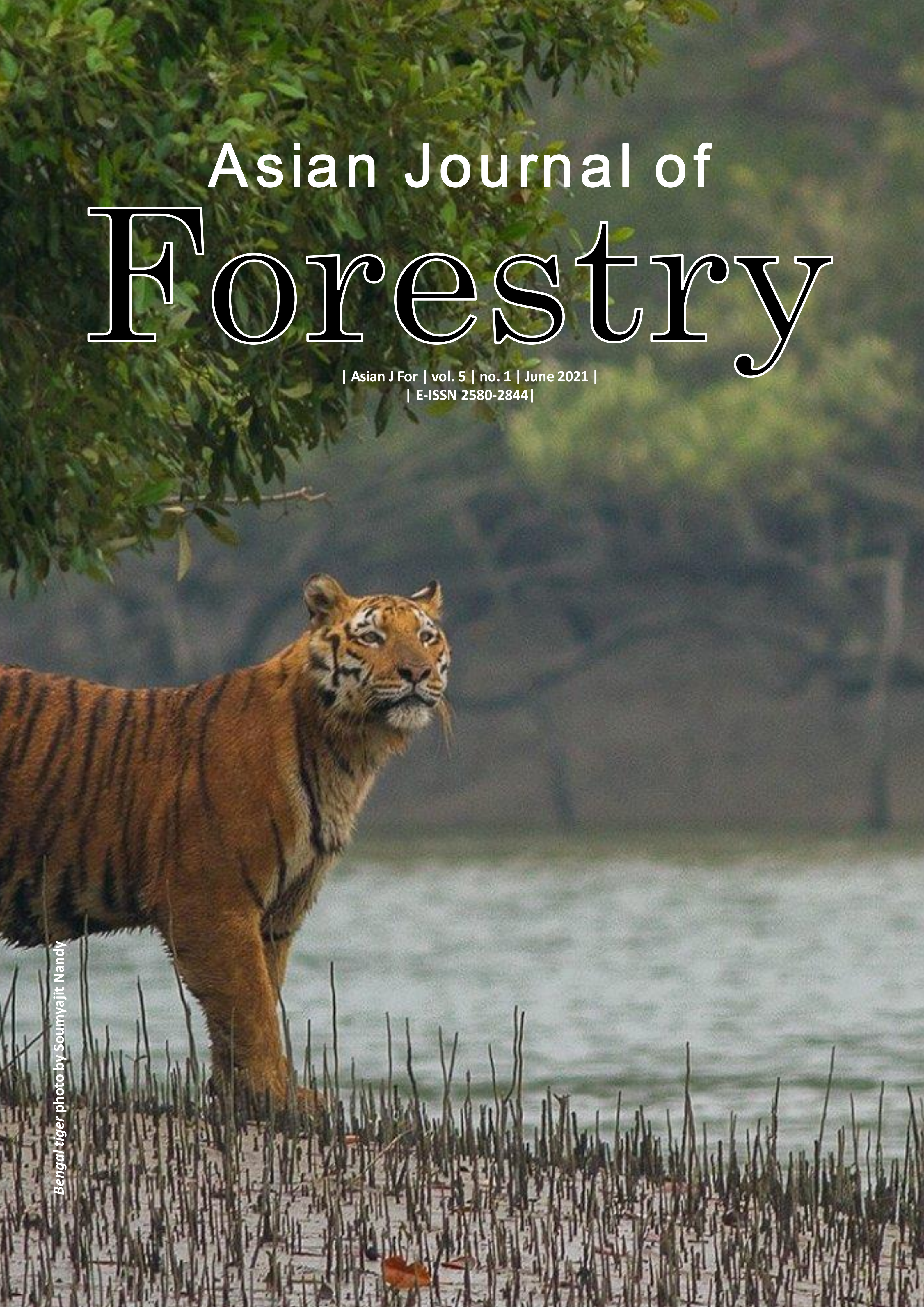

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Bengal tiger photo by Soumyajit Nandy

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Saharjo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic peat natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158. DOI: 10.13057/biodiv/d070213.

The usage of "et al." in long author lists will also be accepted:

Smith J, Jones M Jr, Houghton L et al. 1999. Future of health insurance. N Engl J Med 965: 325-329. DOI: 10.10007/s002149800025.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in the book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds.). Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th annual symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.). Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

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Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. DOI: 10.1038/msb.2008.24. www.molecularsystembiology.com.

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Quantitative assessment of tree species diversity of Himchari National Park (HNP) in Cox's Bazar, Bangladesh

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Abstract. *Hossen S, Hossain MK, Hossain MA, Uddin MF. 2020. Quantitative assessment of tree species diversity of Himchari National Park (HNP) in Cox's Bazar, Bangladesh. Asian J For 5: 1-7.* Himchari National Park (HNP) in Cox's Bazar is an important conservation area in Bangladesh that is threatened by human disturbances, urging for vegetation assessment for monitoring and management purposes. The aim of the study was to assess the tree species diversity, composition and structure of HNP through stratified random sampling method using sample plots (51) of 20 m x 20 m in size during the period of January 2017 to May 2018. A total of 961 stems (dbh ≥ 5 cm) of 88 tree species belonging to 64 genera and 37 families were enumerated where the stem density and basal area were 457.39 stem ha^{-1} and 10.979 m^2 ha^{-1} respectively. On the other hand, the species diversity index, Shannon-Wiener's diversity index, Shannon's maximum diversity index, species evenness index, Margalef's diversity index, and Simpson's diversity index were 0.092, 3.733 ± 0.0071, 4.477, 0.834, 12.667 and 0.039 ± 0.0003 respectively. The highest Importance Value Index (IVI) was found for *Acacia auriculiformis* (23.23) followed by *Tectona grandis* (13.05), *Gmelina arborea* (12.66), *Syzygium fruticosum* (12.34), *Casuarina equisetifolia* (10.57), and *Dipterocarpus turbinatus* (10.55). Height range of 3 - <8 m and dbh class of 5 - <15 cm had the highest percentage of individuals with 59.83% and 65.97%, respectively. The outcome of present study suggests the protection, sustainable management, and conservation of the tree resources of HNP, Cox's Bazar, Bangladesh.

Keywords: Basal area, density, diversity indices, conservation, importance value index

INTRODUCTION

The vegetation of Bangladesh is a part of the Indo-Myanmar region, which is one of the ten global biodiversity hotspots (Mittermeier et al. 1998) and possesses rich biological diversity due to its unique geophysical characteristics (Chowdhury 2001; Hossain 2001; Nishat et al. 2002). In terms of flora, Bangladesh has a rich biological heritage containing about 3,611 flowering plants (Ahmed et al. 2008) of which 2,260 species are reported from Chittagong region alone (Khan et al. 2008).

The diversity of trees is fundamental in representing total biodiversity in tropical forests (Canon et al. 1998) because forest trees provide resources and habitats for almost all other forest organisms (Canon et al. 1998; Huston 1994). Tree species diversity may serve as a preliminary indicator of diversity of plants in a forest type. Moreover, information on diversity, floristic composition and their quantitative structure are vital for understanding the functioning and dynamics of forest ecosystems (Hossain et al. 2015). A higher number of tree species increases the number of associated species such as understory plants and animals. An understanding of phytosociological characteristics of tree species diversity is necessary to facilitate the planning and implementation of more effective conservation measures for sustainable management of tropical forests (Pielou 1995; Feroz et al. 2014; Biswas and Misbahuzzaman 2008).

The extent of biodiversity loss in Bangladesh is not exactly known due to very poor databases and scarce information (Hossain et al. 2004). Numerous plant species in the country are also at risk of being lost in all or part of their distribution ranges because of their population decline caused by overexploitation. The depletion of native species was also accelerating at an alarming rate (Rahman et al. 2000) as the impact of the rapid loss and degradation of forests in Bangladesh. In Bangladesh, it is an urgent need to effectively protect and manage the existing natural forests for sustainable livelihoods (Hossain et al. 2018; Hossain et al. 2019) for the future generation. Quantitative floristic inventories are fundamental to an understanding of the ecology of tropical forests and for developing national forest management strategies.

Himchari National Park (HNP), located in southeastern region of Bangladesh comprising an area of 1729 ha, is very important conservation area due to its proximity to Cox's Bazar tourist city. The forest was rich in floral and faunal diversity (Hossen et al. 2019), unfortunately, it is now heavily pressured by anthropogenic factors like encroachment, illegal felling, and conversion of land to agriculture and betel leaf cultivation (Hossen et al. 2019a). Therefore, the present study was undertaken to determine the structure, composition, and to make an inventory of tree species of HNP. We expected the results of this study can serve as baseline information for monitoring the dynamics of tree vegetation in the national park and for developing management and conservation strategies.

MATERIALS AND METHODS

Study area

Himchari National Park (HNP) geographically lies at 21º35` to 21º44`N and 91º98` to 92º05` E and is located on the outskirts of Cox's Bazar city extending from Lighthouse para on the north to Rejhukhal on the south (Hossen et al. 2019a, 2019b). It consists of three unions namely South Mithachari, Jhillonja, and Khuniapalong union. The park area is about 1,729 ha. The Protected Forest (PF) is about 10,849 ha of which 1,729 ha core zone, 5,247 ha buffer zone, and 3,873 ha private land (Figure 1). The area lies under the tropical climate zone having monsoon rainfall and climate. Normal rainfall occurs during the month of May to September for five months. The temperature in the area varies between 14.3 ^{0}C and 31.85 ^{0}C (Hossen et al. 2019a). The hills are elevated from the south and west towards the east and the north. The landscape has a broken topography comprising of steep hills and V-shaped valleys. The topography of the park area is almost flat and undulated low rolling hills (Hossen et al. 2019a).

Sampling design

The study was conducted from January 2017 to May 2018. The composition and diversity of the tree species in Himchari National Park (HNP) were assessed through stratified random sampling methods applied separately for tree species. Considering beat (smallest administrative forest unit) area namely Chainda (62 ha), Jhilongja (450 ha), Kolatoli (872 ha), and Link Road (345 ha), the whole HNP was divided into four broad areas (1,729 ha) (Hossen et al. 2019b). Fifty-one quadrats in four sampled sites were established. The number of quadrats was fixed considering the sample plot size (20 m x 20 m) to have a sampling intensity of more than 0.117% for quantitative measurement of the tree species throughout the park area/sites. All trees in the quadrats with dbh of ≥ 5 cm were recorded and identified by expert, counted the number of individuals, and measured. The stem/tree relative density, relative frequency, relative abundance, and Importance Value Index (IVI) were calculated following Shukla and Chandal (2000). Different diversity indices were analyzed following several references (e.g. Pielou 1995; Hossen et al. 2019a, 2019c; Odum 1971) to obtain overview of tree diversity in HNP. Empirical data (height, dbh, etc.) were analyzed using MS Excel.

RESULTS AND DISCUSSION

Species richness and abundance of trees

Eighty-eight species (dbh ≥5cm) belonging to 64 genera and 37 families were recorded. The species richness was highest in the Chainda (59 species) beat and lowest in the Jhilongja beat (Table 1). The most dominant families were the Moraceae with 11 species and 2 genera followed by the Mimosaceae (8 species and 5 genera) (Table 2). Family basal area was highest in Moraceae (4.31 m^2) family followed by Mimosaceae (3.38 m^2) (Table 2).

A total of 961 individual tree stems having dbh ≥ 5cm were counted from the sampled area under the four beats (Table 2). Stem density (562 stems ha^{-1}) was highest in Kolatoli beat followed by Chainda (518 stems ha^{-1}), Link Road (379 stems ha^{-1}), and Jhilongja (368 stems ha^{-1}) (Table 1). Basal area (13.38 m^2 ha^{-1}) was highest in the Chainda beat followed by Kolatoli (12.99 m^2 ha^{-1}), Link Road (12.29 m^2 ha^{-1}), and Jhilongja (5.25 m^2 ha^{-1}).

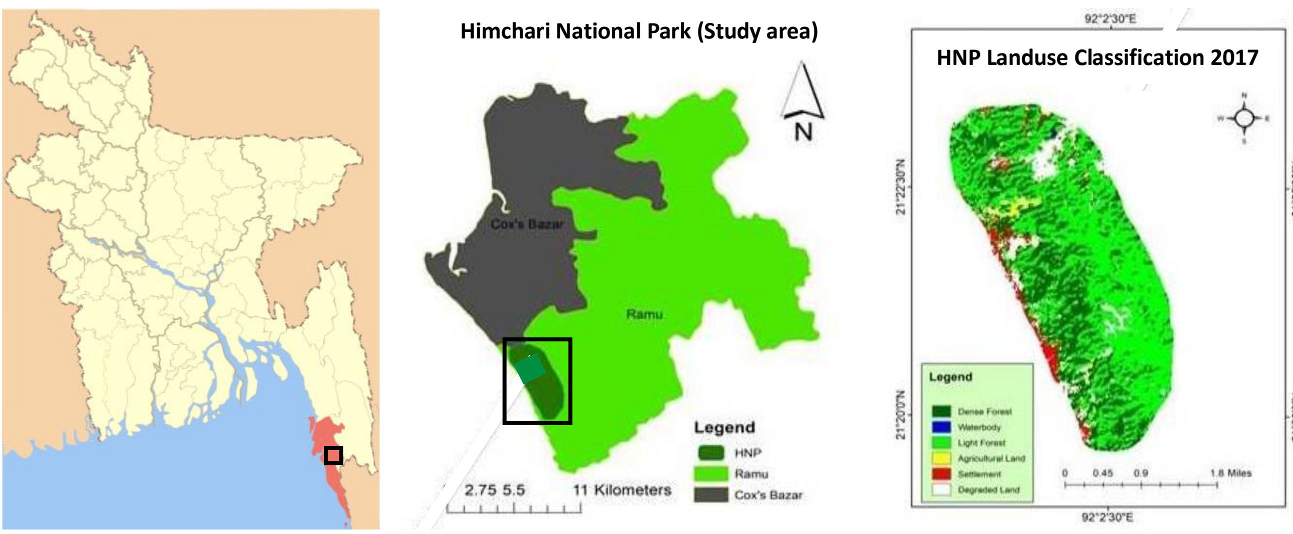

Figure 1. Location of Himchari National Park (HNP) at Cox's Bazar District, Bangladesh

Table 1. Tree species density and basal area of the trees in the four forest beats

Density and basal area	Kolatoli	Chainda	Jhilongja	Link road
No. of representing tree species	49	59	37	46
Density (Stem ha^{-1})	562	518	368	379
Basal Area (m^2 ha^{-1})	12.99	13.38	5.25	12.29

Table 2. Family basal area (m^2), number of genus, species, and number of individual tree stems

Family	Basal area (m^2)	No. of genus	No. of species	No. of individual tree stems
Anacardiaceae	1.31	2	2	47
Annonaceae	0.01	1	1	1
Apocynaceae	0.85	1	1	18
Arecaceae	0.17	1	1	2
Bignoniaceae	0.01	1	2	2
Bombacaceae	0.17	1	1	1
Burseraceae	0.02	2	2	4
Caesalpiniaceae	0.72	5	5	28
Casuarinaceae	1.41	1	1	24
Clusiaceae	0.08	1	2	4
Combretaceae	0.52	1	4	42
Dilleniaceae	0.01	1	1	2
Dipterocarpaceae	0.64	2	2	72
Ebenaceae	0.01	1	1	2
Elaeocarpaceae	0.33	1	2	17
Euphorbiaceae	0.38	2	2	24
Fabaceae	0.8	2	2	30
Fagaceae	0.01	2	2	2
Juglandaceae	0.04	1	1	3
Lauraceae	0.02	1	1	6
Lythraceae	0.26	1	2	16
Magnoliaceae	0.04	1	1	3
Meliaceae	1.0	5	5	68
Mimosaceae	3.38	5	8	168
Moraceae	4.31	2	11	89
Myrtaceae	2.55	3	5	97
Myrsinaceae	0.01	1	1	1
Oxalidaceae	0.01	1	1	2
Rhamnaceae	0.29	1	2	17
Rubiaceae	0.93	2	2	16
Rutaceae	0.01	2	2	3
Sabiaceae	0.02	1	1	2
Sapindaceae	0.01	1	1	1
Sapotaceae	0.02	1	1	2
Thymeliaceae	0.01	1	1	2
Tiliaceae	0.78	2	4	27
Verbenaceae	2.09	4	4	116
Total	23.23	64	88	961

Diversity indices

The stem density was 457.39 stems ha^{-1} and basal area was 10.979m^2 ha^{-1}. The value of species diversity index in the whole survey area was 0.092. The Shannon-Wiener's diversity index in the area was 3.733 ± 0.0071 with Shannon's maximum diversity index of 4.477. The species evenness index was 0.834. Margalef's diversity index was 12.667. Simpson's diversity index was 0.039 ± 0.0003 (Table 3).

