Research article

Changes of land use land cover and floristic composition in sacred forests of West Karbi Anglong district, Assam, India

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Abstract: Sacred forests help in sustaining the biodiversity of a region. Assam, a state from Northeast India, has sacred forests where studies on the changes of land use land cover and floristic composition are limited. Therefore, our study aimed to analyze the changes caused by land use land cover and assess floristic composition in the Bichikri and Harlong sacred forests of West Karbi Anglong district of Assam. For land use land cover, we studied the decadal change for two periods, the first period (1998 to 2008) and the second period (2008 to 2018). We observed a 43.5% variation of dense forest cover in the first period. However, in the second period, there was an increase of 6.4%. Open forest and fallow land showed an increase of 37.6% and 6.6% in the first period and a decrease of 15.6% and 5% in the second period, respectively. These changes may be because of the increasing production of rubber and broom grass cultivation. The species diversity in the studied sacred forests recorded a total of 116 species (46 trees, 27 shrubs, and 43 herbs) belonging to 84 genera under 44 families. 21% of species are found common in both the sacred forests. As there is no boundary of the sacred forests, there is an exploitation of the plant resources, and the existence of invasive species may have led to low plant diversity. Therefore, in the future, there is a high possibility of extinction of plant species from these sacred forests. So, it is highly recommended to conserve and protect the species of sacred forests with the involvement of community support and policymakers.

Keywords: Floristic composition - Species richness - Karbi - Conservation - Invasive - Decadal.

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INTRODUCTION

Sacred forests, also termed as sacred groves, are community conserved forests protected due to the religious and cultural beliefs of the indigenous communities. In these forests, access to forest resources is a taboo, and collection of timber, non-timber forest products, and lopping of fuelwood are prohibited except for those connected with religious functions or ceremonies (Tiwari *et al.* 2010). The old idea behind protecting a particular area or forest patch by declaring it as sacred is unarguably based on the cultural, social, spiritual, and religious factors (Avasthe *et al.* 2004). It has resulted in maintaining a desirable ecosystem or habitat for the plant species of the sacred forests. Previous studies on the plant community structure have shown that the sacred forests are rich in species composition (Singh & Khurana 2001, Khumbongmayum *et al.* 2005, Sukumaran *et al.* 2008). It was recorded that the total plant species in the sacred forests were higher than a natural reserve and the other forest (Liu *et al.* 2000, Bhagwat & Rutte 2006). However, in present times, population explosion and decline of the traditional ecological knowledge affected the existing forests cover, which has inclined in loss of valuable biodiversity (Singh *et al.* 2017). There are significant changes in the extent of the sizes, vegetation structure, peoples' attitude towards them, and the religious beliefs and taboos associated with the sacred forests (Khan *et al.* 2008, Naidu *et al.* 2015). The use and abuse of resources by the neighbouring human settlements have caused pressure in these forests (Tripathi *et al.* 2016). These problems have resulted in the decline of species composition of the sacred forests. Therefore, studies related to land use land cover (LULC) and floristic composition of the sacred forests is essential to understand the species composition and the impact caused on its

Figure 2. Sacred pond in Bichikri sacred forest.

Figure 3. Rocks worshipped as a deity in Harlong sacred forest.

Land cover classification

For the land cover change, we have taken the satellite imageries of three years 1998, 2008, and 2018. The satellite imageries of the study areas were downloaded from United States Geological Surveys (*GloVis*). We have analysed the decadal LULC changes in two periods, first period (1998 to 2008) and second period (2008 to 2018). The year-wise changes were also calculated to understand the land cover changes systematically. The scenes were acquired from Landsat 4-5 (TM C1 level-1) for the years 1998 and 2008. However, for downloading scenes of the year 2018, we used Landsat-8 (OLI/TIRS C1 Level-1). The imageries with geometric and atmospheric correction (less than 10% cloud cover) were done for the better quality of images that helps in improve visual analysis of the data. After that, Landsat images were projected to the Universal Transverse Mercator (UTM) coordinate system of 46 North zone. Then, we created a few training samples and generated the signature files for LULC in different categories in Arc GIS 10.7. Subsequently, we performed a supervised classification technique by interactive supervised classification tool which accelerates the maximum likelihood classification process. These classes were categorized as water bodies, dense forest, open forest, fallow land, cropland and settlement. For the change detection of each categorised classes, we have analysed the rate of change (m^2) in Microsoft Excel 16.

