhum land, enables the land to partially rejuvenate itself. 5-10 years fallow periods enable the growth of dense bamboo thickets and small trees (Raman, 2001). In YLWLS jhum plots lay fallow for seven to eight years during 2000-2016 and coupled with afforestation initiatives, aided its recovery. An improvement of the forests accrued as the Forest Department planted some 0.1 million different saplings annually in three different phases engaging 8-10 labourers for one week in every phase. The introduction of the National Rural Employment Guaranteed Scheme (NREGS) by the Government of India in 2006 which guaranteed 100 days wages to every household enabled the forest communities to become financially stable and thus reduce their total dependence on forest resources. This played a positive role in minimizing the degradation of the PA that occurred during the early years.

Landscape metrics and fragmentation

Analysis of such metrics, viz. *NP*, *LPI*, AREA_*MN*, *CA* and PLAND during 1978-2016 gives the characteristics of landscape fragmentation in the YLWLS and its buffer area (Tab. 8). The PLAND of both dense forest and moderate forest declined markedly during 1978-2000. At the same time gains in PLAND were recorded in degraded forests indicating that some dense or moderate forests may have got converted to degraded forest. For moderate forest the declining trend continued during 2000-2016 as well (Tab. 8).

In the buffer area a marginal improvement in moderate forests was seen along with a decline in dense forest. However, the marginal improvement in moderate forest of YLWLS could plausibly be the result of plantation activities undertaken by the Forest Department, Government of Manipur in the YLWLS. Similar outcomes were also found in Jigme Dorji National Park of Bhutan where PLAND of both dense and moderate forest had improved marginally during 2000-2015 due to the forest plantation policy undertaken in PAs of Bhutan (Sharma et al., 2017).

On the other hand, PLAND for degraded forest and built-up areas remarkably increased in YLWLS during the study period (1978-2016). PLAND of degraded forest increased from 14% in 1978 to 19% in 2016, whereas the PLAND for built-up which was only 1% in 1978 increased to 7% in 2016. Such developments require the attention from protection agencies to preserve the YLWLS landscape, so that built–up areas do not accelerate within the PA.

The *NP* of dense forest and degraded forest recorded a more than two-fold increase and while moderate forest and built-up areas registered a more than four-fold increase during 1978-2016 in both YLWLS and its buffer area. Such trends clearly indicate the existence of forest fragmentation in the study area. The increase in *NP* for built-up area during 2000-16 demonstrated that during this period very few new built-up areas had come up compared to the previous study period. However, the existing built-up areas had significantly expanded, thereby encroaching into the neighbouring forest areas. This is also evident by the increasing *LPI* for built-up areas. The dense forest had the largest *LPI* among the LULC classes, but during 1978-2000, the *LPI* for dense forest reduced considerably due to the increasing fragmentation activities like jhum cultivation etc. Anthropogenic activities contributed to the degradation of forest in the YLWLS and its buffer. Unfortunately, there are no official records or secondary data on the existence of such activities in many PAs in north east India. Better information is needed to analyse grazing pressure, selective logging and small scale agricultural encroachments in PAs in India (Reddy, Saranya, Jha, Dadhwal, & Murthy, 2017) and remote parts of north east India are often data-poor (Lele & Joshi, 2009). Encroachment and small holding logging are not activities which state forest departments are in a position to monitor and these are a grey and un-inventoried aspect. At the same time if anthropogenic disturbances can be kept within control tropical rainforests in north east India can survive (Shankar & Tripathi, 2017) given the conducive climatic conditions prevailing.

Table 7. Temporal characteristics of LULC in YLWLS and buffer area

Categories of land	1978				2000				2016			
	[ha]		[%]		[ha]		[%]		[ha]		[%]	
	YLWLS	Buffer	YLWLS	Buffer	YLWLS	Buffer	YLWLS	Buffer	YLWLS	Buffer	YLWLS	Buffer
Dense Forest	8,239.3	20,961.4	46.5	49.2	7,223.6	24,096.3	40.8	56.5	8,063.6	18,293.9	45.5	42.9
Moderate Forest	6,732.0	13,497.1	38.0	31.7	5,012.1	11,362.1	28.3	26.6	4,971.8	17,028.5	28.1	39.9
Degraded Forest	2,557.8	8,142.8	14.4	19.1	5,102.1	7,075.8	28.8	16.6	3,409.7	7,084.6	19.2	16.6
Built-up	180.4	45.7	1.1	0.1	371.6	112.8	2.1	0.3	1,264.4	239.9	7.2	0.6
Total	17,709.5	42,647.0	100.0	100.0	17,709.5	42,647.0	100.0	100.0	17,709.5	42,647.0	100.0	100.0