Phytosociological characters of the tree species

The basal area, stem density, relative density, relative frequency, relative abundance, relative dominance, and Importance Value Index (IVI) of the recorded tree species are shown in Table 4. Fifteen (15) dominant tree species accounted for 59.73% of the total recorded tree individuals. The highest IVI was found for *Acacia auriculiformis* (23.23) followed by *Tectona grandis* (13.05), *Gmelina arborea* (12.66), *Syzygium fruticosum* (12.34), *Casuarina equisetifolia* (10.57), and *Dipterocarpus turbinatus* (10.55) (Table 4).

Structural composition based on height class distribution

The distribution height class shows that height range of 3 - <8 m had the highest (59.83%) percentage of tree individuals. The lowest percentage (0.62%) was represented by the height range of 23 - <28 m (Figure 2). Different height classes were found dominated by different tree species. But, *Acacia auriculiformis* was found dominating in height classes 3 - <8 m, 8 - <13 m, and 13 - <18 m, respectively. Height range 18 - <23 m was dominated by old-growth *Casuarina equisetifolia* (0.42%) followed by *Bombax insigne* (0.21%) and *Eucalyptus camaldulensis* (0.104%). Height range 23 - <28 m was also dominated by *Casuarina equisetifolia* (0.62%). It was also found that both the number of species and number of individuals decreased regularly with the increase of total tree height. Both the number of tree species and number of individuals (80 species; 575 individuals) were highest in the height range of 3 - <8 m and lowest (1 species and 6 individuals) in height range of 23 - <28 m (Figure 2).

Table 3. Density, basal area, and tree diversity indices of the Himchari National Park (HNP), Cox's Bazar District, Bangladesh

Diversity indices	Total for HNP
Density (stem ha^{-1})	457.39
Basal area (m^2 ha^{-1})	10.979
Species diversity index (SDi)	0.092
Shannon-Wiener's diversity index (H)	3.733 ± 0.0071
Shannon's maximum diversity index (Hmax)	4.477
Species evenness index	0.834
Margalef's diversity index (R)	12.667
Simpson's diversity index (D)	0.039 ± 0.0003
Dominance of Simpson's index (D')	0.961
Simpson's reciprocal index (Dr)	25.641

Table 4. Phytosociological characters of the tree species in Himchari National Park (HNP), Cox's Bazar District, Bangladesh

Botanical name	BA (m^2)	Stem no.	RD (%)	RF (%)	Rdo (%)	IVI
Acacia auriculiformis A. Cunn. ex Benth.	1.199	128	13.32	4.64	5.27	23.23
Acacia mangium Willd	0.383	14	1.46	1.03	1.68	4.17
Acronychia pedunculata (L.) Miq.	0.003	1	0.10	0.17	0.01	0.29
Albizia chinensis (Osb.) Merr.	0.115	1	0.10	0.17	0.51	0.78
Albizia lebbeck (L.) Benth. & Hook.	0.281	5	0.52	0.69	1.24	2.44
Albizia procera (Roxb.) Benth.	0.297	6	0.62	1.03	1.31	2.96
Alstonia scholaris (L.)	0.846	18	1.87	2.58	3.72	8.17
Aphanamixis polystachya (Wall.) Parker.	0.005	1	0.10	0.17	0.02	0.30
Aquilaria agallocha Roxb.	0.01	1	0.10	0.17	0.04	0.32
Artocarpus chama Buch.-Ham.	1.501	11	1.14	1.55	6.60	9.29
Artocarpus heterophyllus Lamk.	0.841	11	1.14	2.75	3.70	7.59
Artocarpus lacucha Buch.-Ham	0.111	3	0.31	0.52	0.49	1.32
Averrhoa carambola L.	0.004	1	0.10	0.17	0.02	0.29
Azadirachta indica A. Juss	0.248	18	1.87	2.06	1.09	5.03
Bombax insigne Wall.	0.172	3	0.31	0.34	0.76	1.41
Borassus flabellifer L.	0.135	1	0.10	0.17	0.59	0.87
Brownlowia elata Roxb.	0.016	5	0.52	0.86	0.07	1.45
Butea monosperma (Lamk.) Taub.	0.691	21	2.19	2.41	3.04	7.63
Caesalpinia pulcherrima (L.)	0.211	6	0.62	0.34	0.93	1.90
Callicarpa arborea Roxb.	0.028	11	1.14	1.72	0.12	2.99
Cassia fistula L.	0.109	9	0.94	1.03	0.48	2.45
Casuarina equisetifolia Forst.	1.407	24	2.50	1.89	6.19	10.57
Chukrasia tabularis A. Juss.	0.249	19	1.98	1.72	1.09	4.79
Citrus maxima (Burm.) Merr.	0.005	2	0.21	0.17	0.02	0.40
Delonix regia Rafin.	0.331	8	0.83	0.86	1.46	3.15
Dillenia scabrella Roxb. ex Wall	0.005	2	0.21	0.17	0.02	0.40
Diospyros montana Roxb.	0.007	2	0.21	0.17	0.03	0.41
Dipterocarpus turbinatus Gaertin.	0.366	43	4.47	4.47	1.61	10.55
Elaeis guineensis Jacq.	0.032	1	0.10	0.17	0.14	0.42
Elaeocarpus floribundus Blume.	0.003	1	0.10	0.17	0.01	0.29
Elaeocarpus tectorius (Lour.) Poir	0.329	16	1.66	2.58	1.45	5.69
Engelhardtia spicata Leschen ex Blume	0.037	3	0.31	0.34	0.16	0.82
Erythrina variegata L.	0.114	10	1.04	0.86	0.50	2.40
Eucalyptus camaldulensis Dehnhardt.	0.672	22	2.29	1.72	2.95	6.96
Ficus auriculata Lour.	0.033	2	0.21	0.34	0.15	0.70
Ficus benghalensis L.	0.493	3	0.31	0.52	2.17	2.99
Ficus benjamina L.	0.046	1	0.10	0.17	0.20	0.48
Ficus hispida L.f.	0.436	36	3.75	4.30	1.92	9.96
Ficus lamponga Miq.	0.127	1	0.10	0.17	0.56	0.83
Ficus lanceolata Buch.-Ham. ex Roxb.	0.007	1	0.10	0.17	0.03	0.31
Ficus microcarpa L.f.	0.128	2	0.21	0.34	0.56	1.11
Ficus racemosa L.	0.024	1	0.10	0.17	0.11	0.38
Ficus religiosa L.	0.559	8	0.83	1.37	2.46	4.66
Garcinia cowa Roxb. ex DC.	0.082	4	0.42	0.52	0.36	1.29
Garuga pinnata Roxb.	0.013	2	0.21	0.34	0.06	0.61
Gmelina arborea Roxb.	0.836	55	5.72	3.26	3.68	12.66
Grewia nervosa (Lour.) Panigrahi	0.318	22	2.29	2.92	1.40	6.61
Hopea odorata Roxb.	0.014	1	0.10	0.17	0.06	0.34
Lagerstroemia speciosa (L.) Pers.	0.264	16	1.66	2.06	1.16	4.89
Lannea coromandelica (Houtt.) Merr.	0.078	6	0.62	1.03	0.34	2.00
Lepisanthes rubiginosa (Roxb.) Leenh	0.002	1	0.10	0.17	0.01	0.28
Leucaena leucocephala (Lamk.) de Wit	0.006	1	0.10	0.17	0.03	0.30
Lithocarpus elegans (Blume) Hatus.ex Soepad	0.004	1	0.10	0.17	0.02	0.29
Lithocarpus polystachya (Wall.ex A.DC.) Rehder	0.007	1	0.10	0.17	0.03	0.31
Litsea glutinosa (Lour.) C.B. Robinson	0.013	6	0.62	0.86	0.06	1.54
Macaranga denticulata (Bl.)Muell.-Arg.	0.008	3	0.31	0.34	0.04	0.69
Macaranga indica Wight	0.002	1	0.10	0.17	0.01	0.28
Mangifera indica L.	0.908	29	3.02	3.26	3.99	10.27
Mangifera sylvatica Roxb.	0.321	13	1.35	2.23	1.41	5.00
Meliosma simplicifolia (Roxb.)Walp.	0.006	2	0.21	0.17	0.03	0.41
Michelia champaca L.	0.035	3	0.31	0.52	0.15	0.98
Mimusops elengi L.	0.021	2	0.21	0.17	0.09	0.47
Mitragyna parvifolia (Roxb.) Korth	0.024	4	0.42	0.69	0.11	1.21

Neolamarckia cadamba (Roxb.) Bosser	0.904	12	1.25	1.89	3.97	7.11
Phyllanthus emblica L.	0.368	22	2.29	2.92	1.62	6.83
Polyalthia longifolia (Sonn.)	0.011	1	0.10	0.17	0.05	0.32
Protium serratum (Wall. ex.Colebr.) Engl.	0.007	2	0.21	0.34	0.03	0.58
Psidium guajava L.	0.111	26	2.71	3.61	0.49	6.80
Samanea saman (Jacq.) Merr.	1.055	12	1.25	1.55	4.64	7.43
Senna siamea (Lamk.)	0.035	2	0.21	0.34	0.15	0.71
Shorea robusta Roxb. ex Gaertin. f.	0.258	28	2.91	2.23	1.13	6.28
Sterculia villosa Roxb. ex Smith	0.004	1	0.10	0.17	0.02	0.29
Stereospermum colais (Buch.-Ham. ex Dillw)	0.015	1	0.10	0.17	0.07	0.34
Stereospermum suaveolens (Roxb.)	0.014	1	0.10	1.89	0.06	2.06
Swietenia mahagoni Jacq.	0.486	28	2.91	2.06	2.14	7.11
Syzygium cumini (L.) Skeels	0.178	7	0.73	0.69	0.78	2.20
Syzygium firmum Thw.	0.211	15	1.56	2.41	0.93	4.89
Syzygium fruticosum DC	1.377	29	3.02	3.26	6.05	12.34
Tamarindus indica L.	0.032	4	0.42	0.69	0.14	1.24
Tectona grandis L.f.	1.222	49	5.10	2.58	5.37	13.05
Terminalia arjuna (Roxb. ex Dc.) Wight & Am.	0.277	33	3.43	2.06	1.22	6.71
Terminalia bellirica (Gaertin.) Roxb.	0.093	2	0.21	0.34	0.41	0.96
Terminalia catappa L.	0.018	1	0.10	0.17	0.08	0.36
Terminalia chebula Retz.	0.147	6	0.62	0.86	0.65	2.13
Toona ciliate Roem.	0.009	4	0.42	0.17	0.04	0.63
Vitex peduncularis Wall. ex Schauer in A.DC.	0.003	1	0.10	0.17	0.01	0.29
Xylia xylocarpa Roxb. Taub.	0.048	1	0.10	0.17	0.21	0.49
Ziziphus mauritiana Lamk.	0.287	17	1.77	2.23	1.26	5.26
	22.748	961	100	100	100	300

Note: BA: Basal Area, RD: Relative Density, RF: Relative Frequency, RDo: Relative Dominance and IVI : Importance Value Index

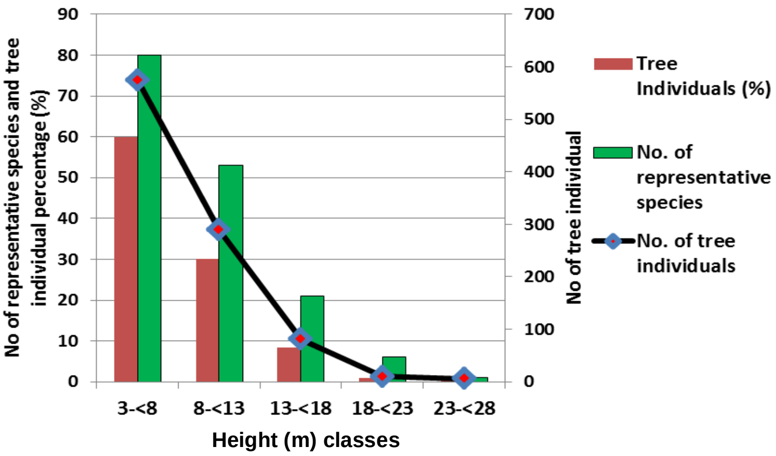

Figure 2. Distribution of tree species and individual number in different height (m) classes of Himchari National Park (HNP), Cox's Bazar District, Bangladesh

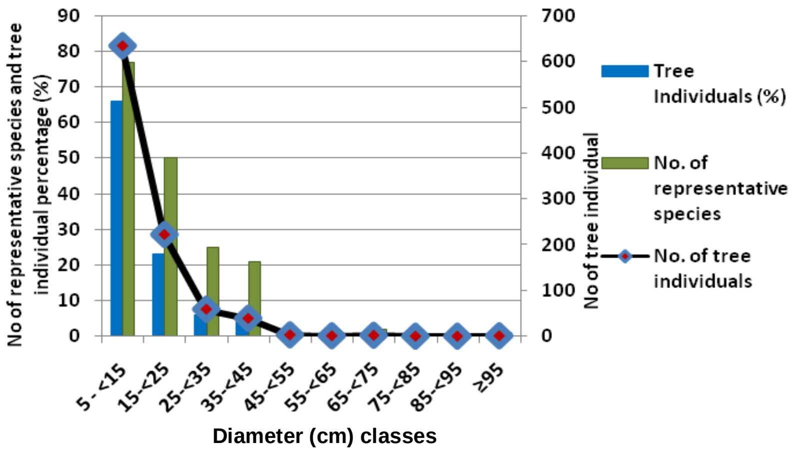

Figure 3. Distribution of tree species and individual number in different dbh (cm) classes of Himchari National Park (HNP), Cox's Bazar District, Bangladesh

Structural composition based on diameter class distribution

The distribution of dbh classes shows that most of the trees (65.97%) belonged to dbh range 5 - <15 cm. Different tree species were found to dominate in different dbh classes. But, dbh range 5 - <15 cm was dominated by *Acacia auriculiformis* (11.34%) followed by *Gmelina arborea* (4.99%). The number of species and tree individuals was found to decrease with increasing diameter with very little exception. Both the tree species and individuals were the highest (77 species and 634 individuals) in 5 - <15 cm dbh range (Figure 3). As the dbh increased, both the number of species and number of tree individuals decreased.

Discussion

Tree species abundance

The tree species composition of HNP found in 51 quadrats (88 tree species, 64 genera, 37 families) was higher than many tropical forests, i.e. 38 tree species in Ukhia Range of Cox's Bazar (Ahmed and Haque 1993), 50 tree species belonging to 28 families in Rampahar Natural Forest (Malaker et al. 2010), 78 tree species in Lawachara forest (Malaker et al. 2010), 85 tree species in Sitapahar Reserve forest of Chittagong Hill Tracts (South) Forest Division (Nath et al. 1998), 85 tree species in Bamu reserve forest of Cox's Bazar (Hossain et al. 1997), and 62 tree species in Tankawati natural forest (Motaleb and Hossain 2011). However, the tree species diversity was comparatively lower than 150 tree species in Teknaf Wildlife Sanctuary (Uddin et al. 2013), 151 tree species in Inani Protected Forest (Nath et al. 2000), 143 tree species in Teknaf Wildlife Sanctuary (Feeroz 2013), 92 tree species in Chunati Wildlife Sanctuary (Rahman and Hossain 2003) and 400 tree species in the forests of Sylhet (Alam 2008) in Bangladesh. However, considering the results of these similar studies, it can be inferred that the HNP possesses comparatively well-diversified natural forests with higher number of tree species.

The stem density (457.39 stems ha^{-1}) ranks highest in comparison to 381 stems ha^{-1} (but it was >10 cm diameter) in Sitapahar reserve forest of Chittagong Hill Tracts (South) Forest Division (Nath et al. 1998), 257 stems ha^{-1} in Ukhia Natural Forests of Cox's Bazar (Ahmed and Haque 1993) 369 stems ha^{-1} (10 cm and above) in Bamu reserve forests of Cox's Bazar (Hossain et al. 1997), but lower than 709 stems ha^{-1} in Tropical Forest of Eastern Ghats, India (Reddy et al. 2011).

Basal area and diversity indices

From the value of basal area, it seems that the trees in the HNP were large in diameter. The basal area (10.979 m^2 ha^{-1}) of HNP was much lower than that of 53.5 m^2 ha^{-1} in Sitapahar reserve forests of Chittagong Hill Tracts (South) Forest Division (Nath et al. 1998) or 47.02 - 62.16 m^2 ha^{-1} in Tankawati natural forest of Chittagong South Forest Division (Motaleb and Hossain 2011). The lower basal area indicates that the forest area was suffering from illegal felling of mature trees. The lower species diversity index (0.092) indicates the lower number of species with respect to the total number of individuals of all species. The Shannon-Wiener's diversity index (3.733 ± 0.0071) and Shannon's maximum diversity index (4.477) indicate that even though the HNP was under serious threats, the forests still had a reasonable floristic diversity which needs effective conservation measures for sustainable management. The value of Margalef's diversity index (12.667) indicates proficient presence of tree species in the area. Lower value of Simpson's index (0.039 ± 0.0003) also indicates the diverse tree species.