Floristic composition

For understanding the floristic composition in both sacred forests, a two years (2017–2018) phytosociological study was carried out by quadrat sampling method (Misra 1968, Kershaw 1973). A total of hundreds of quadrats with sub quadrats were randomly laid down such that $10 \text{ m} \times 10 \text{ m}$ quadrats (100 sampling unit) was used for sampling of trees ($>30 \text{ cm gbh}$), $5 \text{ m} \times 5 \text{ m}$ (100 sampling unit) for shrubs while $1 \text{ m} \times 1 \text{ m}$

(200 sampling units) for herbs sampling. In the present study, a girth at breast height (gbh), collar diameter, and species name were recorded with the help of measuring tape, a digital Vernier calliper and caretaker's knowledge respectively. Plant species that were difficult to identify in the field, their sample were identified based on the botanical Flora of Assam (Kanjilal & Bor 1938). Scientific nomenclature of recorded plant species was documented as per the plant list (<http://www.theplantlist.org/>).

For the quantitative analysis, important community parameters such as frequency (%), density, abundance, and basal area for plant species were calculated using the formulae given by Curtis & McIntosh (1950), Cottam & Curtis (1956), Phillips (1959), and Misra (1968). Important value Index (IVI) was calculated from relative values of frequency, density, and basal area given by Curtis (1959).

$$\text{Frequency} = \frac{\text{No. of quadrats in which the species occurred}}{\text{Total no. of quadrats studied}} \times 100$$

$$\text{Density} = \frac{\text{Total no. of individuals of each species in all quadrats}}{\text{Total no. of quadrats studied}}$$

$$\text{Abundance} = \frac{\text{Total no. of individual of a species in all quadrats}}{\text{Total no. of quadrats in which the species occurred}}$$

$$\text{Basal area} = \frac{(\text{Circumference at breast height})^2}{12.56}$$

$$\text{Relative frequency} = \frac{\text{No. of occurrence of the species}}{\text{No. of occurrence of all the species}} \times 100$$

$$\text{Relative density} = \frac{\text{No. of individual of the species}}{\text{No. of individuals of all the species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

$$\text{Important value Index (IVI)} = \text{Relative frequency} + \text{Relative density} + \text{Relative Dominance}$$

Plant species diversity were computed based on different diversity indices such as Margalef's species richness index (Margalef 1958), Shannon-Wiener index of diversity (Shannon & Weiner 1963), Simpson's index of dominance (Simpson 1949), Pielou's evenness index (Pielou 1963), and distribution pattern by Whitford index (Whitford 1949).

Margalef's species richness index,

$$SR = (S - 1)/\ln(N)$$

Shannon-Wiener diversity index,

$$H' = -\sum_{i=1}^s p_i \ln p_i$$

Simpson's index of dominance,

$$C_D = \sum_{i=1}^s (p_i)^2$$

Evenness index,

$$e = H'/\log S$$

Whitford index,

$$WI = \text{Abundance} / \text{Frequency}$$

The Pearson correlation was done to establish a relationship between density, basal area, and diversity indices among trees, shrubs, and herbs using SPSS 21 software.

RESULTS

Land cover classification

Comparing the land use and land cover (LULC) maps of both the periods, we observed that there is a change in the land cover (Fig. 4). In the first period (1998–2008), we observed that the dense forest area was decreased by 43.5%; however, in the second period (2008–2018), there was an increase of 6.4%. Similarly, open forest and

fallow land showed an increase of 37.6%, 6.6% in the 1st period and a decrease of 15.6%, 5% in the 2nd period, respectively. We also observed that the settlement land has increased by 0.2% and 2.6% in both the first and second periods, respectively. Water bodies of the district did not show any changes in the first period; however, in the second period, there is an increase of 0.8%. The study on decadal changes of land cover classes also showed similar variation in all the three years (Fig. 5). The dense forest was observed highest in the year 1998 (61%) and lowest in the year 2008 (18%). The open forest was recorded highest in the year 2008 (71%) and lowest in the year 1998 (33%). Similarly, the fallow land also recorded highest in 2008 (8.8%) and lowest in 1998 (2.2%). Crop land recorded highest area cover in the year 2018 (12.2%) and lowest in the year 2008 (1.4%). The land cover of settlement recorded highest in 2018 (3.4%) and lowest in 1998 (0.6%). The waterbodies recorded highest in the year 2018 (1%) and lowest in the year 1998 and 2008 (0.1%).

