Recognizing the rapid expansion of rubber plantation – a threat to native forest in parts of northeast India

Kasturi Chakraborty[1,*], S. Sudhakar[1], K. K. Sarma[1], P. L. N. Raju[1] and Ashesh Kr. Das[2]

[1]North Eastern Space Applications Centre, Umiam 793 103, India
[2]Department of Ecology and Environmental Science, Assam University, Silchar 788 011, India

With the current trend of land use/land cover (LULC) change taking place globally, several parts of northeast India are also showing signs of change in LULC pattern leading to forest loss. This study focusses on the expansion of monoculture rubber plantation (*Hevea brasiliensis*) in selected sub-watersheds in northeast India, and distributed in parts of north Tripura, Mizoram and a major portion in the Karimganj district of Assam. Remote sensing and GIS technique has been used to map and analyse the extent of rubber plantation using temporal IRS LISS III satellite data from 1997 to 2013. It has been observed that rubber plantation increased from 4.47 sq. km to 28.42 sq. km in various parts of the study area. The expansion was more rapid during recent times, i.e. during 2010 to 2013. The plantation took place in dense forest, open forest and degraded forest areas. The spread of the plantation was also observed in one reserved forest located within the study area. There are several instances of negative impacts of rubber plantation expansion in Southeast Asia. Similar expansion of rubber plantation has been observed in northeast India as well. Further spread of rubber plantations in the region needs to be regulated to avoid conversion of dense and reserved forest areas by fostering use of mixed cropping methods instead of rubber monocultures, and by adopting more sustainable land use and management practices.

Keywords: Northeast India, Remote sensing and GIS, rubber plantation.

NATURAL rubber is a 'hot' commodity with worldwide utilization increasing annually at an average rate of 5.8% since 1900 (ref. 1). The area of rubber (*Hevea brasiliensis*) plantation is expected to increase four-fold by 2050 replacing secondary forests and land under shifting cultivation[2]. This transition of secondary forests and traditionally managed fields[3–5] to widespread rubber plantations may affect ecological processes[6] and energy balance and water fluxes[7–11]. The single-species plantations are thought to offer a less favourable habitat than natural forests[12,13] and have a reputation of being 'biological deserts'[14]. Thomas *et al.*[15] brought out the concentration of rubber plantation areas in Southeast Asian countries in comparison to worldwide extent. The monoculture rubber plantations are expanding in southeast Asia, across southwest China, Laos, Cambodia, Myanmar, northeast Thailand and northwest Vietnam, leading to a large decrease in the regions' forest cover[11]. More research studies are needed on land use transitions including forest-to-rubber plantation conversion. The issue of rubber plantations spreading at the cost of natural forests is often overlooked because rubber trees look like forests. Ahrends *et al.*[16] observed that new rubber plantations are frequently sites on lands that are important for biodiversity conservation and ecological functions.

Globally, India ranks second in the land area under plantation[17], but determining the precise rate of plantation expansion is challenging because data are incomplete and scattered among different Indian states. Puyravaud *et al.*[18] discussed the evidence for the native forest decline and increase in plantation areas which are not being addressed in the ongoing forest assessments at national level. The distribution of native forests in India is being obscured by the fast expansion of plantations being included in assessment of total forest cover. The FAO data highlights that in India, the plantations increased at a mean annual rate of ~15,400 sq. km/year from 1995 to 2005 (ref. 18). Recently Chen *et al.*[19] from their study in the second largest rubber planting area Xishuangbanna, in China, located in the Indo-Burma biodiversity hotspot observed the rapid expansion of rubber plantations into higher elevations, steeper terrain, and into nature reserves, posing serious threat to biodiversity and environmental services. Thomas *et al.*[20] highlighted that the increasing demand for natural rubber is leading to spread of monoculture plantations with establishment of >2 million ha during the last decade. They estimated that an additional 4.3–8.5 million ha of rubber plantations were required to meet the anticipated demand by 2024, threatening important areas of Asian forests, including many protected areas.