Phytosociological characters of the tree species

The IVI value indicates a complete picture of phytosociological character of a species in the community (Hossain et al. 2004). *Acacia auriculiformis* possessed the highest IVI values (23.23) followed by *Tectona grandis* (13.05), *Gmelina arborea* (12.66), *Syzygium fruticosum* (12.34), *Casuarina equisetifolia* (10.57), *Dipterocarpus turbinatus* (10.55). *Acacia auriculiformis* had the highest IVI value among planted tree species as well as considering all species indicating that the number of tree species was declining.

The Shannon-Wiener diversity index (3.733) was higher than that of 2.98 in Sithapahar reserve forest (Nath et al. 2000) or 3.25 in Tankawati natural forest of Chittagong (South) Forest Division, but lower than that of 4.27 of Garo Hills of India (Ahmed and Haque 1993). The value of Shannon-Wiener index (3.733), Margalef's index (12.667), and lower value of Simpson's index (0.039) represent the higher diversity in HNP. These values indicate that the restoration and recolonization program of native tree species is essential as to recover the native tree species.

Structural composition based on height class distribution

Patterns of height (m) class distribution designate general trends of population dynamics and recruitment process to the maximum species in HNP. Considering the other previous studies, distribution of individuals among different height classes showed a reverse J-shaped curve that indicates presence of more or less stable population structure or good regeneration status. That means, as the height class increases, the number of individuals and species are decreasing and indicates that old, mature trees are very scarce in the study area.

Structural composition based on diameter class distribution

Distribution of individuals among different dbh (cm) classes showed a reverse J-shaped curve that indicates progressive decrease of tree individuals in larger tree size classes. The number of species and percentage of tree individuals was maximum in the lower dbh (cm) ranges and the number of tree individuals was progressively decreasing with the increase of dbh (cm). As the dbh increased, both the number of species and number of tree individuals decreased showing successful recruitment of some native species. It also indicates incidence of illegal felling of more or less mature trees, and economically important trees and land-use changes in the National Park. The higher number of trees in lower size classes also indicates recent initiatives for conservation, protection, and improvement of the national park.

In conclusion, this study concluded that although the forest in Himchari National Park had been degraded severely, but it harbors a rich diversity of plant species, and the advancement of gradual restoration process initiated after massive anthropogenic disturbances through both artificial and natural means are essential to bringing back the native tree species in HNP. A proper strategy for conservation and management in the study area is required for the best utilization of HNP tree species by the local villagers.

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Rate of timber harvest and the effects of illegal activities on forest conservation in Southwestern Nigeria

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Abstract. *Daramola JO, Adesuyi FE, Olugbadieye OG, Akinbowale AS, Adekunle VAJ. 2020. Rate of timber harvest and the effects of illegal activities on forest conservation in Southwestern Nigeria. Asian J For 5: 8-16.* Availability of accurate data on timber harvest is very important for sustainable forest management. These data are not readily available, making forest management more complex. This study aimed at investigating the rate of timber harvest, illegal activities and its impacts on forest conservation in Osun State Forest Reserves. The selected reserves were Shasha Forest Reserve (SFR), Ago-Owu Forest Reserve (AFR), and Ikeji-Ipetu Forest Reserve (IFR). Data were collected using two sets of semi-structured questionnaires. One for the forest community dwellers and the other for forest officers. Simple random sampling was used to select 120 respondents from the population of concessionaires, saw millers, rural community dwellers, taungya farmers, and the government officers in the study area. Secondary data was collected and compiled from the State Forestry Department to provide results for timber harvested only in SFR from January to July 2019. The results revealed that SFR is under massive timber exploitation as illegal logging and timber processing are the most prevalent driver of exploitation in this area; while AFR and IFR are degraded forest reserves marred with grazing and poaching, and illegal logging, respectively. The impacts of the illegal activities on forest conservation were categorized under economic, social, and environmental impacts. The most exploited species in SFR were *Celtis* spp. (3024 stems), *Ricinodendron heudelotii* (1789 stems), and the least exploited was *Anthocleista* spp. (3 stems). The study showed that many economic tree species that contribute to national development and rural livelihood have been exploited from the study sites and therefore recommend that timber harvesting should be carried out on a sustainable basis.

Keywords: Conservation, illegal activities, timber harvest

INTRODUCTION

The International Union for the Conservation of Nature (IUCN) describes a conserved area as "an area of land and/or sea particularly dedicated to the maintenance and protection of biodiversity, and of cultural and associated natural resources which are managed through lawful or other effective means". The conservation areas could be in-situ or ex-situ conserved areas. In-situ conserved areas include forest reserves, game reserves, biosphere reserves, strict nature reserves, sacred grooves, national parks, etc., while ex-situ are zoological gardens, forest herbarium, botanical gardens, seed stock or gene banks, etc.

Reservation of Nigerian forest estates started in 1901 with the promulgation of the Forestry Ordinance and creation of a Forestry Department run by conservators of forests (Imasuen et al. 2013). Under most of the forestry laws and edicts, the Federal and State governments are backed by law to conserve and protect the resources of forest estates from illicit exploitation (Imasuen et al. 2013). However, nowadays most of conservation reserves could not be accounted for due to the progression of corruption in the Nigerian government, which has paved the way for people to encroach on the reserves, thereby facilitating uncontrollable rate of logging activities.

The logging activities remained lucrative for some people with its related forest degradation and deforestation right from the colonial era (Adekunle et al. 2010). It encompasses tree felling, de-branching, skidding, loading, and primary transportation (Adekunle and Olagoke 2010). Each of the above activities has significant impacts on many people's livelihoods (Adekunle and Olagoke 2010) and the impacts are more devastating when logging activities are conducted illegally through unauthorized operations. As a consequence of the illegal actions, the loggers and concessionaires have refused to strictly adhere to the logging policies and laws enforced by the State Department of Forestry. Challenges such as illegal forest activities along with clearance of forest for agriculture, road construction and plantation establishment, uncontrolled exploitation, poor organization and funding of the forestry subsector (Adekunle 2006), population and industrial growth, and advanced civilization and politicization of the traditional laws which have made the traditional rulers abandon the custom and practice of forest, pose a serious threat to forest conservation in the country today (Adetula 2008).

Nigeria once had an extensive distribution of the tropical rainforest, which covers up to 45% of the country's landmass (WRI 2003). Most of this is now lost due to the above-mentioned challenges. This continuous loss of forest lands has led to many biodiversity crises and climatic issues in the nation, even globally. As one of the important components of the tropical forest, tree species are fundamental to rainforest biodiversity (Olawoyin et al.

2020). Hence there is a need to research the rate of timber harvesting and the effect of illegal activities on forest biodiversity and conservation. This research is important to be carried out as causes of frequent loss of forest reserves in the study area were strictly dealt with and the current status of forest conserved areas was made open to the residents of the areas. All of these were tailored towards opening the eyes of the bodies concerned with measures and policies to be taken by them to prevent further loss of forest in conserved areas in Nigeria.

MATERIALS AND METHODS

Study area

This work was carried out in communities located around Shasha Forest Reserve, Ago-Owu Forest Reserve, and Ikeji Ipetu Forest Reserve (Figure 1).

Shasha Forest Reserve (SFR)

SFR is located at 7.0935° N, 4.4182° E with an elevation of 146 m above sea level in Osun State, Southwestern Nigeria. SFR shares boundaries with Omo Forest Reserve on the west. The eastern and northern boundaries are with Oluwa Forest Reserve and Ife Native Authority Reserve in Ondo and Osun States respectively. The total size of the reserve land is currently 23,064 ha. Out of this, about 1,523 ha are under plantation of various species such as *Pinus* spp., *Nauclea diderichii*, *Gmelina arborea, Tectona grandis,* and *Terminalia* spp. The remaining 21,541 ha is currently dominated by degraded natural forests characterized by broken canopy. The reserve is subdivided into two major areas: Areas 4 and 5. There are about forty communities within and around the Forest Reserve. Their population ranges from 200 to 2000 inhabitants.

Ago-Owu Forest Reserve (AFR)

Ago-owu forest reserve was one of the functional forests situated under Isokan local Government, Osun State, Nigeria. It is located at 7.1929° N, 4.1207° E with an elevation level of 204 m above sea level. AFR is in a thick forest zone and it consists of 32,116 ha in the high forest area. The land area was originally 30,725 ha, but later approximately 3,522 ha was de-reserved by the then Government of Oyo state to the Coco Development unit, which was named Ago-Owu farm settlement. The working area now remains approximately 27,203 ha. The major occupations of the people in the area are farming, trading, sawmilling, and civil servicing. There are forest adjoining communities in and around the reserve. They include Mokore, Araromi Owu, Ajegunle, Alabameta, Elewe, Alaguntan, and Okodowo, in which the majority of the dwellers are farmers.

Ikeji-Ipetu Forest Reserve (IFR)

IFR is also known as Ikeji Forest Reserve and located at 7.400000°N, 4.933333°E with an elevation of 342 m above sea level. It covers 4849 ha of land. Communities located very near to the reserve include Orisunbare, Apoti, Ayetoro, Ikeji, etc. The major occupations of the people in the area include farming, trading, sawmilling, civil servicing, etc.

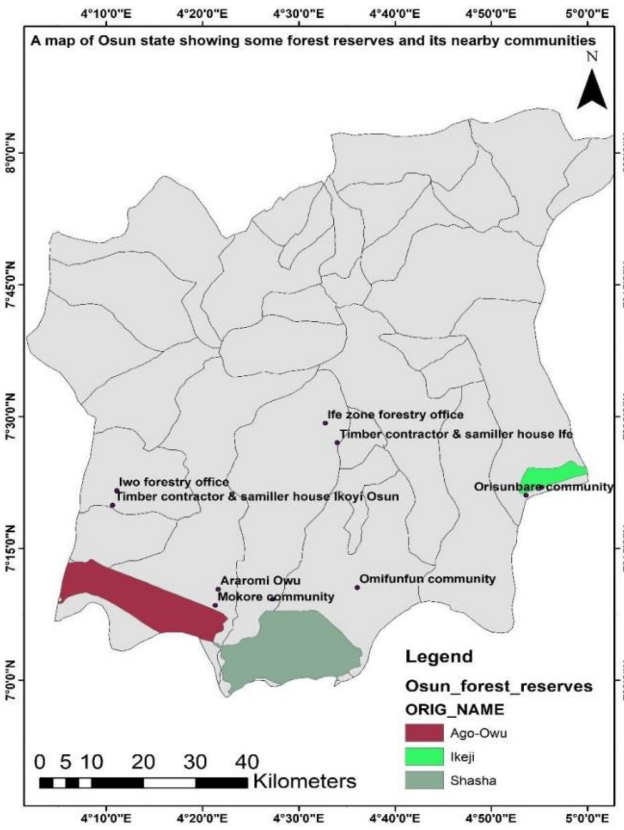

Figure 1. Map of Osun state (Nigeria) showing the forest reserves and the sampled communities

Method of data collection

Three forest reserves, which are SFR, AFR, and IFR, were purposefully selected based on their functionality. Two nearby forest communities were also randomly selected from each of the selected Forest Reserves. During the study, targeted respondents were forest officers of each Forest Reserve, saw millers, timber contractors, and taungya farmers in each selected forest community. To reach the contractors and saw millers that were few in the nearby communities, one closest community to the city (where timber contractors, saw millers and taungya farmers could be reached) was selected from the selected reserves to make a total of nine forest communities. The communities selected from SFR were Omifunfun, Araromi Oke Odo, and Ile Ife; AFR were Mokore, Araromi Owu, and Ikoyi Osun; IFR includes Orisunbare, Apoti Ayetoro, and Ilesa. List of questions is shown in Appendix 1 and 2.

Pre-tested and validated semi-structured questionnaire was used to obtain information from ten (10) randomly selected respondents in each selected Forest Reserves and in each sampled forest community to make a total of one hundred and twenty (120) respondents in the study. Finally, secondary data was collected from Osun State Forestry Department, and compiled to determine the rate of logging in SFR between January to July 2019.

Method of data analysis

Descriptive statistics were carried out on the administered questionnaire using Statistical Package for Social Sciences (SPSS) and Microsoft Excel. The expected results were presented in the form of bar charts, frequency and percentage distribution tables.

RESULTS AND DISCUSSION

Profiles of the respondents

The socio-economic information of the respondents sampled from the selected communities is presented in Table 1, while the cadre of the forest officers sampled from the selected reserves is presented in Table 2.

Table 1. Social-economic information of the respondents sampled from selected forest communities

Variable	SFR		AFR		IFR	
Age range (Years)	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**
0-20	1	3.3	2	6.7	1	3.3
21-40	13	43.3	11	36.7	12	40
41-60	13	43.3	12	40	12	40
>60	3	10	5	16.7	5	16.7
Total	30	100	30	100	100	100
Variable	**SFR**		**AFR**		**IFR**	
Respondents	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**
Saw miller	5	16.7	4	13.3	7	23.3
Timber contractor	7	23.3	6	20	4	13.3
Taungya farmer	18	60	20	66.7	19	63.3
Total	30	100	30	100	30	100
Variable	**SFR**		**AFR**		**IFR**	
Experience level (Years)	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**
0-5	1	3.3	2	6.7	5	23.3
6-10	2	6.7	3	10	13	43.3
11-20	9	30	10	33.3	4	13.3
21-30	12	40	8	26.7	2	6.7
> 31	6	20	7	23.3	4	13.3
Total	30	100	30	100	30	100
Variable	**SFR**		**AFR**		**IFR**	
Year of residence	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**	**Freq.**	**Percent (%)**
0-5	2	6.7	1	3.3	9	30
6-10	3	10	4	13.3	2	6.7
11-20	6	20	7	23.3	10	33.3
21-30	9	30	4	13.3	4	13.3
>30	10	33.3	14	46.7	5	16.7
Total	30	100	30	100	30	100

Note: SFR-Shasha forest reserve, AFR-Ago-Owu Forest Reserve, IFR- Ikeji Ipetu Forest Reserve

Table 2. Cadre of officers across the sampled Forest Reserves

Cadre	Frequency	Percentage (%)
Principal Forest Superintendent	1	4.5
Senior Forest Superintendent	3	13.6
Higher Forest Superintendent	5	22.7
Forest Superintendent	2	9.1
Forest Ranger	3	13.6
Forester	7	31.8
Forest Guard	1	4.5
Total	22	100

The level of experience of the forest officers across the selected reserves ranges from 1-5 (18.2%), 6-10 (40.9%), to 11-20 (40.9%) years.

Types of illegal activities in Osun State Forest Reserves

Types of illegal forest activities in the communities sampled are presented in Figure 2 and Table 3 respectively. Figure 2 accounts only for the proportion of respondents who claim that each of the illegal forest activities serves as a barrier in the study area, while Table 3 shows percentage of both claims. According to the respondents from the sampled communities, it is obvious that illegal occupation of forest reserve land, grazing, and poaching, and illegal Non-Timber Forest Products (NTFPs) exploitation is common most in AFR with 40%, 80%, and 40% values respectively; illegal timber processing, and illegal logging are also common in SFR with 63.3% and 56.7% values respectively; while timber smuggling is the most rampant in IFR with 43.3% value.

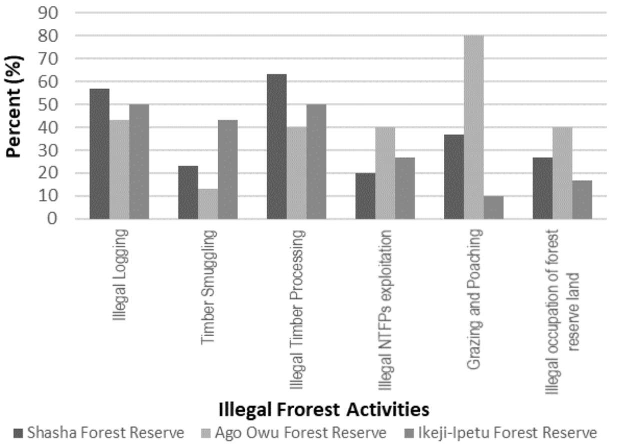

Figure 2. Illegal forest activities across the sampled communities

Table 3. Illegal forest activities common to forest reserves based on forest officers' claim

Illegal forest activities in Osun State	Yes (%)	No (%)
Illegal logging	72.7	27.3
Timber smuggling	18.2	81.8
Illegal timber processing	40.9	59.1
Practices specifically aimed at reducing payment of taxes and other fees	18.2	81.8
Illegal NTFPs exploitation	22.7	77.3
Illegal occupation of forest reserve land	9.1	90.9

Economic, social and environmental impacts of illegal forest activities on forest conservation in Osun State

The result of the economic, social, and environmental impacts of illegal forest activities on forest conservation highlighted by the sampled communities and the forest officers' claim are identified in Figure 3 and Table 4 respectively. Figure 3 accounts only for the proportion of respondents attesting to economic, social, and environmental loss as a result of the illicit forest activities in the study area, while Table 4 shows the percentage of both claims.