Figure 4. Land use land cover map of West Karbi Anglong.

Figure 5. Comparison of LULC change based on land cover classes.

Floristic composition

Our study recorded a total of 116 plant species (46 trees, 27 shrubs, and 43 herbs) belonging to 84 genera under 44 families. The community parameters in all the layers (tree, shrub and herb) of both the sacred forests are indicated in table 1, 2 and 3. In tree species, family Moraceae (6) recorded the highest number of species. In shrubs, Acanthaceae and Malvaceae (4 species each), and in herbs, Compositae (8) recorded as the dominant families. Comparing both the sacred forests, we observed highest plant species in Bichikri sacred forest having 68 plant species (26 trees, 18 shrubs, and 24 herbs) belonging to 65 genera and 38 families than Harlong sacred forest recorded 48 plant species (20 trees, 9 shrubs, and 19 herbs) belonging to 47 genera and 29 families. 21 % of species recorded common plants in both the sacred forests. *Bauhinia purpurea* L. recorded the highest tree frequency (%) in both the sites, while *Clerodendrum infortunatum* L. and *Lantana camara* L. shrub species, indicated the higher frequency (%) in Bichikri and Harlong, respectively. The herbs species that recorded the highest frequency (%) include *Ageratum conyzoides* L. and *Spilanthes acmella* (L.) L. in Bichikri and Harlong, respectively. Tree species such as *Acacia pennata* (L.) Willd., *Psychotria asiatica* L., *Tectona grandis* L.f. and *Toona ciliata* M.Roem. in Bichikri, while *Bauhinia purpurea* L. in Harlong recorded as abundance species. *Rauvolfia serpentina* (L.) Benth. ex Kurz and *Musa flaviflora* N.W. Simmonds were recorded to be abundant shrub species in Bichikri and Harlong, respectively. Similarly, *Chrysopogon zizanioides* (L.) Roberty and *Cynodon dactylon* (L.) Pers. herb species were more abundant in the two sites. The highest tree density (ha^{-1}) and basal area ($\text{m}^2 \text{ha}^{-1}$) were recorded in *Bauhinia purpurea* L. for both the sites, in contrast to shrub species that recorded *Leea indica* (Burm. f.) Merr. and *Clerodendrum infortunatum* L. as well as *Canna indica* L. and *Musa flaviflora* N.W. Simmonds for density (ha^{-1}) and basal area ($\text{m}^2 \text{ha}^{-1}$) in Bichikri and Harlong, respectively. Herb species recorded *Chrysopogon zizanioides* (L.) Roberty and *Spilanthes acmella* (L.) L. as highest density (ha^{-1}) in Bichikri and Harlong, whereas, *Chrysopogon zizanioides* (L.) Roberty was recorded as highest basal area ($\text{m}^2 \text{ha}^{-1}$) in Bichikri and *Spilanthes acmella* (L.) L. in Harlong, respectively. The dominant tree species recorded in Bichikri and Harlong was *Bauhinia purpurea* L. (IVI- 57.52 and 140.69; Fig. 6A). *Clerodendrum infortunatum* L. (IVI- 26.26) and *Musa flaviflora* N.W. Simmonds (IVI- 114.75) were dominant shrub species in Bichikri and Harlong, respectively (Fig. 6B). Similarly, different herb species dominated the two studied sites were *Chrysopogon zizanioides* (L.) Roberty and *Thysanolaena latifolia* (Roxb. ex Hornem.) Honda, with the IVI of 50.44 and 82.33 in Bichikri, and Harlong, respectively (Fig. 6C). The study also recorded invasive species such as *Ageratum conyzoides* L., *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L., *Mimosa pudica* L., *Mikania micrantha* Kunth. in both sites.