The northeast states of India contribute to one fourth of the India's forest cover. But in recent years, rubber and bamboo have attracted a lot of investment opportunities in the northeast region of India. Tripura is the chief production hub and it is the 'second rubber capital of India' after Kerala as indicated by the Indian Rubber Board. The other rubber producing states in the region are Meghalaya, Mizoram and Assam[21]. According to the North Eastern Development Finance Corporation (NEDFi)[22] data on the extent of rubber plantation in northeast India, the rubber plantation growth in Tripura is found to increase from 574 ha during 1976–77 to an area covering 70,295 ha in 2014–15. Estimates available from NEDFi show that in Assam, the area of rubber plantation grew from 16.5 thousand hectares in 2006–07 to 49.0 thousand hectares in 2013–14; in Meghalaya the area under rubber grew from 4029 ha during 2000–01 to 5331 ha

*For correspondence. (e-mail: kasturi.nesac@gmail.com)

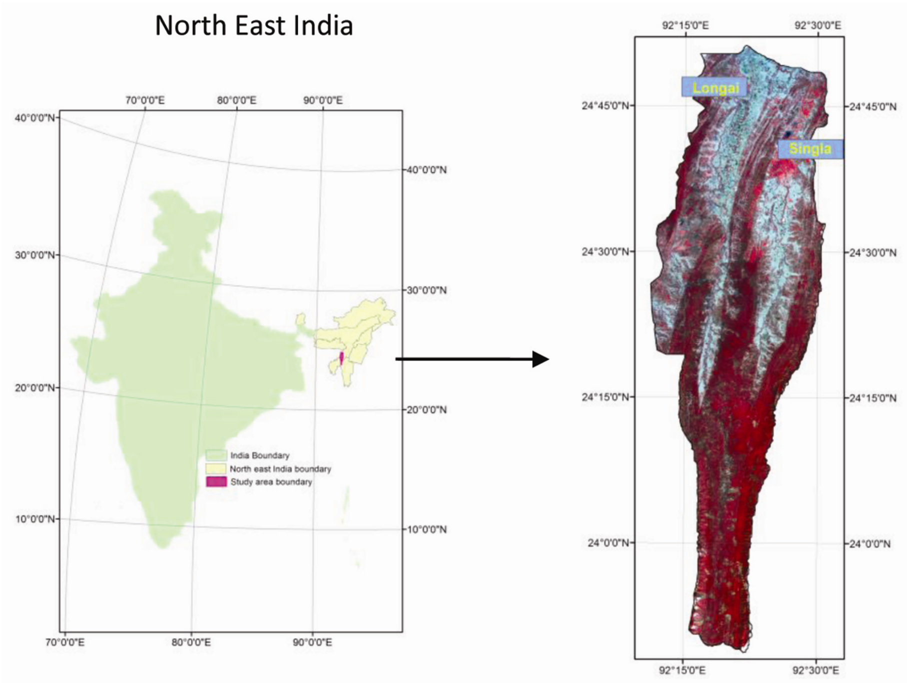


Figure 1. Selected study area.

in 2006–07; Manipur showed marginal increase from 1588 ha to 1859 ha from 2000–01 to 2006–07; Mizoram showed growth in area of 507 ha to 525 ha during 2005–06 to 2006–07; Nagaland showed comparatively high increase from 585 ha during 2000–01 to 2486 ha during 2006–07. The rubber board has been promoting rubber cultivation in non-traditional regions like northeast India to increase natural rubber production in the country. As suitable lands for expansion in the traditional areas have been exhausted, attempts were made to identify other suitable regions in the country and northeast states of India, viz. Assam, Meghalaya, Mizoram and Tripura that were found suitable for cultivation[23]. The northeast region is identified as an agro-climatically suitable potential area due to which accelerated rubber cultivation was taken up both by public and private participation[24]. Although rubber industry is important for socio-economic development, there is growing concern on the negative environmental impacts of increasing rubber plantation areas in this region. Roy *et al.*[25] have expressed concerns on the ecological impacts of rubber plantation bringing out the adverse effects on soil, biodiversity, microclimate stability, etc. in Tripura. In another study from Tripura, Mazumdar *et al.*[26] expressed concern on the generation of waste water and soil contamination, depletion of groundwater, shrinking of natural forests and loss of diversity and impacts on local rainfall and temperature.

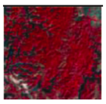
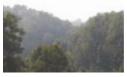
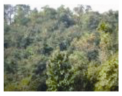
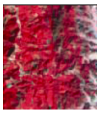
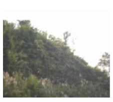
Therefore, accurate and up-to-date monitoring and mapping of rubber plantations is pertinent for understanding the implications in ecological processes. This study is an attempt to understand the expansion of rubber plantation areas, in a selected site from northeast India adjacent to Tripura which has shown a large expansion in rubber plantation over the years.