Across the communities sampled, it can be inferred that reduction in the revenue generated by the reserves is the most prevalent economic impact of illegal activities across SFR, AFR, and IFR with 53.3%, 43.3%, and 63.3% values respectively. Also, the result of social impacts of illicit forest activities on forest conservation across the communities sampled shows that large scale job losses mostly by the contractors are on the higher rate in AFR with 56.7% value; restricted access by local communities to forest products that provide income for small-scale local business is rampant in SFR with 36.3% value; land-use conflicts stemming from allocation of timber concession was identified most in SFR with 43.3% value; while restricted access to forest materials, including food, that is essential to the welfare of the rural people was rampant in IFR with 40% value.

Furthermore, it can be deduced from the result on environmental impacts of illicit forest activities highlighted by the respondents across the sampled communities that conversion of forest lands to agricultural lands is the most rampant across SFR, AFR, and IFR with 83.3%, 80%, and 60% values respectively, while the least environmental impact across the sampled communities is health impacts and increase in greenhouse gas emission with 6.7%, 20%, and 26.7% respectively.

Family distribution of tree species and their stems number

The family distribution of tree species exploited from SFR from January to July 2019 is presented in Table 5. The total number of families exploited is 17 with Fabaceae and Malvaceae having the highest species number (eight tree species each) and the total number of stands removed being 518 stems and 3272 stems respectively. This is followed by *Annonaceae* with five species (total of 973 stems) and Moraceae with four species (total of 364 stems). The total number of tree species exploited during this period was 41 tree species and 12161 stems, excluding trees without botanical names. Also, the tree species exploited most is *Celtis* spp. (3024 stems) belonging to the family Cannabaceae, while the least exploited is *Anthocleista* spp. (3 stems) from the family *Gentianaceae*. The remaining reserves have been exploited.

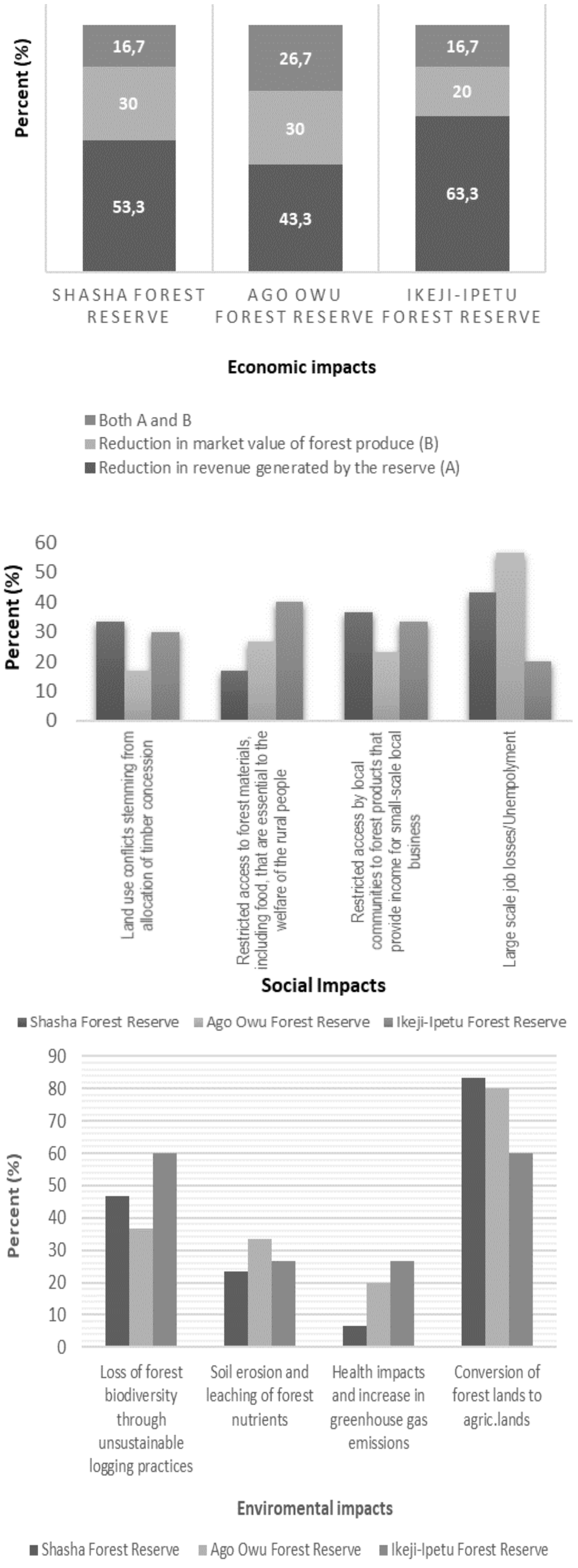

Figure 3. Economic, social and environmental impacts of illegal activities based on the sampled communities

Table 4. Economic, social and environmental impacts of illegal activities based on forest officer's claim

Economic impacts on forest conservation	Yes (%)	No (%)
Reduction in revenue generated by the reserve (A)	68.2	31.8
Reduction in market value of forest produce (B)	22.7	77.3
Both A and B	9.1	90.9
Social impacts of illegal forest activities		
Land-use conflicts stemming from allocation of timber concession	22.7	77.3
Restricted access to forest materials, including food, that are essential to the welfare of the rural people	59.1	40.9
Restricted access by local communities to forest products that provide income for small-scale local business	22.7	77.3
Large scale job losses/Unemployment	13.6	86.4
Environmental impacts of illegal forest activities		
Loss of forest biodiversity through unsustainable logging practices	36.4	63.6
Soil erosion and leaching of forest nutrients	27.3	72.7
Health impacts and increase in greenhouse gas emissions	4.5	95.5
Conversion of forest lands to agriculture. lands	59.1	40.9

Table 5. Family distribution of tree species exploited and their stems number

Family	Tree species names	No. of stands	Total no. of stands
Annonaceae	*Cleistopholis patens*	438	973
	Monodora myristica	56	
	Alstonia spp.	213	
	Funtumia elastic	262	
	Holarrhena floribunda	4	
Arecaceae	*Borassus aethiopum*	52	52
Boraginaceae	*Cordia millenii*	798	798
Cannabaceae	*Celtis* spp.	3024	3024
Combretaceae	*Anogeissus leiocarpa*	27	394
	Terminalia superba	367	
Euphorbiaceae	*Ricinodendron heudelotii*	1789	1789
Fabaceae	*Afzelia Africana*	43	518
	Amphimas pterocarpoides	78	
	Albizia spp.	132	
	Berlinia confuse	47	
	Brachystegia spp.	119	
	Daniellia oliveri	4	
	Erythrophleum spp.	77	
	Parkia biglobosa	18	
Gentianaceae	*Anthocleista* spp.	3	3
Irvingiaceae	*Irvingia gabonensis*	104	104
Lamiaceae	*Vitex doniana*	74	74
Malvaceae	*Bombax buonopozense*	86	3272
	Ceiba pentandra	136	
	Cola spp.	407	
	Mansonia altissima	21	
	Nesogordonia papaverifera	283	
	Pterygota macrocarpa	278	
	Sterculia spp.	1655	
	Triplochiton scleroxylon	406	
Meliaceae	*Entandrophragma* spp.	14	98
	Khaya spp.	67	
	Trichilia monadelpha	17	
Moraceae	*Antiaris africana*	27	364
	Artocarpus altilis	13	
	Ficus spp.	292	
	Milicia excels	32	
Myristicaceae	*Pycnanthus angolensis*	168	168
Rubiaceae	*Nauclea diderrichii*	25	25
Sapindaceae	*Blighia* spp.	82	82
Sapotaceae	*Chrysophyllum albidum*	423	423

Note: *Data source: Department of Forestry, Ife, Osun State.

Rate of logging in Shasha forest reserve between January to July 2019

The compilation of the total number of species and the total number of stems harvested in SFR for the seven consecutive months in 2019 are given in Figure 4. The number of stems removed is the highest in April, February, and March with 2388 stems, 2380 stems, and 1959 stems respectively.

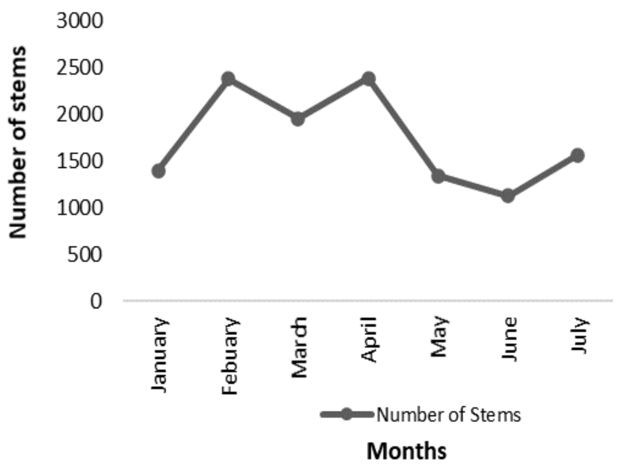

Figure 4. Rate of timber exploitation from January to July 2019 in Shasha Forest Reserve

Discussion

Due to lack of management planning, timber exploitation in the tropical rainforest ecosystem has become deleterious to environmental and biodiversity conservation over the years. The continuous exploitation in this ecosystem has led to an increased rate of timber harvesting, which is detrimental to the achievement of the objectives of sustainable forest management in Nigeria (Adekunle et al. 2010). The findings of this study were based on information provided by the respondents and available official documents, annual reports, and files in the state forestry service between January to July 2019. All the logging data for previous years 2018, 2017, etc. were not precise, since the track record of what is logged in the forest was not properly kept. However, logging data before the time of data collection (late July) was provided, might be as a result of new policy within the state ministry. The targeted respondent with the most output was the rural community dwellers across the reserves. The cadre of the forest officers from which information was also obtained showed that Forester has the highest number of respondents, while the Principal Forest Superintendent is the least.

The study showed that Shasha Forest Reserve is under massive timber exploitation. Illegal logging and timber processing are the most common drivers of exploitation in this area; while Ago-Owu and Ikeji-Ipetu Forest Reserve are degraded forests reserves marred with grazing and poaching, and illegal logging, respectively. Other illegal forest activities include illegal NTFPs exploitation, timber smuggling, etc. This result conforms with the findings of Adekunle et al. (2010), who reported that illegal logging in many developing countries is very widespread to the point that what is illegally taken from the forest estate may be much more than what is legally extracted. As a consequence of this action, both Ago-Owu and Ikeji-Ipetu Forest Reserve have been overexploited and few scattered trees could only be accounted for in the forest, except for *Gmelina arborea* and *Tectona grandis* that were planted. Although Ikeji-Ipetu Forest reserve is gradually regenerating, thereby has a chance of replacing the exploited trees in the future. Nevertheless, the regenerating trees may not become better-graded timber due to the trees' damage during the felling and transportation of the exploited trees. However, some tree species that are slightly wounded can recover from the stress inflicted during logging (Adekunle, Olagoke 2010).

The economic, social, and environmental impacts of the illegal activities across the sampled communities and selected reserves are in accordance with the work of Callister (1999) that illegal activities in the forestry sector have a range of negative impacts and this can either be economic, social, and environmental impacts. Economic impacts identified in this study involve a reduction in the market value of forest produce and reduction in revenue generated by the reserve, with most emphasis on the latter impact accounts for 63.3%, 53.3%, and 43.3% in IFR, SFR, and AFR. This complements Kaimowitz (2003) findings, who argue that illegal forestry practices deprive the government of a substantial amount of financial resources in tax revenues. According to a World Bank report (2006), it was estimated that illegal timber logging causes a loss of approximately US$15 billion every year (the legal forest industry loses more than US$10 billion while governments lose about US$5 billion in revenues). In a recent report (UNEP/INTERPOL 2012), this value has increased between two folds and 6.7-folds, that is, the economic value of global illegal timber logging, including processing, is now estimated to be worth between US$30 and 100 billion, or 10-30 % of the global wood trade.

The continuous decline in the revenue generated by the reserve does not seem to stop soon, and this has brought a huge economic loss and a negative impact in Nigeria and across the world due to lack of coherent and consistent forest policy, excessive bureaucracy in harvest management, poorly defined property rights, non-transparent allocation of concessions, corrupt government officials in charge of log control, over-capacity utilization in some timber industries, use of outdated management practices and inefficient log tracking system and rural poverty (Swan 2013).

Social impacts revealed that restricted access to forest materials including food that is essential to the welfare of the rural people was rampant in IFR while restricted access by local communities to forest products that provide income for small-scale local business and land-use conflicts stemming from allocation of timber concession were mostly common SFR. The restricted access of forest material in IFR and SFR can be as a result of over-reliance of the rural community dweller on provisioning services of the forest (food, raw material, etc.) and timber which if not properly checked can further lead to heavy decline of the ecosystem functioning of the forest and more illegal activities (Obasi et. al. 2015). However, large-scale job losses/ unemployment by the contractors is at a higher rate in AFR. These are all similar to the report of the Department of Forestry and Wildlife (1998) in Cambodia.

The environmental impact of illegal harvest from the result shows that the conversion of forest lands into agricultural lands is ranked highest which is about 59.1%. However, this can be attributed to the problem of food insecurity and reduction in food production caused by poverty in the state. Poverty is seen as a major problem in many developing countries in the world, including Nigeria. It is described as a vicious cycle, causing hunger and malnutrition, and is aggravated by rapid population growth. The causes of poverty have been linked to food insecurity in the state (Fasoyiro and Taiwo 2012). Food insecurity among rural and low-income urban households is 71 % and 79 %, respectively (Orewa, Iyangbe 2010), and such households have limited economic and physical capacity to sustain their present level of wellbeing or cope with economic shocks (IFPRI 2008). As a strategy to survive and to be able to meet the ends, the community dwellers result in the conversion of forest lands into agricultural land. Other identified environmental impacts from these studies include loss of forest biodiversity, soil erosion, and leaching of soil nutrients. The negative economic, social, and environmental impacts of logging are severe. Continuous harvesting without appropriate restoration strategies would result in forests that are structurally and genetically degraded, which are highly difficult and costly to rehabilitate (Adekunle et al. 2010)

A total number of 12,409 stems have been removed across 41 tree species, including stems with no tree species scientific names, in SFR. What has been removed has exceeded the forest's natural capacity to recover and resume its normal functions. The highest number of species exploited, *Celtis* spp., *Ricinodendron heudelotii*, *Sterculia* spp., comply with the argument of Oyagade (1997), that due to the worsening shortages of the primary species like Iroko, Mahogany, etc. lesser utilized species such as *Celtis* spp., *Ceiba pentandra*, *Brachystegia* spp., etc. are now becoming available in the market. Also, the four most diverse families were Fabaceae (eight stems), Malvaceae (eight stems), Annonaceae (five stems), and Moraceae (four stems), which partly conform with the report by Akinyemi and Oke (2014), that Euphorbiaceae, Moraceae, Papilonaceae and Rubiaceae were the overall diverse families (in terms of species richness) present in the reserve.

Timber harvest was more intense during the dry season. It reduced drastically during the rainy season, which agrees with Adekunle et al. (2010) that loggers take advantage of exploiting more trees due to favorable roads during the dry season. Also, difficulty in having access to the forest during rainy season, due to erosion, flood, and seasonal streams that destroy roads, reduces the rate of exploitation.

Conclusion and recommendations

Tropical forest is the largest source of species biodiversity in the world and is currently faced with challenges when it comes to its conservation. Besides fulfilling various social, ecological, and economic needs, it is a source of livelihood for millions of people who live around it. The investigation of illegal activities in Osun State Forest Reserves and its impacts on forest conservation in this study show that most of the respondents agree that forest illegalities are prevalent in the study area. The activities include illegal logging, illegal timber processing, illegal NTFPs exploitation, timber smuggling, practices specifically aimed at reducing payment of taxes and other fees, illegal occupation of forest reserve land, and grazing and poaching. The illegal forest activities were agreed to have social, economic, and environmental impacts on forest conservation. As a result of the high demand of the people for timber and high extinction rate of economical and durable tree species, tree species with lesser values that can compete favorably in the market and satisfy human wants were harvested the most during the study. As a result of the exploitation of many economic tree species that contribute to national development and rural livelihood from the study sites, the study recommends that timber harvest be carried out on a sustainable basis.

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Appendix 1
FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE, NIGERIA.
DEPARTMENT OF FORESTRY AND WOOD TECHNOLOGY.

Questionnaire for Forestry Personnel

Project Topic: Rate of timber harvest and the effects of illegal activities on forest conservation in Osun state, Nigeria.

Dear Respondent

The purpose of this questionnaire is to gather useful information on the rate of timber harvest and the effects of illegal activities on forest conservation in Osun state, Nigeria.

All information supplied here will be kept confidential and will be used strictly for research purposes. Kindly supply answers correctly to the best of your knowledge. Your cooperation is highly needed and will be appreciated.