The results of plant species diversity of studied sacred forests are shown in table 4. Margalef's index recorded species richness ranged from 3.9–5.05, 1.83–3.15 and 3.59–7.93 for trees, shrubs and herbs respectively in two sites. The recorded value for Shannon- Wiener index (H') was 2.86, 2.7 and 2.69 while, 2.44, 2.08, and 2.62 for tree, shrub and herb species in Bichikri and Harlong, respectively. Simpson's index (C_D) recorded 0.08, 0.07 and 0.08 of trees, shrubs and herbs in Bichikri, at the same time; the value of 0.16, 0.05 and 0.09 was recorded in Harlong. Pielou evenness index recorded a maximum of 0.94 and 0.81 as the lowest value. Whitford index (WI) showed a contagious pattern of species distribution in either of the study sites. Correlation between densities, basal area, Shannon-Weiner index, (H') and Simpson's index (C_D) are indicated in table 5.

Table 1. Enumeration of tree species and their frequency, abundance, density, basal area and important value index in sacred forests of Assam.

Scientific name	Family	F (%)	A	Density (ha^{-1})	BA ($\text{m}^2 \text{ha}^{-1}$)	IVI
Bichikri sacred forest						
<i>Acacia pennata</i> (L.) Willd.	Leguminosae	2	1.5	3	0.18	4.20
<i>Ardisia arborea</i> Koord. & Valetton	Primulaceae	2	1	2	0.09	3.33
<i>Azadirachta indica</i> A.Juss.	Meliaceae	2	1	2	0.06	3.28
<i>Bauhinia purpurea</i> L.	Leguminosae	22	1.36	30	9.78	57.52
<i>Chukrasia tabularis</i> A.Juss.	Meliaceae	8	1	8	1.77	15.75
<i>Dillenia indica</i> L.	Dilleniaceae	2	1	2	0.46	3.97
<i>Dipterocarpus retusus</i> Blume	Dipterocarpaceae	2	1	2	0.80	4.56
<i>Fernandoa adenophylla</i> (Wall. ex G.Don) Steenis	Bignoniaceae	2	1	2	3.72	16.50
<i>Ficus benghalensis</i> L.	Moraceae	1	1	1	0.76	2.90
<i>Ficus racemosa</i> L.	Moraceae	3	1.33	4	1.64	8.31
<i>Ficus religiosa</i> L.	Moraceae	2	1	2	0.96	4.84

<i>Garcinia pedunculata</i> Roxb. ex Buch.-Ham.	Clusiaceae	2	1	2	1.49	5.76
<i>Gmelina arborea</i> Roxb.	Lamiaceae	9	1	9	2.68	18.91
<i>Kalopanax septemlobus</i> (Thunb.) Koidz	Araliaceae	4	1	4	1.68	11.39
<i>Macaranga denticulata</i> (Blume) Müll.Arg.	Euphorbiaceae	3	1	3	0.54	5.70
<i>Mallotus tetracoccus</i> (Roxb.) Kurz	Euphorbiaceae	4	1	4	0.75	7.64
<i>Mangifera indica</i> L.	Anacardiaceae	8	1	8	1.36	15.05
<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Rubiaceae	2	1	2	0.67	4.33
<i>Phyllanthus emblica</i> L.	Phyllanthaceae	2	1	2	0.05	3.26
<i>Psidium guajava</i> L.	Myrtaceae	2	1	2	0.06	3.27
<i>Psychotria asiatica</i> L.	Rubiaceae	2	1.5	3	0.36	4.50
<i>Pterospermum acerifolium</i> (L.) Willd.	Malvaceae	6	1	6	7.87	19.98
<i>Tectona grandis</i> L.f.	Lamiaceae	4	1.5	6	3.42	13.69
<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Combretaceae	10	1.2	12	5.77	27.27
<i>Tetrameles nudiflora</i> R. Br.	Tetramelaceae	3	1	3	9.52	24.09
<i>Toona ciliata</i> M.Roem.	Meliaceae	4	1.5	6	1.28	9.98
Harlong sacred forest						
<i>Albizia procera</i> (Roxb.) Benth.	Leguminosae	8	1.125	9	0.99	16.36
<i>Areca catechu</i> L.	Arecaceae	6	1	6	0.31	10.75
<i>Artocarpus heterophyllus</i> Lam.	Moraceae	3	1	3	0.62	6.39
<i>Azadirachta indica</i> A.Juss.	Meliaceae	6	1.16	7	0.51	11.95
<i>Bauhinia purpurea</i> L.	Leguminosae	35	1.37	48	33.10	140.6
<i>Callicarpa arborea</i> Roxb.	Lamiaceae	2	1	2	0.04	3.45
<i>Carica papaya</i> L.	Caricaceae	6	1	6	0.39	10.91
<i>Caryota urens</i> L.	Arecaceae	2	2	4	0.13	5.18
<i>Dillenia indica</i> L.	Dilleniaceae	2	1	2	0.33	4.08
<i>Ficus benjamina</i> L.	Moraceae	4	1	4	1.11	9.13
<i>Ficus hispida</i> L.f.	Moraceae	3	1.33	4	0.77	7.48
<i>Gmelina arborea</i> Roxb.	Lamiaceae	2	1	2	0.23	3.85
<i>Mangifera indica</i> L.	Anacardiaceae	4	1.25	5	0.41	8.37
<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Rubiaceae	3	1.33	4	0.51	6.91
<i>Oroxylum indicum</i> (L.) Kurz	Bignoniaceae	1	1	1	0.02	1.72
<i>Phyllanthus emblica</i> L.	Phyllanthaceae	2	1	2	0.05	3.46
<i>Pterospermum acerifolium</i> (L.) Willd	Malvaceae	4	1	4	0.98	8.84
<i>Tectona grandis</i> L.f.	Lamiaceae	3	1	3	2.60	10.69
<i>Tetrameles nudiflora</i> R. Br.	Tetramelaceae	8	1	8	1.62	16.94
<i>Zanthoxylum rhetsa</i> (Roxb.) DC.	Rutaceae	6	1	6	1.28	12.86