The study area (Figure 1) is located in northeast India between the geographical coordinates 92°10′54.77″ to 92°32′48.85″ and 23°48′39″ to 24°52′1.43″. The boundary of the study area is comprised of two sub-watersheds, viz. Singla and Longai which cover small parts of Mizoram and north Tripura. The major portion of the sub-watershed, constituted by the Karimganj district of Assam, is one of the largest rubber growing areas located in southern Assam. The study area was chosen to observe the expansion as it lies adjacent to the northeast state of Tripura which ranks as the second largest rubber growing state in India. Statistics from NEDFi for recent trend of rubber plantation in Karimganj district show increase from 4200.74 ha during 2011–12 to 8815.00 ha during 2013–14.

For mapping the rubber plantation area, the temporal satellite data of IRS LISS III of 23.5 m resolution was used. Based on satellite data availability, the temporal data chosen for the study were the images of March 1997, 2003, 2005, 2010 and 2013. The satellite data were carefully registered to the same projection. The top of atmosphere correction (ToA) was applied on the images to minimize atmospheric effects. To observe the expansion of rubber plantation in various land use categories, the satellite imagery was classified by visual interpretation for preparing temporal LULC maps. Figure 2 *a* and *b* (satellite data and corresponding field photograph) shows the typical spectral signature and homogeneous patches

Figure 2. ***a***, Occurrence of rubber plantation; ***b***, Field photograph of rubber plantation; ***c***, Land use/land cover map of 1997.

Table 1. Interpretation key

Land use/forest category	Section of satellite data and ground photographs	
Dense forest		
Open forest		
Degraded forest		
Rubber plantation		

of rubber plantation. An interpretation key was developed to segregate the forest category and the rubber plantation as shown in Table 1. The tonal and textural characteristics helped delineate each land use/forest category. The LULC map generated by visual interpretation is shown in Figure 2 *c* for 1997 as an example. Similarly, LULC maps were also generated for the remaining years. The dense forest category in the classified map is the forest areas with more than 40% canopy cover and open forest areas are the forests with 10–40% canopy cover, whereas the degraded forests are forests with less than 10% canopy cover. While classifying the forests category, the Forest Survey of India (FSI) forest density map was consulted along with ground truth verification. The scrub areas are wastelands with degraded lands that can be brought under vegetative cover with appropriate management practice, while other categories include water body, sandy areas, etc. The expansion of the plantation in respective years in various land use categories was observed from the classified maps and the results presented only the rubber plantation expansion in the respective land use category. Change in all the LULC classes has not been presented because it is beyond the scope of the study.

The expansion of rubber plantation in the study area was observed from 1997 to 2013, a zoomed section of the study area from satellite image of 1997 to 2013 shown in Figure 3. From Table 2, plantation expansion in different LULC types can be accounted. The spread of plantation in the study area is shown in Figure 4. Dense forest, open forest, degraded forest, dense scrub and open scrub areas have contributed to the expansion of rubber plantation. The area under plantation considerably increased during 2013 in open forest. It is important to note that maximum spread took place in the degraded forest area during 2013. The plantation areas expanded throughout the years under study and maximum expansion occurred during 2010–2013. The expansion of plantation is further explained in Table 3. The per cent change shows the high change during 2010–2013 time periods to an extent that approximately 9.47 sq. km per year came under rubber plantation. As observed from satellite images, in the earlier years of 1997 and 2003, there was a tendency of dense forests being affected; however in later years, dense forest change remained constant, but the open forest was affected. Most spread was observed in the degraded forest category. The rate of forest change due to plantation abruptly increased during the 2010–2013 period. An instance of rubber plantation expansion was observed in a reserved forest located within the study area (Figure 5). It is worth noting that reserved forest is the land notified under provisions of the Indian Forest Act or State Forest Acts to have full protection. In reserved forests, activities are prohibited without permission. Hence, occurrence

Table 2. Rubber plantation (area in sq. km) in selected study area

LULC class	1997	2003	2005	2010	2013
Dense forest	4.47	5.09	5.23	5.42	5.66
Open forest		1.41	1.54	2.37	6.58
Degraded forest		1.66	2.22	4.70	15.09
Dense scrub		0.05	0.07	0.07	0.22
Open scrub		0.39	0.39	0.41	0.88
Total	4.47	8.61	9.45	12.98	28.42