Thank you.

Daramola, Joseph O.

Please fill and tick boxes respectively in this questionnaire as appropriate:

Background information

1. Name of Forest Reserve……………………………………………………………………
2. Your cadre……………………………………………………………………………….
3. How long have you been working in forestry department
   a. 1-5 years ( ) b. 6-10 years ( ) c. 11-20 years ( ) d. 21-30 years ( )

Information on problems of forest conservation

4. Please indicate the illegal activities that serve as barrier to forest conservation that does occur in the forest reserve under your jurisdiction.
   a. Illegal logging ( ) b. Timber smuggling ( ) c. Illegal timber processing ( )
   d. Practices specifically aimed at reducing payment of taxes and other fees ( )
   e. Illegal non-timber forest products (NTFPs) exploitation ( )
   f. Others……………………………………………………………………………….
5. How will you describe the intensity of the activities identified above on the forest reserve under your jurisdiction?
   a. Very high ( ) b. High ( ) c. Moderate ( ) d. Low ( ) e. Very low ( )
6. Tick possible reasons for the occurrence of the activities around the forest reserve under your jurisdiction:
   a. Clearance for agriculture ( )
   b. Road construction and urbanization ( )
   c. Plantation establishment ( )
   d. Poor organization, management, and funding of the forestry subsector ( )
   e. Increasing demand for food or high poverty level of the exploiters ( )
   f. Others…………………………………………………………………………….
7. Indicate from below the economic impacts the illegal activities listed above has on the forest reserve under your jurisdiction:
   a. Reduction in revenue generated by the reserve ( )
   b. Reduction in market value of forest produce due to increased availability of produce from illegal activities ( )
   c. Others…………………………………………………………………………
8. Indicate from below the social impacts the illegal activities listed above has on the forest reserve under your jurisdiction:
   a. Land-use conflicts stemming from allocation of timber concessions ( )
   b. Restricted access to forest materials, including food, that are essential to the welfare of the rural people ( )
   c. Restricted access by local communities to forest products that provide income for small-scale local business ( )
   d. Large scale job losses/Unemployment ( )
9. Indicate from below the environmental impacts the illegal activities listed above has on the forest reserve under your jurisdiction:
   a. Loss of forest biodiversity through unsustainable logging practices ( )
   b. Soil erosion and leaching of forest nutrients ( )
   c. Health impacts and increase in greenhouse gas emissions ( )
   d. Conversion of forest lands to agricultural lands ( )

Appendix 2
FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE, NIGERIA.
DEPARTMENT OF FORESTRY AND WOOD TECHNOLOGY.

Questionnaire for Community Dwellers

Project Topic: Rate of timber harvest and the effects of illegal activities on forest conservation in Osun state, Nigeria.

Dear Respondent

The purpose of this questionnaire is to gather useful information on the rate of timber harvest and the effects of illegal activities on forest conservation in Osun state, Nigeria.

All information supplied here will be kept confidential and will be strictly for research purposes. Kindly supply answers correctly to the best of your knowledge. Your cooperation is highly needed and will be appreciated.

Thank you,

Daramola, Joseph O.

Please fill and tick boxes respectively in this questionnaire as appropriate:

Background information

1. Name of Community…………………………………………………………………….
2. Your age range. a. 0-20 ( ) b. 21-40 (v) c. 41-60 ( ) d. 61 and above ( )
3. Indicate if you are one of these: a. Saw miller ( ) b. Timber contractor ( ) c. Taungya farmer ( )
4. Indicate your level of experience in the above ticked. a. 0-5 years ( ) b. 6-10 years c. 11-21 years d. 21-30 years
5. Educational qualification a. Primary school certificate ( )
   b. Secondary school certificate ( ) c. Tertiary institution certificate ( )
6. Indicate how long you have been living in the community? a. 0-5 years ( ) b. 6-10 years c. 11-21 years d. 21-30 years

Information on problems of forest conservation

7. Please indicate the illegal activities that serve as barrier to forest conservation that do occur in the forest reserve near to your community:
   a. Illegal logging ( ) b. Timber smuggling c. Illegal Timber Processing ( )
   d. Practices specifically aimed at reducing payment of taxes and other fees ( )
   e. Illegal non-timber forest products (NTFPs) exploitation ( )
   f. Others………………………………………………………………………………
8. How will you describe the intensity of the activities identified above on the forest reserve near to your community? a. Very high ( ) b. High ( ) c. Moderate ( ) d. Low ( ) e. Very low ( )
9. Tick possible reasons for the occurrence of the activities around the forest reserve near to your community.
   a. Clearance for agriculture ( )
   b. Road construction and urbanization
   c. Plantation establishment ( )
   d. Poor organization, management, and funding of the forestry subsector ( )
   e. Increasing demand for food or high poverty level of the people ( )
   f. Others………………………………………………………………………………
10. Indicate from below the economic impacts the illegal activities listed above has on the forest reserve near to your community:
    a. Reduction in revenue generated by the reserve ( )
    b. Reduction in market value of forest produce due to increased availability of produce from illegal activities ( )
    c. Others…………………………………………………………………………….
11. Indicate the social impacts the illegal activities listed above has on the forest reserve near to your community.
    a. Land-use conflicts stemming from allocation of timber concessions ( )
    b. Restricted access to forest materials, including food, that are essential to the welfare of the rural people ( )
    c. Restricted access by local communities to forest products that provide income for small-scale local business ( )
    d. Large scale job losses/Unemployment ( )
12. Indicate from below the environmental impacts the illegal activities listed above have on the forest reserve near to your community.
    a. Loss of forest biodiversity through unsustainable logging practices ( )
    b. Soil erosion and leaching of forest nutrients ( )
    c. Health impacts and increase in greenhouse gas emissions ( )
    d. Conversion of forest lands to agricultural lands ( )

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Spatial alteration of fragmented landscape in evergreen and semi-evergreen rainforest: A case study in Chittagong Hill Tracts, Bangladesh

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Abstract. *Mamnun M, Hossen S. 2021. Spatial alteration of fragmented landscape in evergreen and semi-evergreen rainforest: A case study in Chittagong Hill Tracts, Bangladesh. Asian J For 5: 17-27.* Evergreen and semi-evergreen forests in Bangladesh are important areas that hold a large number of biodiversity. Yet, these unique forest types are pressured by various human activities in the last decades, resulting in deforestation, forest degradation and fragmentation. The principal aim of the study was to explore the level of fragmentation and underlying drivers in forests of Bandarban Sadar Upazila, Chittagong Division, Bangladesh from 1988-2018. The ArcGIS v10.5 and ERDAS Imagine v15 software were used to process satellite imageries and assess quantitative data. The study revealed that the area under forest land decreased very rapidly; it was lost about 7165.13 ha and the annual destruction rate was 17.92%. The edge density of forest area and agricultural crops rapidly increased from 1988-2018, while barren land and water bodies were almost consistent. Forest land became fragmented as its total edge area increased by 275.87% from 16469.6 km in 1988 to 61905 km in 2018. There was gradual decline in Shannon Diversity Index from 1988 (1.004), 2003 (0.878), and 2018 (0.615). Among the different factors, agro-horticultural plantation was the main factor for reduction in landscape diversity. This analytic study would help policymakers take necessary steps for sustainable forest management.

Keywords: Forest fragmentation, GIS, land-use, landscape metrics, patch

INTRODUCTION

Tropical rainforests cover only 7% of the earth's land surface, however, they have the highest amount of species diversity which contributes to almost 50% of the world's wildlife (Tchoumbou et al. 2020). Tropical forests are also one of the most important carbon sinks which store about 25% of terrestrial carbon (Zapfack et al. 2020). Nonetheless, species extinction and climate change are the most significant problem in tropical forests (Harper et al. 2007, Echeverria et al. 2008). Huge areas of rainforests are threatened due to deforestation, fragmentation, over-exploitation, and climate change which vary from region to region (Bhusal et al. 1998, Morris 2010).

Fragmented landscape corroborates habitat loss and alters spatial characteristics and configuration, resulting in changes in physical and biological factors in a forest environment (Hansen et al. 2001, Jha et al. 2005). Fragmentation results in an extreme level of edge effects of the remaining forests area with strong differences between habitat near the edge and away from edges (Donovan et al. 1997, Broadbent et al. 2008). The effects of habitat fragmentation on species richness are often predicted by the landscape matrix (Öckinger et al. 2012). Within the last century, the increasing level of fragmentation associated with the rapid land-use change has made the landscape as a crucial and auxiliary scale of studies in wildlife ecology and forest management (Rodewald 2003). Landscape metrics are effectively applied to understand phenomena including the measurement of environmental change, landscape change, and forest fragmentation measurement (Hansen et al. 2001). Spatial or landscape metrics can be used to measure the numerous aspects of the land cover/land-use pattern including composition, spatial configuration, and spatial neighborhood of the land cover/land-use or landscape in a given area (Kowe et al. 2015). Different types of matrix are utilized in forest fragmentation study, among them the most common metrics are used to analyze forest fragmentation at the category or patch type-level include Number of Patches, Mean Patch Size, Patch Shape, Edge Density/Total Edge Distance, Mean Core Area, Patch Density, Fractal Dimension, Interpatch Distance and Interspersion and Juxtaposition (Hansen et al. 2001).

As one of the forest-poor countries in the world, Bangladesh has forest area 10.96% of its total land and it is struggling to conserve it (Baten et al. 2010). Among them, 4.54% of the country's total forests are evergreen and semi-evergreen forests covered with Chittagong Hill Tracts are included in this category. Like other mountainous regions of Asia, Chittagong Hill Tracts (CHT) of Bangladesh are also facing a great level of degradation, especially in recent four decades. The natural resources in this area have been exploited enormously to inappropriate land-use systems such as shifting cultivation associated with incendiary fires, population pressure, the encroachment of reserve forests, soil erosion, agroforestry practices, and commercial teak plantation (Rasul et al. 2004; Rasul and Thapa 2006;

Biswas et al. 2012). As a result, forest areas in CHT are cleared, degraded, and fragmented.

So far, there is no study that investigates the fragmentation phenomena occurring in CHT. Therefore, the aim of the study was to explore the level of fragmentation in forests of Bandarban Sadar Upazila, Chittagong Hill Tracts using fragmentation matrices as well as to elucidate drivers related to fragmentation. The result of the study will provide insight into the fragmentation and underlying drivers in CHT which can help the government, organizations associated with natural resources management, policymakers, and other researchers to take necessary steps for sustainable management in the future.

MATERIALS AND METHODS

Description of the study area

The study area was Bandarban Sadar Upazila District, Chittagong Division, Bangladesh located at 21°55' and 22°22' N and 92°08' and 92°20' E, having an area of about 501.99 km^2. The Upazila is bounded by Rajasthali Upazila on the North, Lama Upazila on the South, Rowangchhari and Ruma Upazilas on the East, and Rangunia, Satkania and Lohagara Upazilas on the West and is bordered by Cox's Bazar, Chittagong, Rangamati and Khagrachari. On the other side of the 129 km, international border lies Chin and Arakan provinces of Myanmar. It consists of 5 unions namely Rajbila Union, Kuhalong Union, Bandarban Sadar Union, Swalak, and Tankabati (Figure 1).

Digital data collection and processing

This study used multi-temporal satellite imagery data provided by USGS (United States Geological Survey) for Landsat 8 OLI-TIRS (Operational Land Imager/ Thermal Infrared Sensor), Landsat 5 TM (Thematic Mapper) of the year 2018, 2003, and 1988 for visual image interpretation, land-use identification and land-use classification. Cloud-free satellite imagery during winter season was selected (November-February) to get accurate data for classification. The spatial resolution of Landsat 2 was 60 m and 30 m for Landsat 5 and 8 (Table 1). Landsat 8 raw image constitutes 11 bands and only 5,4,3 bands for Landsat 8 and 4,3,2 bands for both Landsat 5 and Landsat 2 were used. Composite layer of these 3 bands was created in Arc GIS 10.5, the pictures were then projected and clipped by using subset tools using the shapefile of Bandarban Sadar Upazila. A complete of 47,290.05 hectares (ha) of land was estimated for the entire Bandarban Sadar Upazila after supervised image classification using ERDAS Imagine v15.

Land-use and land cover change detection process

During June 2018-December 2018, a field survey was conducted within the study area to record specific land-use categories according to their latitude and longitude. A total of 500 GPS point locations were taken using convenient sampling. The land use of study area was classified into 5 groups including croplands, barren lands, settlements, water bodies and forest areas. The collected land-use data were used to determine the color tone of 2018 Landsat 8 images while training dataset. Afterward, maximum likelihood classification (MLC) was used for LULC assessment. After land-use classification, forest areas from supervised classification were exported to raster through spatial analysis tools in Arc GIS 10.5 and converted from raster to polygon in Arc map 10.5.

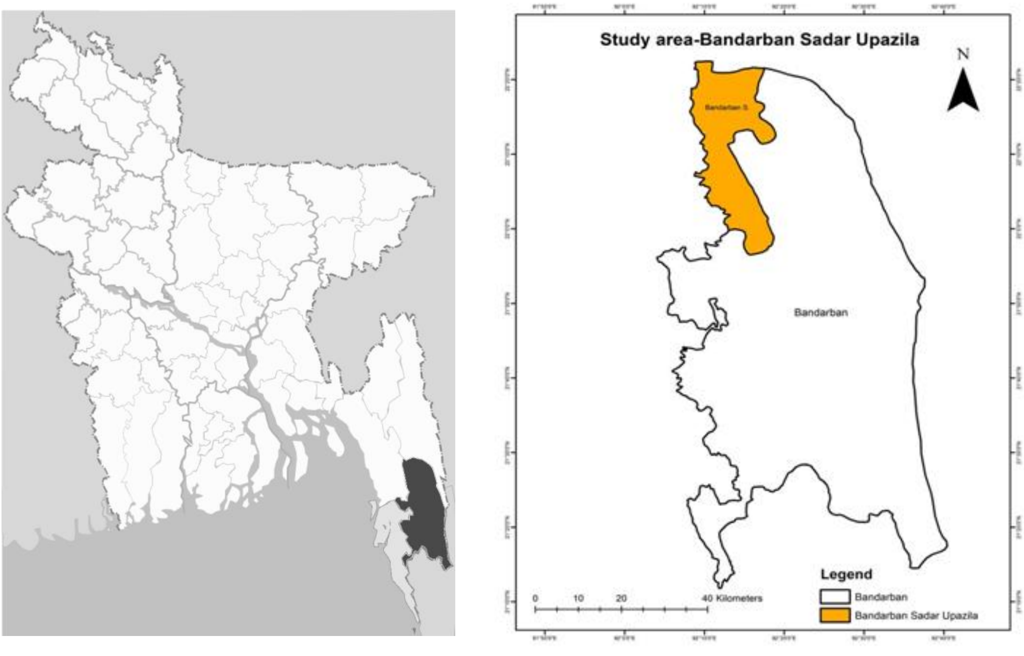

Figure 1. Study area of Bandarban Sadar Upazila District, Chittagong Division, Bangladesh

Table 1. Detailed information about satellite images

Satellite	Sensor	Path/row	Acquisition date	Spatial resolution (m)	Spectral bands (μm)
Landsat 8	OLI-TIRS	136/44	29-01-2018	30×30	B2-Visible Blue: 0.450-0.515 μm B3-Visible Green: 0.525-0.600 μm B4-Visible Red: 0.630-0.680 μm B5-Near-infrared: 0.845-0.885 μm
Landsat 5	TM	146/44	20-11-2003	30×30	B2-Visible Green: 0.52-0.60 μm B3-Visible Red: 0.63-0.69 μm B4-Near-infrared: 0.76-0.90 μm
Landsat 5	TM	146/44	12-12-1988	30×30	B2-Visible Green: 0.52-0.60 μm B3-Visible Red: 0.63-0.69 μm B4-Near-infrared: 0.76-0.90 μm

Landscape configuration changes and fragmentation analysis

FRAGSTATS and Patch analysts programs were used to explore the landscape patches and modeling of attributes related to patches. This spatial pattern analysis software is useful in determining habitat modeling for biodiversity conservation and forest management. Vector polygon data/ raster-based data derived from the years 2018, 2003, and 1988 were given as input metrics for measuring and quantifying landscape characteristics and their changes in growth dynamics (Table 2).

Probability mapping using satellite imagery and topographic variables to analyze landscape diversity

A probability map was made to classify different agro-horticultural practices within the study area. The probability map mainly represents the high suitability of environmental conditions for particular agro-horticultural practices. For tree species classification, probability mapping using primarily optical multispectral sensor like Landsat images were employed and in the next steps second (the topographic variables) from a digital elevation model (DEM) was used and geographical information systems (GIS) data from study area applied to make the probability map more accurate. For the first set of variables, a Landsat 8 image from USGS earth explorer was used (Figure 2).