Note: F- Frequency, A- Abundance, BA- Basal area, IVI- Importance value index.

Table 2. Enumeration of shrub species and their frequency, abundance, density, basal area and important value index in sacred forests of Assam.

Scientific name	Family	F (%)	A	Density (ha ⁻¹)	BA (m ² ha ⁻¹)	IVI
Bichikri sacred forest						
<i>Antidesma acidum</i> Retz.	Phyllanthaceae	4	1	16	0.006	4.00
<i>Breynia vitis-idaea</i> (Burm.f.) C.E.C.Fisch.	Phyllanthaceae	7	1.57	44	0.005	7.93
<i>Canna indica</i> L.	Cannaceae	11	1.73	76	0.16	24.93
<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.	Compositae	17	1.53	104	0.039	21.08
<i>Citrus medica</i> L.	Rutaceae	3	1	12	0.137	13.31
<i>Clerodendrum infortunatum</i> L.	Lamiaceae	23	1.48	136	0.029	26.26
<i>Hibiscus sabdariffa</i> L.	Malvaceae	7	1.57	44	0.003	7.74
<i>Holmskioldia sanguinea</i> Retz.	Lamiaceae	2	1	8	0.011	2.63

<i>Justicia adhatoda</i> L.	Acanthaceae	5	1	20	0.012	5.39
<i>Justicia gendarussa</i> Burm.f.	Acanthaceae	5	1.2	24	0.005	5.18
<i>Lantana camara</i> L.	Verbenaceae	16	1.5	96	0.026	18.85
<i>Leea indica</i> (Burm. f.) Merr.	Vitaceae	4	1.86	164	0.0001	15.76
<i>Musa flaviflora</i> N.W.Simmonds	Musaceae	13	1.69	88	0.013	15.50
<i>Phlogacanthus curviflorus</i> (Wall.) Nees	Acanthaceae	10	1.4	56	0.009	10.86
<i>Psychotria denticulata</i> Wall.	Rubiaceae	7	1.14	32	0.140	17.41
<i>Rauvolfia serpentina</i> (L.) Benth. ex Kurz	Apocynaceae	18	1.89	136	0.024	23.07
<i>Solanum indicum</i> L.	Solanaceae	8	1.63	52	0.003	8.98
<i>Urena lobata</i> L.	Malvaceae	8	1.63	52	0.010	9.54
Harlong sacred forest						
<i>Clerodendrum infortunatum</i> L.	Lamiaceae	11	1.55	68	0.018	42.60
<i>Dendrocnide sinuata</i> (Blume) Chew	Urticaceae	4	2.25	36	0.052	22.65
<i>Abutilon indicum</i> (L.) Sweet	Malvaceae	3	2.33	28	0.0001	14.23
<i>Justicia adhatoda</i> L.	Acanthaceae	9	0.56	20	0.016	23.65
<i>Lantana camara</i> L.	Verbenaceae	12	0.58	28	0.0066	30.81
<i>Murraya koenigii</i> (L.) Spreng.	Rutaceae	5	1.60	32	0.11	27.76
<i>Musa flaviflora</i> N.W.Simmonds	Musaceae	6	2.67	64	1.06	114.7
<i>Rubus alceifolius</i> Poir.	Rosaceae	4	1.25	20	0.0018	13.62
<i>Urena lobata</i> L.	Malvaceae	2	2.50	20	0.0003	9.92