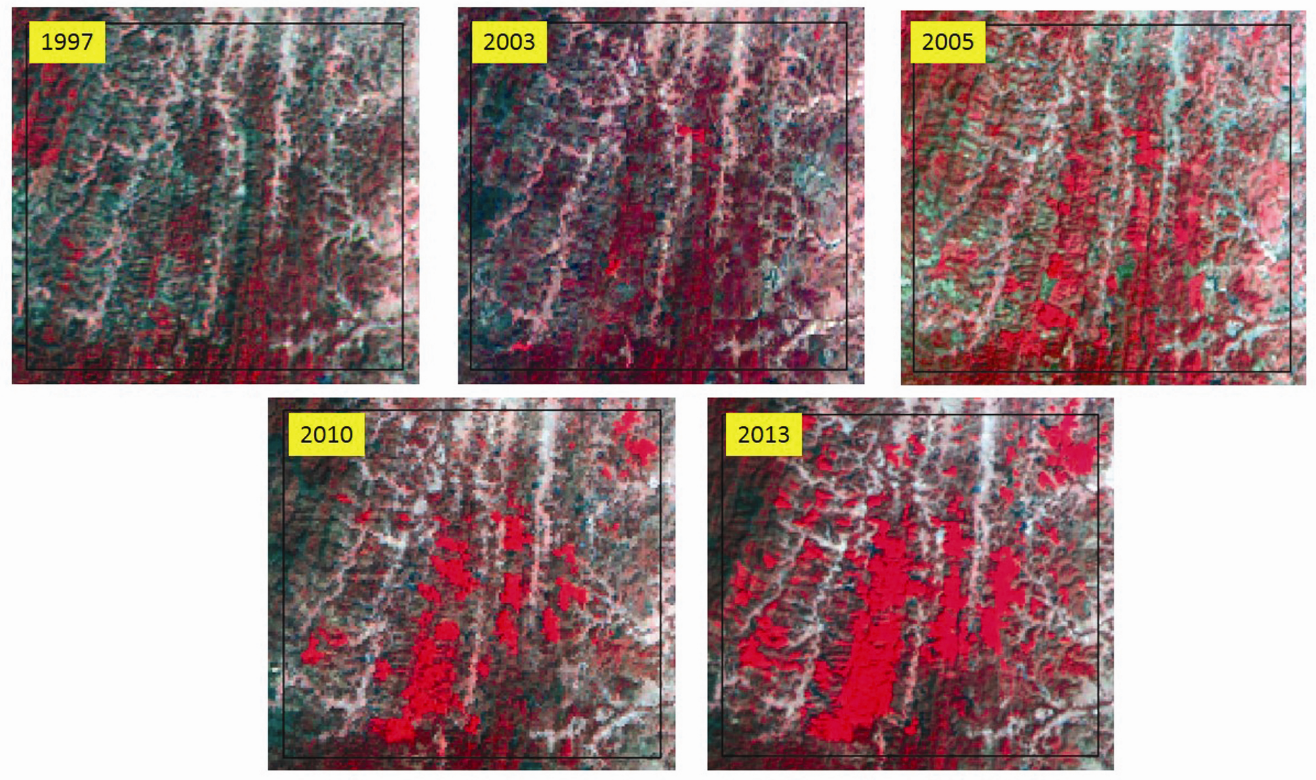


Figure 3. Expansion of rubber plantation from 1997 to 2013 as observed on satellite imagery in selected part of the study area.

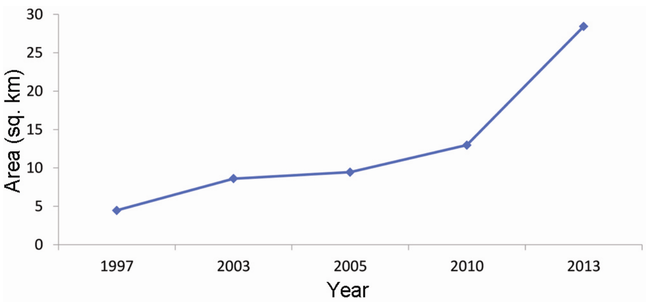


Figure 4. Expansion of rubber plantation area (sq. km).

of rubber monoculture is unlikely in such reserved forests.