Table 2. Quantifying changes in landscape configuration and composition for fragmentation analysis (class-level metrics)

Parameter	Equation	Meaning
Number of patches (NP)	$NP = ni$	ni : Number of patches in the patch type of landscape (class) i.
Mean Patch size (MPS)	$\frac{\sum_{j=1}^{n} aij}{ni}\left(\frac{1}{10{,}000}\right)$	aij: Area (m²) of patch ij.
Total edge (TE)	$TE = E$	E: Total length (m) of edge in landscape.
Edge density (ED)	$\frac{E}{A}(10{,}000)$	E : Total length (m) of edge in landscape. A : Total landscape area (m2).
Area weight mean shape index (AWMSI)	$\sum_{i=1}^{m}\sum_{j=1}^{n}[(\frac{Pij}{2\sqrt{\Pi_o aij}})(\frac{aij}{A})]$	Pij: Perimeter (m) of patch ij.
Area-weighted mean patch fractal dimension (AWMPFD)	$\sum_{j=1}^{n}\left[\left(\frac{2\ln Pij}{\ln aij}\right)\left(\frac{aij}{\sum_{j=1}^{n} aij}\right)\right]$	aij: Area (m²) of patch ij. Pij: Perimeter (m) of patch ij.
Shannon Evenness Index (SHEI)	$\frac{-\sum_{i=1}^{m}(Pi * \ln Pi)}{\ln m}$	m : Landcover types. Pi : Relative abundance.
Shannon Diversity Index (SHDI)	$-\sum_{i=1}^{m}(Pi * \ln Pi)$	m : number of classes, Pi: the landscape percentage that is occupied by class i.

Source: McGarigal (1995), Hansen et al. (2001), McGarigal et al. (2012), Chowdhury et al. (2020)

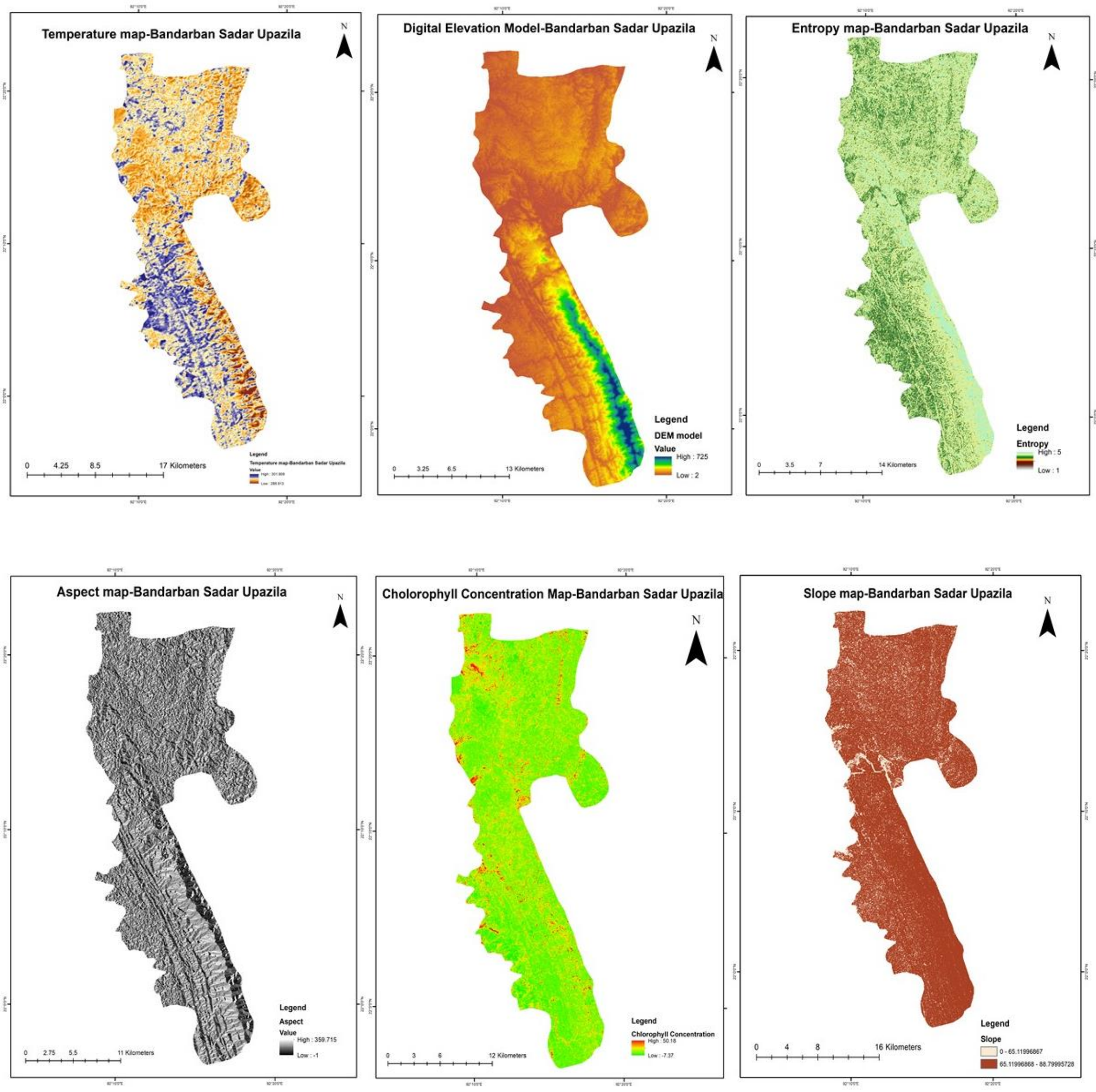

Figure 2. Model inputs to develop probability map to classify different agro-horticultural practices

To derive the topographic variables, the Global Digital Elevation Model (GDEM) version 2 data with a resolution of 30 m was obtained from the advanced spaceborne thermal emission and reflection radiometer (ASTER) that is operated by the National Aeronautics and Space Administration (NASA). By applying topographic variables, the logistic probability model was calculated, whose accuracy is more than the forest inventory maps (Chianga et al. 2016). For the study, maps of temperature, slope, aspect, chlorophyll and entropy of the study area were also used (Figure 2). Field level survey data for ground truth inventory map was overlapped upon entropy map and in this way, probability map for various agro-horticultural practices and plantations of the study area was prepared. After observing the classification result and comparing it with the tree species inventory, the foremost dominant practices within the study area were found to be teak plantations. In the study area, 7 main vegetation types viz. agroforestry, horticultural, fast-growing forest tree species plantation, teak plantation, jhum cultivation, homestead forestry and bamboo were found at the study site.

RESULTS AND DISCUSSION

Relative changes of land-use in Bandarban Sadar Upazila

Land-use mapping of Bandarban Sadar Upazila provided spatial distribution of land-use categories and land-use changes over the past 30 years (Figure 3). Table 3 and Table 4 show relative changes in Bandarban Sadar Upazila land-use from 1988-2018. Three trends were noticed from the results viz (i) proportion of area under barren land and settlements continuously increased from 2.53% and 1.57% respectively in 1988 to 10.42% and 5.33% respectively in 2018; (ii) percentage of forest areas were continuously declined from 84.56% in 1988 to 69.41% in 2018; (iii) while proportion of agricultural crops peaked in 2003 (13.66%) from 1988 (8.06%) and again decreased to 11.74% in 2018 and percentage cover of waterbody decreased to 2.72% in 2003 from 3.28% in 1988, however, it again increased to 3.10% in 2018.

Table 4 shows land-use change from 1988 to 2018. During this period, agricultural land area increased by 45.66% (58.01 hectares), barren land 312.39% and settlement 239.10%. On the other hand, forest land area decreased very rapidly (238.83-hectare annual rate of change) and 7165.13 ha of forest land was lost during 1988-2018. The area of waterbody decreased by 5.47% (84.77 hectares).

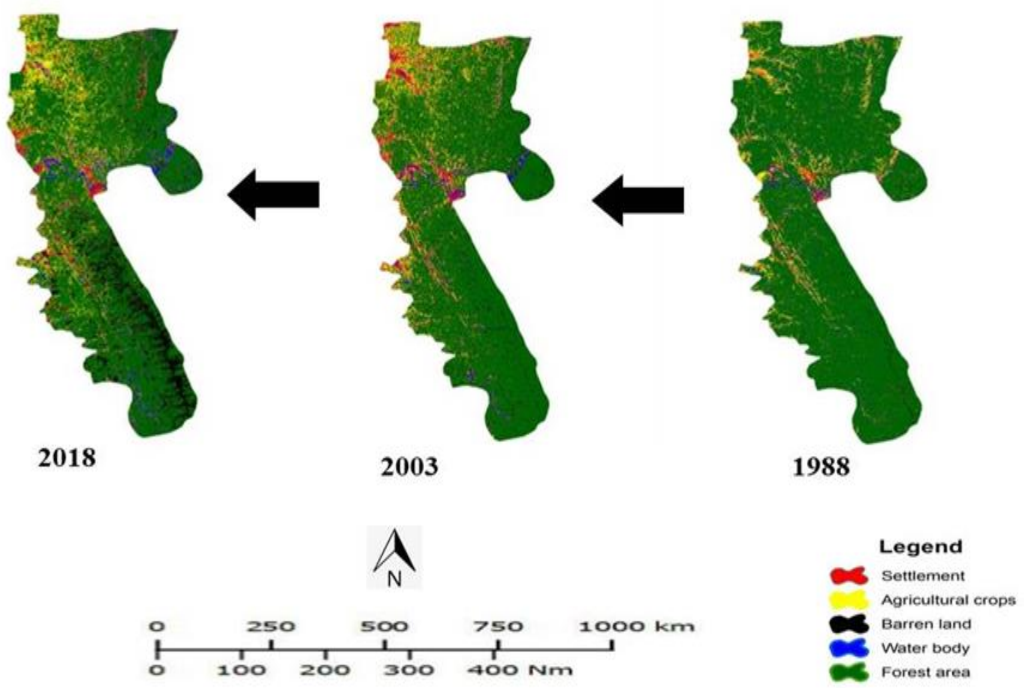

Figure 3. Relative changes of land-use from 1988-2018 of Bandarban Sadar Upazila, Bangladesh

Table 3. Land-use pattern of Bandarban Sadar Upazila, Bangladesh (1988-2018)

Land-use category	1988		2003		2018	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agricultural crops	3811.92	8.06	6461.91	13.66	5552.48	11.74
Barren land	1194.85	2.53	2704.95	5.72	4927.41	10.42
Forest area	39989.29	84.56	35078.13	74.18	32824.16	69.41
Settlement	743.11	1.57	1760.37	3.72	2519.89	5.33
Waterbody	1550.88	3.28	1284.69	2.72	1466.11	3.10

Table 4. Land-use change assessment of Bandarban Sadar Upazila, Bangladesh from 1988 to 2018

Land-use category	Land-use change: 1988-2003			Land-use change: 2003-2018			Land-use change: 1988-2018		
	Changed area (ha)	% change	Annual rate of change	Changed area (ha)	% change	Annual rate of change	Changed area (ha)	% change	Annual rate of change
Agricultural crops	2649.99	69.52	176.67	-909.43	-14.07	-60.63	1740.56	45.66	58.01
Barren land	1510.1	126.38	100.67	2222.46	82.16	148.16	3732.56	312.39	124.41
Forest area	-4911.16	-12.28	-327.41	-2253.97	-6.43	-150.26	-7165.13	-17.92	-238.83
Settlement	1017.26	136.89	67.82	759.52	43.15	50.63	1776.78	239.10	59.22
Waterbody	-266.19	-17.16	-17.75	181.42	14.12	12.09	-84.77	-5.47	-2.82

Note: (-) sign denotes decrease of magnitude of change of land-use category in different time frame

Forest cover loss associated with land-use conversion from 1988-2018

Table 5 presents land-use conversions among inter-land-use classes between 1988 and 2018. The area under agriculture was 3811.92 ha in 2018, and it was found that only 1096.37 ha of land remained unchanged while, and 2715.55 ha of agricultural lands were converted into other types of land-uses. Here, 1043.50 ha land area was converted into forest area and settlement 988.74 ha. About 484.51 ha of barren land came under re-plantation programs and about 255.18 ha was converted for agricultural use.

Within 30 years, the forest land has lost 9359.55 ha. From the 39989.29 ha forest area in 1988, about 30629.74 ha area remained unchanged, while about 3640.79 ha forest area was converted into agricultural land, about 893.49 ha area was converted into settlement and about 4371.31 ha land became barren area. In case of settlement, about 172.40 ha land was converted to waterbody, on the other hand, about 291.14 ha waterbody remained unchanged and the rest portion of the waterbody area was converted into other types of land-uses like forest area (584.06 ha), settlement (206.91 ha) and agricultural crops land (382.3) (Table 5 and Figure 4).

Metrics calculation

Classified LULC images of 1988, 2003 and 2018 were used as inputs in patch analyst extension software of Arc GIS 10.5 to calculate and analyze conversant landscape metrics for each class.

Edge density

Edge density is an indicator of landscape configuration for fragmentation analysis (class-level metrics). The study revealed that the edge density of forest area and agricultural crops rapidly increased from 1988-2018, while barren land and water bodies were almost consistent. At the same time period, edge density of the settlement decreased swiftly. This indicates that forest and agricultural cropland were converted into settlement and urbanization (Figure 5).

Class area

Class area indicates the sum of areas of all patches belonging to a particular landscape class. From 1988 to 2003 class area of forest increased rapidly, but it decreased slightly in 2018. On the other hand, from 1988-2003 patch area of settlement decreased drastically and remained unchanged till 2018. Similarly, the total patch areas of forest land increased and settlement decreased. Meanwhile, total patch areas of barren land, agricultural land, and waterbody did not change significantly (Figure 6).

Table 5. Land-use conversions among inter-land-use classes between 1988 and 2018 in Bandarban Sadar Upazila, Bangladesh

	Land-use area (ha)-2018						
	Sum of area (ha)	**Column labels**					
	Row labels	**Agricultural crops**	**Barren land**	**Forest area**	**Settlement**	**Water body**	**Grand total**
Land-use area(Ha)-1988	**Agricultural land**	**1096.37**	**235.24**	**1043.50**	**988.74**	**448.074**	**3811.92**
	Agricultural crops	1096.37					1096.37
	Agricultural crops to forest area			1043.50			1043.50
	Agricultural crops to barren land		235.24				235.24
	Agricultural crops to settlement				988.74		988.74
	Agricultural crops to waterbody					448.074	448.074
	Barren land	**255.18**	**207.18**	**484.51**	**147.44**	**100.54**	**1194.85**
	Barren land		207.18				207.18
	Barren land to settlement				147.44		147.44
	Barren land to forest area			484.51			484.51
	Barren land to agricultural crops	255.18					255.18
	Barren land to waterbody					100.54	100.54
	Forest land	**3640.79**	**4371.31**	**30629.74**	**893.49**	**453.96**	**39989.29**
	Forest area			30629.74			30629.74
	Forest area to agricultural crops	3640.79					3640.79
	Forest area to settlement				893.49		893.49
	Forest area to waterbody					453.96	453.96
	Forest area to barren land		4371.31				4371.30
	Settlement	**177.84**	**27.21**	**82.35**	**283.31**	**172.40**	**743.11**
	Settlement				283.31		283.31
	Settlement to agricultural crops	177.84					177.84
	Settlement to barren land		27.21				27.21
	Settlement to forest area			82.35			82.35
	Settlement to waterbody					172.40	172.40
	Waterbody	**382.30**	**86.47**	**584.06**	**206.91**	**291.14**	**1550.88**
	Waterbody					291.14	291.14
	Waterbody to agricultural crops	382.30					382.30
	Waterbody to barren land		86.47				86.47
	Waterbody to forest area			584.06			584.06
	Waterbody to settlement				206.91		206.91
	Grand Total	**5552.48**	**4927.41**	**32824.16**	**2519.89**	**1466.11**	**47290.05**