Note: F- Frequency, A- Abundance, BA- Basal area, IVI- Importance value index.

Table 3. Enumeration of herb species and their frequency, abundance, density, basal area and important value index in sacred forests of Assam.

Scientific name	Family	F (%)	A	Density (ha ⁻¹)	BA (m ² ha ⁻¹)	IVI
Bichikri sacred forest						
<i>Ageratum conyzoides</i> L.	Asteraceae	25.5	3.63	9250	0.88	44.85
<i>Alpinia galanga</i> (L.) Willd.	Zingiberaceae	21	3.05	6400	0.42	28.01
<i>Arundinella pumila</i> (Hochst.) Steud.	Poaceae	18	1.58	2850	0.08	13.62
<i>Chrysopogon zizanioides</i> (L.) Roberty	Poaceae	17	6.29	10700	1.18	50.44
<i>Colocasia esculenta</i> (L.) Schott	Araceae	9	2.5	2250	0.05	8.26
<i>Cyanthillium cinereum</i> (L.) H.Rob.	Compositae	7	1	700	0.005	4.05
<i>Cyperus rotundus</i> L.	Cyperaceae	16.5	5.30	8750	0.79	38.20
<i>Desmodium triflorum</i> (L.) DC.	Fabaceae	6.5	2.77	1800	0.033	6.12
<i>Dioscorea alata</i> L.	Dioscoreaceae	1.5	2	300	0.001	1.08
<i>Evolvulus nummularius</i> (L.) L.	Convolvulaceae	8.5	0.65	550	0.003	4.41
<i>Hedychium gardnerianum</i> Sheppard ex Ker Gawl.	Zingiberaceae	6	1	600	0.004	3.46
<i>Homalomena aromatica</i> (Spreng.) Schott	Araceae	5.5	1.36	750	0.006	3.52
<i>Houttuynia cordata</i> Thunb.	Saururaceae	2.5	1.6	400	0.002	1.66
<i>Lablab purpureus</i> (L.) Sweet	Leguminosae	0.5	1	50	0.000	0.28
<i>Leucas aspera</i> (Willd.) Link	Lamiaceae	11	2.41	2650	0.07	10.15
<i>Mikania micrantha</i> Kunth	Compositae	9.5	2.58	2450	0.06	8.99
<i>Mimosa pudica</i> L.	Leguminosae	12.5	4.64	5800	0.34	21.83
<i>Paederia foetida</i> L.	Rubiaceae	7.5	2	1500	0.02	5.86
<i>Phyllanthus amarus</i> Schumach. & Thonn.	Phyllanthaceae	4.5	2.44	1100	0.012	3.77
<i>Pseuderanthemum crenulatum</i> (Wall. ex Lindl.) Radlk.	Acanthaceae	3	2.67	800	0.007	2.57
<i>Spilanthes acmella</i> (L.) L.	Compositae	10	2.1	2100	0.046	8.30
<i>Synedrella nodiflora</i> (L.) Gaertn.	Compositae	9.5	1.79	1700	0.030	7.14
<i>Thysanolaena latifolia</i> (Roxb. ex Hornem.) Honda	Poaceae	24	1.81	4350	0.195	20.93
<i>Tinospora sinensis</i> (Lour.) Merr.	Menispermaceae	4	1.25	500	0.003	2.46
Harlong sacred forest						
<i>Ageratum conyzoides</i> L.	Compositae	2	5.25	1050	0.0024	7.25
<i>Amaranthus spinosus</i> L.	Amaranthaceae	2.5	2.6	650	0.0022	6.72
<i>Bryophyllum pinnatum</i> (Lam.) Oken	Crassulaceae	2	3.25	650	0.0011	5.70
<i>Cheilocostus speciosus</i> (J.Koenig) C.D. Specht	Costaceae	3	2	600	0.0024	7.44