Forest-to-rubber plantation conversion land-use change impacts have hardly been studied. In southeast Asia as a whole, estimates of above-ground carbon in mature rubber plantations ranged from 25 to 143 Mg ha^{-1} (ref. 27), whereas Li *et al.*[28] estimated above-ground carbon in rubber plantations at less than one-half the level measured in natural forests. Southeast Asia is the epicentre of rubber cultivation. The reduction in species richness of 19% due to conversion of secondary forest to rubber monoculture[29], suggests secondary forest fallows in traditional shifting cultivation areas might also retain higher biodiversity value compared to rubber monocultures. The transition to rubber plantations has environmental implications such as reduction in water reserves[30,11], carbon stocks[31,28], soil productivity[32] and biodiversity[33].

The inclusion of monoculture rubber plantations has implications on the spread of pathogens and diseases and resulted in a number of negative environmental impacts[11,34–36]. Information on the impacts of rubber

Table 3. Dynamics of area under rubber plantation

Change in rubber plantation area	1997–2003	2003–2005	2005–2010	2010–2013
% change	92.6	9.77	37.36	118.96
Expansion of expansion per year (sq. km)	1.43	4.73	2.6	9.47

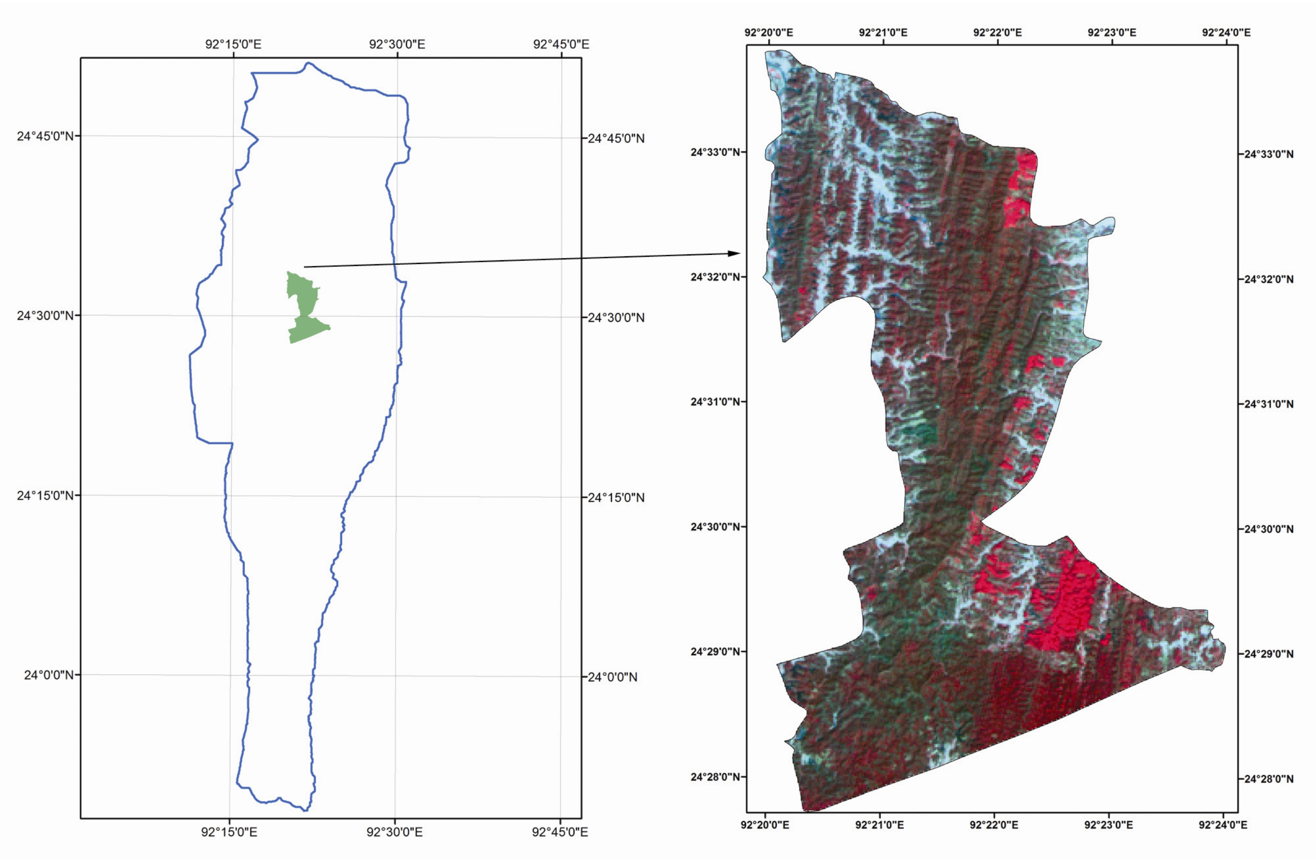


Figure 5. Expansion of rubber plantations into Duhalia Reserved Forest (Karimganj District).

plantation summarized by Ahrends[16] states, that almost 2500 sq. km of land that was earlier classified as natural vegetation with tree cover[37] converted to rubber plantation. About 512 sq. km area was converted in vital areas for biodiversity conservation (key biodiversity areas; KBAs) and 610 sq. km in protected areas. Rubber spread was observed into 1624 sq. km of land that are key habitats for species of conservation (conservation corridors). Approximately 1370 sq. km was converted from a mosaic of cropland and natural vegetation to rubber monoculture (e.g. shifting cultivation)[37].

Southeast Asia producing 97% of the world's natural rubber is facing land conversion due to rapidly expanding industry[38]. A similar trend in change of land use pattern is being observed in northeast region of India. The foundation for rubber expansion in the northeast region is for the benefit of tribal communities while meeting the growing domestic demand for natural rubber. Currently, the seven northeast states together make up the second largest area of rubber planted in the country[39]. Rubber plantation provides gainful self-employment and sustainable livelihood opportunities generating direct employment – approx. 1000 man days/ha (ref. 40). Rubber Board has two important schemes in northeast India, viz. Rubber Plantation Development (RPD) and Rubber Development in North East (RDNE). These schemes provide support to cultivators during the initial years of rubber plantation. An interest subsidy of 3% on loans is given from banks to participants of the scheme according to norms fixed by NABARD (National Bank For Agriculture and Rural Development). Rubber plantation is also encouraged under the rural employment generation programmes.