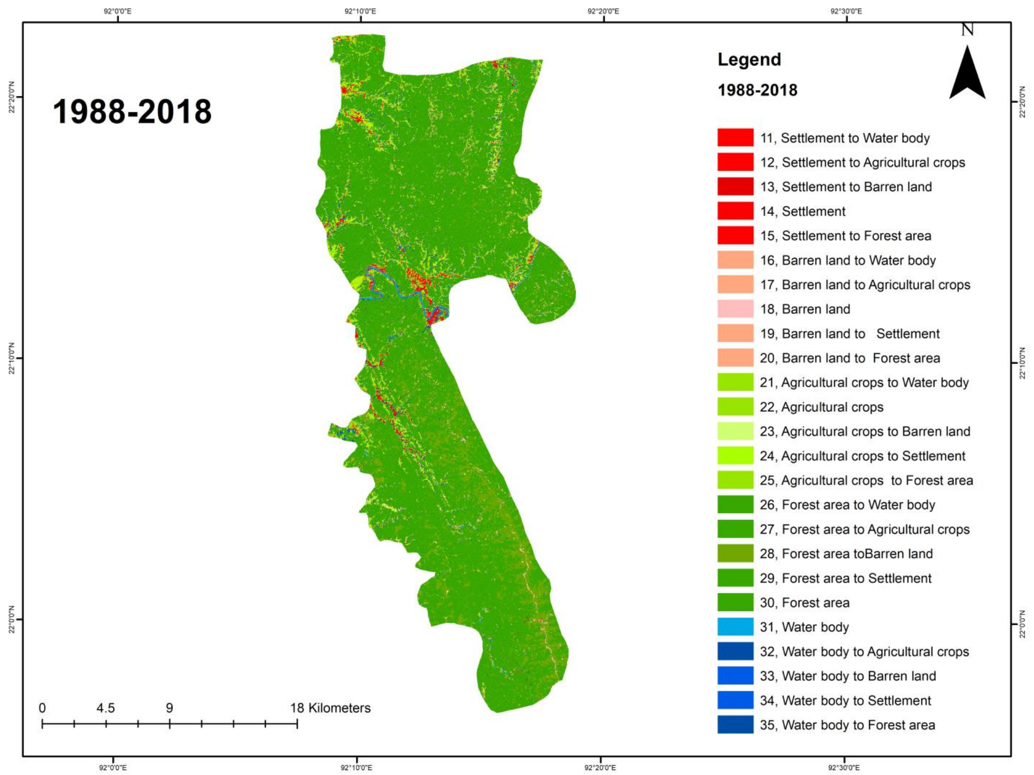

Figure 4. Land-use conversions among inter-landuse classes between 1988 and 2018 in of Bandarban Sadar Upazila, Bangladesh; image class 14, 18, 22, 30 and 31 represent original unconverted areas

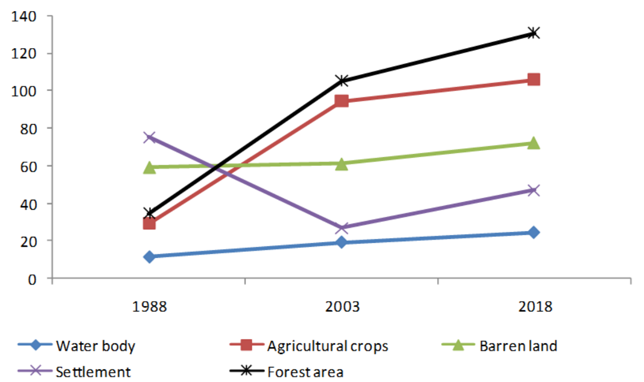

Figure 5. Edge density of Bandarban Sadar Upazila, Bangladesh from 1988-2018

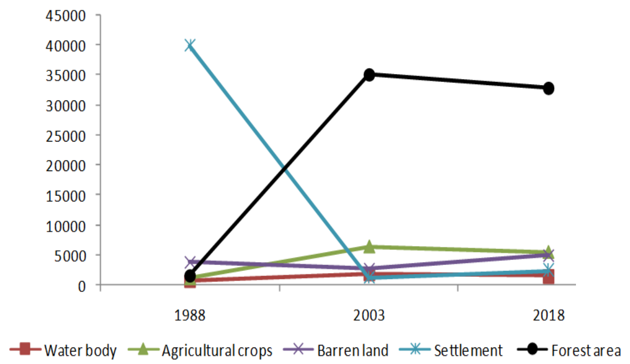

Figure 6. Class Area (CA) of Bandarban Sadar Upazila, Bangladesh from 1988-2018

Mean Shape Index

Mean shape Index (MSI) basically indicates shape complexity which is an indicator of fragmentation analysis. The study revealed that the MSI of settlement and agriculture had increasing trends and the waterbody had a partially increasing trend. The forest area had a drastic decrease during 1988-2003 while it got slightly restored in 2018. On the other hand, barren land was at first increased from 1988-2003 while it started declining 2003 onwards. MSI evaluation led to the understanding that shape complexity of agricultural crops and settlement increased while there was declining trend in forest areas (Figure 7).

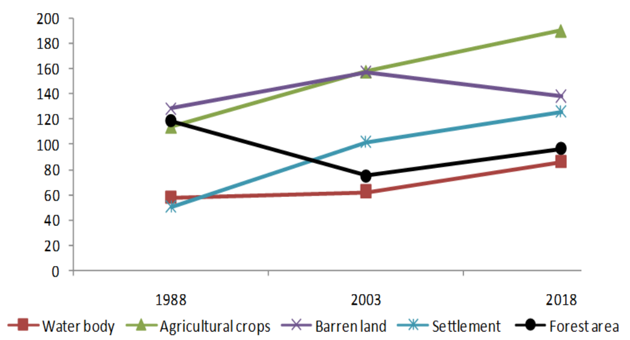

Figure 7. Mean Shape Index of Bandarban Sadar Upazila, Bangladesh from 1988-2018

Landscape configuration and fragmentation analysis

Spatial variation in land-use fragmentation

Land cover/land-use fragmentation varied with each land cover/land-use type as evident from the mean perimeter-area ratio (MPAR) of patches, mean patch size (MPS) and total edge (TE) as presented in Table 6. A more fragmented land cover/land-use pattern is generally associated with a decrease of the MPAR and an increase in total edge and MPS. Forest land became fragmented as its total edge area increased by 275.87% from 16469.6 km in 1988 to 61905 km in 2018 and the MPS increased 31290.05 ha. On the other hand, the mean perimeter area ratio declined from 1060.26 ha in 1988 to 188.48 ha in 2018.

The total edge of settlement declined 37.14% from 1988 to 2018, while MPS of settlement decreased by 37487.11 ha from 1988-2018, whereas the MPAR increased by 896.23% (Table 6). It can be concluded that the fragmentation area of the total forest patch increased and fragmented patch of settlement decreased and forest was converted to settlement and other land cover types. Smaller patches of settlement have become inter-connected and large portion of land cover has transformed to settlement (Figure 8).

Other classes of land cover also have changed with time. The total edge area of agricultural crops and MPS increased by 260.88% and 364.45% respectively, and MPAR decreased by 22.3%, indicating the impact of fragmentation on agricultural crop land between1988-2018. In the case of the waterbody, it was found that the MPAR increased by 6.34% and total edge area increased from 5557.23 km in 1988 to 11646.7 km in 2018 (Table 6).

Changes in patch shape complexity of land cover/land-use categories

Table 7 illustrates that the largest percentage of area-weighted mean shape index (AWMSI) of settlement increased by 150.27% from 1988-2018. The argument behind these can be linked to rapid forest destruction associated with agricultural intensification, shifting cultivation, unplanned settlement pattern in the study area. Due to the unplanned settlement, more complex and irregular shapes of settlement areas were created.

Similarly, the AWMPFD value (% of change) for settlement from 1988-2018 was 12.50%, representing the increase in new irregular settlement patterns and the complex built-up patch shapes. Although, other practices like barren land, agricultural land, waterbody, and forest were less complex in irregularity from1988-2018 (Table 7).

AWMSI value for forest area declined by 18.26% and AWMPFD value by 7.56% from 1988-2018. The forest patches became more irregular, exposed edges, extremely fragmented and the values indicate complex heterogeneous shapes due to human influence. Barren land patches, a number of which were located in open fields and agricultural activities, increased in AWMSI value by 7.35% and decreased in AWMPFD value by 0.59% leading to relatively simple circular shapes. The patches of Agricultural land's AWMSI increased (67.46%) between 1988 to 2018, and its AWMPFD values did not change for the same period. The AWMSI and AWMPFD values of waterbodies increased by 49.29% and 1.20% respectively between 1988 to 2018 (Table 7).

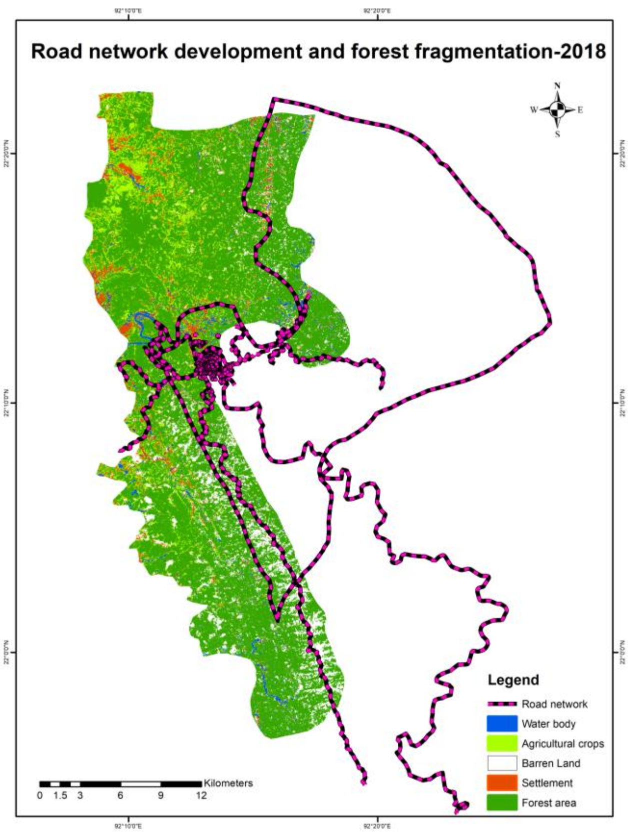

Figure 8. Development of road network and fragmentation of Bandarban Sadar Upazila, Bangladesh in 2018

Table 6. Spatial variation in land cover/land-use fragmentation

Class	Total edge (km) TE 1988	TE 2018	Change from 1988-2018	Mean patch size (MPS)(ha) MPS 1988	MPS 2018	Change from 1988-2018	Mean perimeter-area ratio (MPAR) MPAR 1988	MPAR 2018	Change from 1988-2018	% of change
Waterbody	5557.23	11646.7	109.58	745.24	1468.84	723.59	745.68	792.92	47.24	6.34
Agricultural crops	13904.4	50178.3	260.88	1196.91	5559.08	4362.17	1161.69	902.63	-259.06	-22.3
Barren land	28097	34275.3	21.99	3819.23	4931.2	1111.97	735.67	695.06	-40.61	-5.52
Settlement	35649.7	22408.8	-37.14	40011.7	2524.59	-37487.1	89.09	887.61	798.52	896.31
Forest area	16469.6	61905	275.87	1553.35	32843.4	31290.05	1060.26	188.48	-871.78	-82.22

Table 7. Changes in patch shape complexity of land cover/land-use categories

Area weight mean Shape index (AWMSI)					Area Weighted Mean Patch Fractal Dimension (AWMPFD)				
Class	AWMSI 1988	AWMSI 2018	Change 1988-2018	% of Change	Class	AWMPFD 1988	AWMPFD 2018	Change 1988-2018	% of change
Waterbody	57.42	85.72	28.3	49.29	Waterbody	1.67	1.69	0.02	1.20
Agricultural crops	113.37	189.85	76.48	67.46	Agricultural crops	1.73	1.73	0.00	0.00
Barren land	128.25	137.68	9.43	7.35	Barren land	1.70	1.69	-0.01	-0.59
Settlement	50.27	125.81	75.54	150.27	Settlement	1.52	1.71	0.19	12.50
Forest area	117.88	96.36	-21.52	-18.26	Forest area	1.72	1.59	-0.13	-7.56

This finding shows that forest destruction destroys valuable natural resources of the study areas. As in the current case, swift collapse of evergreen and semi-evergreen forest area was recorded between 1988-2018. Increase in settlement can be considered the main reason behind this. People from different areas migrate to Chittagong Hill Tracts and for settlement in combination with the seen establishment of different organizations, schools, colleges, industries, etc. And the corresponding increase in population has led to rapid forest destruction. Forest and agricultural areas were thus converted into settlements and divided into many smaller patch areas which led to the increase of AWMSI and AWMPFD of settlement areas.

Landscape diversity and probability distribution model for different agro-horticultural practices and artificial plantation

The decrease in Shannon's Diversity Index (SHDI) and Shannon Evenness Index (SHEI) from 1988 to 2018 (Table 8) indicates decrease in landscape heterogeneity and evenness. This was contrary to the expectation that the decrease in forest land would cause reduction in landscape diversity. It can be concluded that once the huge landscape diversity of Chittagong Hill Tracts, Bandarban gradually declined with the passage of time and deforestation and fragmentation (Table 8). The gradual decrease in SHEI from 1988-2018 also indicates that the classes of map units were not uniformly distributed in the study area reflecting the differences in sizes of certain land cover/land-use on the landscape with some practices dominating others at the landscape level.

In 2018, agro-horticultural plantation was the main cause for reducing landscape diversity. Natural forest was replaced by human-modified plantation of teak, horticultural practices, agroforestry practices, etc. To classify different agro-horticultural practices, probability distribution map was generated using satellite imagery and topographic variables with Arc GIS10.5.

The maximum amount of land was found to be deployed for teak (*Tectona grandis*) plantation (Figure 9). After teak plantation, agroforestry was practiced, and together were the top two causes of natural forest destruction. Homestead plantation and horticultural practices occupied additionally outsized portion of Bandarban Sadar Upazila. Though the percentage of jhum cultivation was not high, it spread vastly across all Upazila. Fast-growing tree species were planted by the government through different plantation programs. Naturally, different types of bamboos were found in all hilly areas and were also planted artificially in some places.

In conclusion, it can be enunciated that spatial/ landscape metrics are useful tools to narrate the landscape structure with various aspects especially in fragmentation analysis. Bandarban Sadar Upazila has been undergoing severe deforestation and degradation since the beginning of 1988 due to habitat destruction, fragmentation, shifting cultivation, over-exploitation, encroachment, and agroforestry practices. An enormous amount of forest land and semi-natural vegetation were converted to other land cover types. The increase in population, as well as settlement and urbanization, made forested areas more complex in shape and fragmented. Increasing heterogeneity and fragmentation of habitat were identified through landscape metrics for 1988, 2003, and 2018. The growth pattern of fragmented patches, uniformity, and irregularity, and change in shape complexity was illustrated by using AWMSI and AWMPFD in this study.

Rapid conversion of forest area into agro-horticultural area in an unplanned and unauthorized way, aggravated by intensified shifting cultivation as supported by AWMSI and AWMPFD measurements, gives an urgent message to policy-makers about the extent of rapid fragmentation and natural forest loss in the area. It was also noticed that, spatial configuration changes (as indicated by change in the number of patches, MPS, and total edge) the diversity of landscape. From 1988-2018, forest area decreased swiftly and decreased SHDI and SHEI index. Further, it can be said that settlement expansion, agroforestry practices, and artificial plantation in hilly areas increased fragmentation extent and reduce natural biodiversity.

Table 8. Landscape diversity statistics in Bandarban Sadar Upazila, Bangladesh

Year	Shannon's Diversity Index	Shannon's Evenness Index
2018	0.615	0.382
2003	0.878	0.545
1988	1.004	0.624

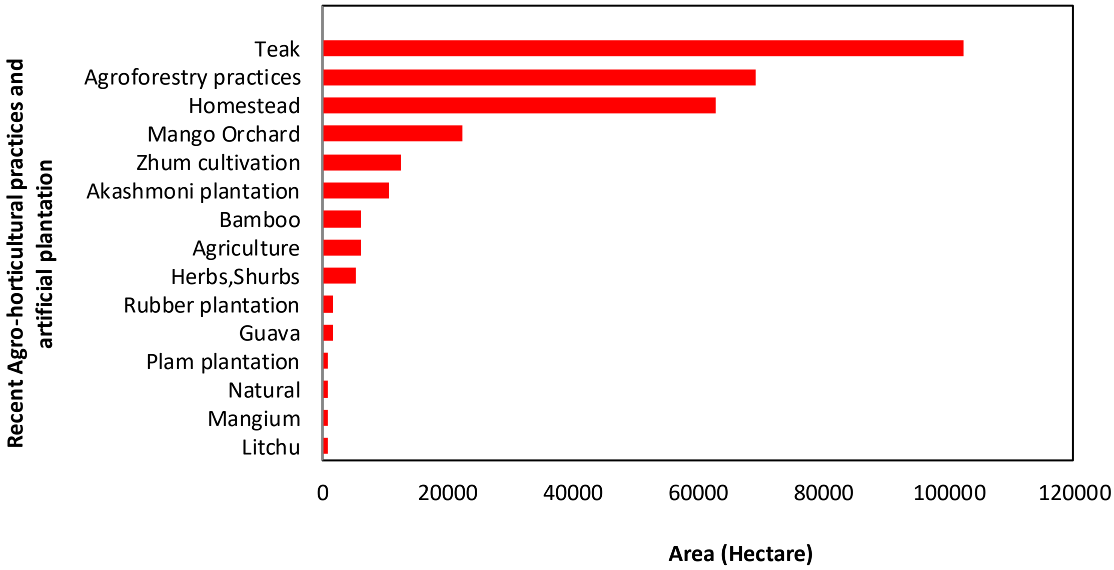

Figure 9. Main reasons for natural forest destruction in Bandarban Sadar Upazila-2018

This study tries to draw attention to rapid fragmentation, biodiversity loss, and poor management of natural resources which has driven vast areas of previously forest land now turned to unplanned settlements, barren hills, or agro-horticultural practices. Appropriate intervention from concerned authorities is required to save remnant natural evergreen and semi-evergreen forest of Bandarban Sadar Upazila, Chittagong Hill Tracts, Bangladesh.