<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.	Compositae	3.5	6.29	2200	0.0204	10.73
<i>Colocasia esculenta</i> (L.) Schott	Araceae	2	5.5	1100	0.008	8.28
<i>Curcuma aromatica</i> Salisb.	Zingiberaceae	2.5	3.2	800	0.0009	17.14
<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	3.5	9.57	3350	0.0002	14.51
<i>Cyperus rotundus</i> L.	Cyperaceae	4	5.875	2350	0.0124	11.26
<i>Drymaria cordata</i> (L.) Willd. ex Schult.	Caryophyllaceae	2.5	5.8	1450	0.0011	8.03
<i>Euphorbia hirta</i> L.	Euphorbiaceae	3	2.83	850	0.0011	4.36
<i>Homalomena aromatica</i> (Spreng.) Schott	Araceae	1.5	3.33	500	0.0010	11.17
<i>Kyllinga brevifolia</i> Rottb.	Cyperaceae	3.5	4.43	1550	0.0003	5.05
<i>Leucas aspera</i> (Willd.) Link	Lamiaceae	2	2.5	500	0.0005	6.24
<i>Mikania micrantha</i> Kunth	Compositae	2	4.25	850	0.0005	8.25
<i>Mimosa pudica</i> L.	Leguminosae	3.5	2	700	0.0003	13.70
<i>Paederia foetida</i> L.	Rubiaceae	4.5	4.11	1850	0.023	28.40
<i>Spilanthes acmella</i> (L.) L.	Compositae	9	8.11	7300	0.83	28.43
<i>Thysanolaena latifolia</i> (Roxb. ex Hornem.) Honda	Poaceae	3.5	5.14	1800	0.38	82.33

Note: F- Frequency, A- Abundance, BA- Basal area, IVI- Importance value index.

Figure 6. Dominance distribution curve: **A**, Tree species; **B**, Shrub species; **C**, Herb species recorded in two sacred forests. [— Bichikri; — Harlong]

Table 4. Plant species diversity found in the studied sacred forests of Assam.

Diversity indices	Sacred forests					
	Bichikri			Harlong		
	Tree	Shrub	Herb	Tree	Shrub	Herb
Margalef's species Richness index (SR)	5.05	3.15	7.93	3.9	1.83	3.59
Shannon-Weiner diversity index (H')	2.86	2.7	2.69	2.44	2.08	2.62
Simpson's index of dominance (C_D)	0.08	0.07	0.08	0.16	0.05	0.09
Pielou's evenness index (e)	0.88	0.91	0.85	0.81	0.94	0.83
Whitford Index (WI)	0.42	0.2	0.4	0.37	0.43	1.57

Table 5. Correlation between densities, basal area and diversity indices.

Variables	Sacred forests					
	Bichikri			Harlong		
	Tree	Shrub	Herb	Tree	Shrub	Herb
Density and Basal area	0.701**	-0.103 ^{ns}	0.965**	0.979**	0.599 ^{ns}	0.095 ^{ns}
Density and H'	0.954**	0.984**	0.980**	0.927**	0.989**	0.957**
Density and C_D	0.952**	0.965**	0.965**	0.985**	0.992**	0.958**
Basal area and H'	0.715**	-0.064 ^{ns}	0.896**	0.840*	0.542 ^{ns}	0.177 ^{ns}
Basal area and C_D	0.614**	-0.150 ^{ns}	1.000**	0.996**	0.590 ^{ns}	0.014 ^{ns}

Note: **Correlation p- value < 0.01, * Correlation p- value < 0.05, ns means not significant.

DISCUSSION

Our study on LULC change in the West Karbi Anglong district resulted that there is a conversion of land cover for different uses in both the periods as well as in decadal stages. The reason for the increase in dense forest cover in the year 2018 is mainly due to the production of rubber plantation. Tokpi (2017) reported that in 2011 rubber plantation was introduced by the state government at a large scale in different parts of the district. It was observed that the local people of the area are more dependent on rubber plantation (*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.) as it gives high income than the traditional Jhum cultivation. There is also a high demand for broom grass (*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda) from the region as the district is the largest producer of broom grass in India (Kakati 2017). This may be another cause for the increase in crop land area cover in 2018. The district is also rich in bamboo species. However, with the increasing demand for rubber and broom grass, the people have changed their way of occupation. With the changing of time, there is also transformation in the way of living. These changes have caused in declination of natural resources of the forest and has changed the environment of surrounding areas (Ray *et al.* 2014). Hence the large scale conversion of forests into other land use categories are the main causes of climate change and biodiversity loss (Kuchay & Ramachandra 2016).