Table 8. Landscape metrics of YLWLS and Buffer

Metric	Year	Dense Forest		Moderate Forest		Degraded Forest		Built-up		Total	
		YLWLS	Buffer	YLWLS	Buffer	YLWLS	Buffer	YLWLS	Buffer	YLWLS	Buffer
CA [ha]	1978	8,239.3	20,961.4	6,732.0	13,497.1	2,558.4	8,142.8	180.8	45.7	17,709.5	42,647.0
	2000	7,224.6	24,096.3	5,012.1	11,362.1	5,102.1	7,075.8	372.6	112.8	17,709.5	42,647.0
	2016	8,064.6	18,293.9	4,972.8	17,028.5	3,410.7	7,084.6	1,264.4	239.9	17,709.5	42,647.0
PLAND [%]	1978	47.5	49.1	38.0	31.6	14.4	19.1	1.0	0.1	100.0	100.0
	2000	41.8	56.5	28.3	26.6	29.8	16.6	2.1	0.3	100.0	100.0
	2016	46.5	42.9	28.1	39.9	19.3	16.6	7.1	0.5	100.0	100.0
AREA_*MN*	1978	463	23.2	392.0	7.6	999.0	4.5	58.0	1.3		
	2000	5,427	12.7	1,996.0	2.8	2,136.0	1.7	235.0	0.3		
	2016	1,061	8.6	1,547.0	3.3	1,808.0	0.9	265.0	1.5		
NP	1978	18.8	905.0	17.2	1,763.0	3.6	1,817.0	3.1	35.0		
	2000	1.3	1,895.0	3.5	3,987.0	2.3	4,022.0	1.2	119.0		
	2016	8.6	2135.0	3.2	5,067.0	2.8	7,606.0	5.8	126.0		
LPI	1978	12.0	9.4	14.0	1.2	0.0	0.4	0.0	0.0		
	2000	6.0	18.7	10.0	0.5	9.0	0.8	0.0	0.0		
	2016	16.0	3.9	4.0	2.2	3.0	0.2	3.0	0.0		

CA: Core area; PLAND: Percentage of landscape, AREA_*MN*: Mean area;
NP: Number of patches and *LPI*: Largest patch index

Illicit activities like selling of fuelwood, charcoal, bamboo, pole-wood and timber prevalent in the YLWLS are no different from other wildlife sanctuaries in the region. The Nameri Tiger Reserve of Assam experienced a similar situation wherein fuelwood and timber were extracted from the forest and openly sold in the market and along the roadside (Saikia et al., 2013).

The sanctuary is managed under two ranges, one at Moreh and the second at Lokchao. Personal observation during fieldwork indicated that these Range Offices existed and operated merely on paper, and in reality they barely functioned. The forest village residents had become a challenge to the management authorities of the PA on account of their burgeoning resource utilisation activities inside the sanctuary. Additionally, the existence of militant outfits operating from within the park limits were a deterrent to proper policing of the YLWLS. Militant activity is problematic in some PAs in India, with the instance of Manas National Park during the 1990s (at that time a World Heritage Site) being the most severe case, wherein the fauna were virtually wiped out (Deb Roy & Jackson, 1993). Routine patrolling by forest personnel inside the YLWLS was hampered by the presence of militants. Often such militants were equipped with more sophisticated weapons and firepower than the forest guards. Lack of man-power, chronic law and order problem in the state and withdrawal of arms from the forest personnel are pertinent hindrances to the state Forest Department's ability to curb wildlife exploitation by poachers and smugglers alike. Generally changes in protected area quality in India are not always well documented (Ghosh-Harihar et al., 2019) and the YLWLS is no exception to such a scenario. The fact that it lies in a fairly remote location in India, bordering Myanmar has not helped matters.

Conclusion

This study assessed land cover change (1978-2016) in the YLWLS on the India-Myanmar border, using Landsat imageries. Overall changes in forest cover, as well as the fragmentation of forests within the park, were analyzed using landscape metrics. The study characterized LULC change and forest fragmentation as an agent of landscape change. LULCC analysis during the first two decades revealed a drastic change of land cover in the sanctuary where dense forest and moderate forest decreased remarkably, whereas degraded forest and built-up areas tended to increase. Nevertheless, during 2000-16 the study area experienced some positive changes with dense forest and degraded forest showing a gradual improvement in YLWLS. Landscape metrics indicate that during 1978-2000 extensive fragmentation of landscape occurred in the YLWLS and its buffer. This later reduced more particularly in case of dense forest, plausibly due to natural regeneration and forest plantation programs undertaken by the Forest Department, Government of Manipur. During a span of 38 years the spatial configuration and composition of the landscape of YLWLS underwent considerable transition. Fragmentation of forest environment is a serious issue. Indeed such pressures are a worldwide phenomena with a third of PAs being under intense human pressure from anthropogenic activities along their borders (Veldhuis et al., 2019). While India has strong legislation favouring conservation, the fact remains that conservation success and challenges vary across regions and often a lack of data is problematic; and monitoring eco-sensitive zones around protected areas is a goal to be achieved (Ghosh-Harihar et al., 2019). Thus, YLWLS requires immediate and effective management policies to deal with the issues at hand. However, there is no quick panacea given the presence of forest villages within the sanctuary. The inhabitants of these villages and their sustenance must be sustainably managed and livelihood options that reduce their dependence on the park must be explored.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

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