There is risk of unsustainability in marginal environments where rubber is being planted. Further studies are required for systematic and region-wide monitoring to quantify losses of natural vegetation and its impacts to ecosystem services. Policy interventions and greater awareness are needed as rubber prices are volatile and such widespread rubber plantations are the main drivers of forest loss in continental SE Asia[16]. A management system between economic return and environmental sustainability is required for improving long-term scenario in the region[41].

Strategy may be developed for mixed plantation, i.e. rubber mixed with other trees rather than monoculture plantation. A unique example of such practice is shown in the field photograph (Figure 6) collected in Karimganj district of Assam. The plantation site presents a combination of rubber plantation mixed with areca nut and banana plants. According to Viswanathan[39], the integrated farming systems are of great significance in the context of emerging rubber plantations. A rubber-based agroforestry system, as opposed to rubber monocultures, is recommended as it would improve the micronutrient levels of soils in the plantation[42]. The topics related to plantation management, chemical use, and the role of mixed planting systems needs to be addressed[43]. Leguminous cover crops planted between rubber trees are opted to increase carbon accumulation and to improve soil quality and fertility[27]. Research results from CIRAD Agriculture Research and development[44] showed that coffee or cocoa is a more profitable combination, helping the small holders improve their income source and thereby make better use of their land. Snoeck[45] concluded from the combination of *Hevea* with other tree crops on better land use, seasonal spread of labour, wider range of productivity and reduced susceptibility to market crashes. Diversity of crops including spices, plantation crops, medicinal plants and vegetables combined with rubber help in sustained soil fertility[46].

In India, Kerala is the largest producer of rubber. The agro-climatic conditions of North East Region (NER) of India are quite similar to that of south-west coastal region of India. It is for this reason as well as support from government schemes, that NER registered itself in the list of non-traditional regions of rubber growers. The NER has rich forest resource and maintains traditional LULC systems in tribal belts. More detailed studies at local levels can bring out the local environmental impacts that can be minimized with the help of traditional practices. There is need for adopting sustainable land use management policies for maintaining balance between socio-economic development and ecosystem resilience in this rich biologically diverse region.

Figure 6. Field photograph of mixed plantation practice (location: (92°23′43.8″E, 24°33′47.4″N).

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