Our study recorded a higher number of species in Bichikri than Harlong. This observation could be attributed by differences in the altitude above sea level (amsl). Such that Bichikri has higher altitude (435 amsl) as compared to Harlong (160 amsl). Poulos *et al.* (2007) reported aspect related to elevation as a factor influencing plant species composition and structure. The same observation was reported by Bhat *et al.* (2000), the higher the altitude, the lower the species disturbance, hence higher diversity. Despite the differences in elevation, some species appeared to dominate in either site. The most recorded dominant plant species in both of the studied forests mainly depends on the edaphic factors (Whittaker 1975, Bajpai *et al.* 2020), suitable habitat and favourable environmental conditions which support the growth of individual species.

In comparison to other studies in India, our study recorded lower plant species in term of richness, that contradicts the findings by Page *et al.* (2009) and Pala *et al.* (2016) who recorded a higher number of species in the sacred forest of the Western Ghats and Gharwal Himalaya, respectively. The variation on the number of plant species in our study sites is mainly due to no boundary for demarcation. This has resulted in the utilisation of the plant resources by the local people from both the sites. The other factors like physiography, the suitability of the habitat for the species, and disturbance variation also affected the composition of plant species (Whitmore 1998). On the other hand, Rawat & Chandra (2014) reported that variation in vegetation structure depends upon the species composition, their relative number, and diversity.

According to Patel *et al.* (2014), the frequency, density and abundance are important ecological parameters for the indication of status in the respective plant community. Besides, the basal area plays a significant contribution in accessing the species diversity (Mandal & Joshi 2014, Naidu & Kumar 2016). We recorded a

diverse plant community in Bichikri than Harlong which is due to higher homogeneity, number, abundance and girth size of species. The other factors that contributed to the difference in diversity between the two sites could be due to intensive non-timber forest product (NTFP) collection, increasing population, and developmental activities. The biotic interference such as farming practices and habitat destruction nearby the surrounding would have also played a major role. Same information had been reported by Ghavzan *et al.* (2006) and Sukumaran *et al.* (2018) in their studies. A study by Bhagwat *et al.* (2005) in sacred forests of Western Ghats revealed that the forests are primarily converted to agriculture and commercial plantation, leaving only small fragments of forests in the region. However, the growth of invasive species has also caused threats to the plant species of the sacred forests. Powell *et al.* (2013) reported that invasive species in a particular area might result in slow, long term extinction of plants.

For Margalef's species richness and Shannon-Weiner diversity indices, Bichikri showed higher diversity than Harlong. However, Simpson's index of dominance recorded higher shrubs in Bichikri with lower trees and herbs. Similarly, Pielou's evenness index recorded higher trees and herbs in Bichikri with corresponding lower shrubs. The findings of our study indicated the species are distributed (Whitford index) in the contagious pattern. A study by Borah and Garkoti (2011) also reported contagious distribution in the forest of Barak Valley in Assam. The relationship between density with Shannon-Weiner index and density with Simpson's index indicated positive in all species of the sacred forests. However, in Bichikri a negative correlation was recorded of basal area with the density, Shannon-Wiener index, and Simpson's index which is not significant.

CONCLUSION

Our study revealed with the increasing demand for cash crops production has resulted in changing the land cover of West Karbi Anglong district. We recorded low diversity in both the sacred forests, which is due to the exploitation of forest resources. Similarly, the presence of invasive species in our study sites brings concern about the status of plant diversity. In future, there is a peril of further change in forest cover resulting in the loss of species diversity of the sacred forest. Therefore, systematic management plan with community participation and taking help of policymakers is necessary for their conservation and sustainable utilisation of plant species. Overall, our findings offer a novel perspective on understanding the change of LULC and species diversity in the sacred forests. Our study has a limitation that no previous works on the species composition were reported from the present study area.

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