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Livelihood status of local communities around Sundarbans mangrove ecosystem in Shymnagar Upazila, Satkhira, Bangladesh

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Abstract. *Azad AK, Pitol MNS, Rakkibu MG. 2020. Livelihood status of local communities around Sundarbans mangrove ecosystem in Shymnagar Upazila, Satkhira, Bangladesh. Asian J For 5: 28-35.* Sundarbans of Bangladesh is the largest single mangrove complex in the world which plays essential roles in delivering economic, ecological, and social functions, including providing livelihoods for local communities. The study aims to know the livelihood status and dependency of local people on Sundarbans in Shymnagar Upazila, Satkhira District, Bangladesh. A questionnaire survey was carried out in the studied area, involving 130 respondents in three unions. Most of the respondents (65%) were middle-aged (30-50 years old) and 22% of them were female and 78% were male. Among them about 51% were illiterate, 24% had primary education, while 25% had secondary education. About 72% of the respondents were fully dependent and 21% were partially dependent on Sundarbans for their livelihoods. Only 37% of people in these areas had their shrimp farm (gher). The respondents collected fuelwood (92%), aquatic resources (80%), small timber (54%), honey (27%), goran (*Ceriops decandra*) (8%), and golpata (*Nypa fruticans*) (6%) from Sundarbans. Only 63% of the respondents had their livestock like cows (2%), poultry (68%), and goats (30%), whereas 84% of respondents were involved with different NGOs. Among the respondents, 70% had the access to disaster warnings, whereas only 24% had shelter facilities. Only 28% of respondents had access to drinking water from deep tube-well and 33% from ponds. About 50% of the respondents did not get better medical treatment and were dependent on village doctors and only 8% of respondents received treatment from Government hospitals. It was alarming to know that about 91% of respondents did not know co-management in Sundarbans. Most of the people living here were not satisfied with their present occupations and about 98% of them were eager to start a new occupation. Only 11% of respondents got benefitted from government Vulnerable Group Feeding / Vulnerable Group Development support. The results of this study suggest that the government and different NGOs might provide necessary supports for local people so that they can start alternative occupations and their dependencies on the Sundarbans may be reduced significantly.

Keywords: Co-management, dependency, literacy, livestock, respondents, shelters, treatment

INTRODUCTION

The management of natural resources must be adaptable and sustainable to ecological and social systems, one of which is the livelihood of people (Allison and Horemans 2006; Chapin et al. 2010). Livelihood includes the capabilities, assets, and activities required for a means of living (Chambers and Conway 1992). The consideration of livelihood aspect is important since the dependency on natural resources is coming under dynamic pressure mainly for population growth (Barbier 2005; Hecht et al. 2012). On the other hand, the increased rate of degradation and depletion has impacted the wellbeing of local communities (Béné et al. 2000; Midmore and Whittaker 2000; Scherr 2000; Kesavan and Swaminathan 2006; Guerin 2007). The continued loss of forests has been ascribed to dependence on livelihoods as one of the options (Chomitz 2007; FAO 2012).

Hundreds of millions of insolvent people around the globe depend on mangroves for their livelihoods and wellbeing (Mohammed 2012). It provides food security, fishery products, and income for coastal communities (Hussain and Badola 2010; Richman 2002; Shervette et al. 2007; Walters et al. 2008). Mangrove ecosystems also serve as a natural barricade, shielding lives and property from storms and cyclones, flooding and soil erosion (Alongi 2008; Badola and Hussain 2005; Dahdouh-Guebas et al. 2005; Dahdouh-Guebas and Koedam 2006; Das and Vincent 2009; Hong 2006; McIvor et al. 2013; Sathirathai and Barbier 2001; Walters 2003, 2004).

Unfortunately, the global mangrove area has been reduced by 35% in the last 20 years and still, it is reducing by about 2.1% per year (Cornforth et al. 2013). The reduction is more rapid in developing countries due to shrimp aquaculture and logging for timber and fuel production (Duke et al. 2007). The growing stock and productivity of mangroves declined by 51% and 25% respectively in the two decades (FAO 2000; Millat-e-Mustafa 2002; Iftekhar and Islam 2004b).

Sundarbans, the world largest single chunk of productive mangrove forest ecosystems, lie within the delta of the Ganges, Brahmaputra, and Meghna rivers and south of the Tropic of Cancer at the northern limits of the Bay of Bengal between 21º30" to 22º30" N and 89°00" to 89°55" E (Das and Siddiqi 1985; Giri et al. 2011; Islam 2006; Islam and Gnauck 2008). It is one of renewable natural resources which plays a momentous role in local economies and livelihoods as well as national economic development. A wide variety of ecosystem, economic and cultural services are provided by Sundarbans (Ewel et al. 1998; Glaser et al. 2003; Moberg and Rönnbäck 2003; Rönnbäck et al. 2007; Barbier et al. 2011; Warren-Rhodes et al. 2011).

Protection of Sundarbans for achieving the sustainable livelihood of its present inhabitants is important. The Sundarbans have an exceptional and sundry range of habitats and biodiversity, but have been poorly understood from livelihoods perspective. Most of the studies that have been implemented in the region are largely concentrated on biodiversity, ecosystem, and watersheds (Ellison et al. 2000; Millat-e-Mustafa 2002; Iftekhar and Islam 2004a, 2004b; Biswas et al. 2007; Wahid et al. 2007; Iftekhar and Saenger 2008; Harun-or-Rashid et al. 2009; Rahman et al. 2010; Islam and Gnauck 2011;), wildlife (Islam et al. 2007; Barlow et al. 2008; Loucks et al. 2010) and fisheries (Hoq et al. 2001; Islam 2003; Islam and Haque 2004; Islam and Wahab 2005; Hoq et al. 2006; Hoq 2007;).

This study was carried out to capture the present livelihood pattern. It aims to know the present occupation and income, literacy rate, dependency rate on Sundarbans, livestock, drinking water sources, involvement in different NGOs and to find out present and future potential alternative livelihood opportunities for local people.

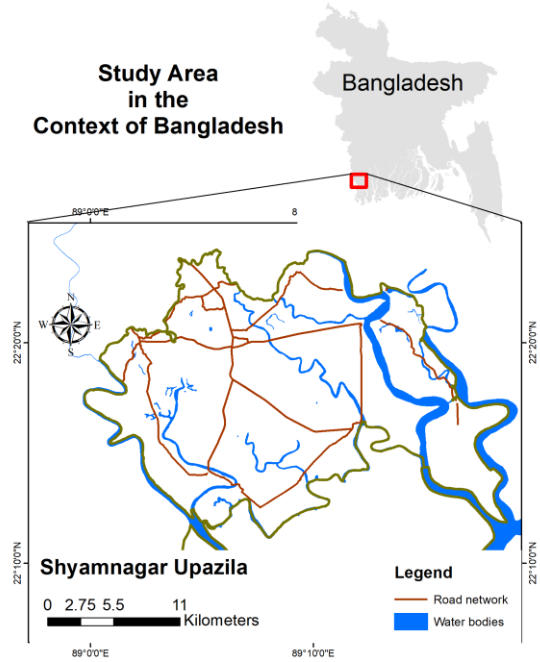

Figure 1. Map of study area in Shyamnagar Upazilla, Satkhira District, Bangladesh

MATERIALS AND METHODS

Study area

This study was conducted in Shyamnagar Upazila, Satkhira District, Bangladesh (Figure 1). This upazila is regarded as the largest in the district and is bounded by Kaliganj (Satkhira) and Assasuni Upazilas on the north, Sundarbans and Bay of Bengal on the south, Koyra and Assasuni Upazilas on the east, West Bengal of India on the west. It is located between 21°26´ and 22°54´ N and between 88°54´ and 89°20´ E (B.B.S 2011). The annual relative humidity ranges between 79-80%, the annual average precipitation is 1,689 mm and daily temperature varies from 21ºC to 30ºC. The main rivers of the study area are Betrabati, Hariabhanga, Ichamati, Jamuna, Kalindi, Kholpatua, Kobadak, Morischap, Sonai and Raimangal.

The upazila occupies an area of 1968.24 km^2 including 1622.65 km^2 of forest (B.B.S 2011). According to B.B.S (2011), the total population was 318,254 people, consisting of 48.21% males and 51.79% females; by religious beliefs, the population consisted of Muslims (79.35%), Hindus (20.37%), Christians (0.01%) and others (0.25%). Some indigenous groups like munda, bhabene, charal and kaiborta also belong to this upazila.

Data collection

A multi-stage sampling scheme was used to select sampling population. A total of 130 respondents from three unions namely Munshigonj (54), Gabura (52), and Burigualini (24) were selected deliberately because of their proximity to the Sundarbans. Secondary statistical data was collected from the forest department, libraries, different journals, newspapers, and different NGOs.

Data processing tools

The data was calculated in the software Statistical Package for Social Sciences (SPSS V) and Microsoft Excel to calculate necessary indices. There were some data, such as the amount of production, landholding size, etc., whose units were in local terms in questionnaires and hence were converted into standard units.

RESULTS AND DISCUSSION

Demographic and socioeconomic status of the respondents

The age of the respondents was characterized into three groups. Most of them (about 65%) were middle-aged (30-50 years old), followed by about 25% old-aged (above 50 years old) and only 10% (below 30 years old) were young. Both male and female respondents used to lead their family and 78% male and 22% female were the earning members of their family (Table 1). The involvement of women in family earnings was very low at Dacope, Shyamnagar, and Kaligonj Upazillas in Satkhira District (Dey et al. 2020; Islam et al. 2020; Nurunnahar et al. 2020). Discrete gender discrepancy is found in contribution where different earning activities are higher at the local level (Angelsen et al. 2011).

About 50% of respondents were illiterate, while 24% of the respondents had primary education and 26% of the respondents had secondary education. Education, a significant socio-economic variable and a key to individual and collective empowerment, make a farmer more accessible to advise from extension agencies and more able to deal with technical recommendations that require a certain level of literacy (Tripp 1993).

About 43% of the respondents had 4-5 members and 25% of the respondents had 5-6 members. According to BBS (2016) the usual family size of Bangladesh is 4.5 members, which specifies large family size of the study area. In these study areas, there were also 5% of the respondents who lived with only their spouses. Most of the respondents in this area were partially or fully dependent (72%) on the Sundarbans for their livelihood where 21% of respondents were partially dependent and only 7% of respondents were not dependent at all. According to Shah and Dutta (2010) about 50% of the mangrove adjoining households depend on forest and earn 75%-100% of their total income from the forest resources.

The monthly income of about 45% of respondents was 3000-4000 BDT/month, while 39% of respondents earned only 1500-2500 BDT/month. Only 1% of the local respondent earned more than 10,000 BDT/month. Islam et al. (2011) and Dey et al. (2020) found the average monthly income of the Sundarban respondents to be between 4620 BDT and 5000 BDT. Above 63% of the respondents had livestock, while 37% didn't have the same. For livelihood, the local people use to enter into the core habitat areas of the Royal Bengal Tiger and in many instances, such people were not fortunate to return back alive. Among three unions in Shymnagar Upazila, Munshigonj union had higher 58% tiger widows, whereas Burigoalini and Gabura had 26% and 16% tiger widows respectively.

Occupation

Primary and secondary occupations

Occupation is an important factor that reflects one's socio-economic position. It found that local people have involved in various occupations viz. fisherman (40.62%), daily labor (15.62%), crab collector (15.62%), fish farmer (9.38%), small business holder (4.71%), etc. (Table 2). A wide variety of livelihood options existed based on people's assets, local resources, knowledge, technology, capacity of the people, and institutional support. On the other hand, a wide range of occupational risks and associated vulnerabilities also existed. Alam et al. (2002) identified that people coped with a variety of livelihood and risk management strategies. When the local people (both male & female) had the scarcity of their primary occupations, they use to switch to secondary occupations which were mainly working as daily labor (22.32%) and fishing (25.38%). Women sometimes migrated from one place to another for searching jobs.

Local people’s attitude towards their present occupations

The local people were dissatisfied with their present occupations and 98% of respondents wanted to change their occupations. But due to the shortage of capital and lack of enough knowledge, they could not afford to start new tasks, such as small business or rearing of livestock.

IGAs (Income Generating Activities) training

Only 18% of respondents had knowledge of different Income Generating Activities (IGAs) training and 82% of respondents did not have any knowledge about IGAs training. The IGAs training with association of different NGOs, Bank or Government steps is the prerequisites (Shonia 2012) for the development of the socio-economic condition of local people. Among the respondents who had IGAs training, their training (some times more than one) were based on poultry rearing (23%), small business (61%), honey collection (7%), vegetable and rice cultivation (23%), crab fattening (7%), sewing (15%) and mat making (7%). Need for dissemination of the ideas of IGAs training was anticipated from concerned sources as it was a major tool for uplifting local socio-economic conditions.

Table 1. Age, household size, literacy, income, earners, dependency on Sundarbans, tiger widow family and livestock status of the respondents

		Percentage
Age (years)	Age range	
	20-30	10.00%
	30-50	65.00%
	51-76	25.00%
Household size	Categories	
	2 members	5.00%
	2-3 members	21.00%
	4-5 members	43.00%
	5-6 members	25.00%
	6-7 members	6.00%
Literacy	Categories	
	Illiterate	50.38%
	Primary education	24.04%
	Secondary education	25.58%
	Higher education	0.00%
Dependencies on Sundarbans	Categories	
	Fully	72.00%
	Partially	21.00%
	No dependency	7.00%
Monthly income (BDT)	Income range	
	500-1000	3.00%
	1500-2500	39.00%
	3000-4000	45.00%
	5000-7000	10.00%
	8000-10000	2.00%
	above 10000	1.00%
Earners	Gender	
	Male	78.00%
	Female	22.00%
Tiger Widow (TW) Family	Union	
	Burigoalini	26.00%
	Gabura	16.00%
	Munshigonj	58.00%
Livestock Status	Yes/no	
	Yes	63.00%
	No	37.00%

Table 2. Occupations of the respondents

Occupations	Percentages (%)
Fishing	40.62
Crab collection	15.62
Daily labor	15.62
Fish farm	9.38
Small business	4.71
Agriculture	3.91
Honey collection	1.56
Carpenter	1.56
Sewing	1.56
Board making	0.78
Board riding	0.78
Mat making	0.78
Motorcycle driving	0.78
Poultry rearing	0.78
Prawn collection	0.78
Prawn farming	0.78

Land distribution

Homestead land

Homestead land is an indicator of the socio-economic condition of the local people. In the study areas, most of the people (33.84% and 33.8%) had 1-3 and 4-6 decimal of land whereas only 18.46% had 7-10 decimal of land (Figure 2). Respondents had very few lands for homestead which were not sufficient for homegarden. Often the house was very small for accommodation.

Arable land

About 37-38% of the respondents had 33-100 decimal arable land and about 26% of respondents had more than 100 decimal arable lands (Figure 3). In the study area, the amount of the arable land was proportionately adequate for the upliftment of socio-economic condition of the local people. However, most of the arable land was found to be utilized as shrimp farms (gher).

Livestock

Types of livestock

Poultry rearing was a popular practice (68%) whereas goat and cow rearing percentages were 30% and 2%, respectively. The respondents had the opportunity to get IGAs training on poultry rearing and poultry feed was also available in the local market. Cow rearing is also a long-term beneficial task, however, goats are relatively more important for poorer households (Thompson 2000).

Fodder sources of the livestock

Most of the respondents (68%) bought fodder for their livestock from market, whereas 32% of the respondents depended upon nature for collecting fodder for livestock. Naturally, available fodder adds to the benefit of the livestock rearers, for this reason, different agricultural crops, some saline tolerant trees, and some grasses may be suggested for the local people so that they may be simultaneously benefitted.

Reasons for not having livestock

Above 25.54% of the respondents had no livestock due to the lack of capital and 23.4% due to the lack of pasture land. Other causes were lack of fodder (14.89%) of livestock and salinity problem (17.02%) (Figure 6). The study area was a polder area and situated towards the Bay of Bengal. Most of the water sources were highly saline. To improve their socio-economic condition, they have to be provided different easy loans and various training for rearing of livestock.

Dependency on the Sundarbans

Mainly the poor people depended on the Sundarbans for fish, fuelwood, small timber, aquatic resources, Goran (*Ceriops decandra*), Golpata (*Nypa fruticans*), and honey. Forest income was important for every income group in the communities, not just for the poorest. Subsistence reliance is relatively higher for the poor (Angelsen et al. 2011). If they may be provided alternative income sources, then their dependencies on the Sundarbans may be reduced.

Products of the Sundarbans

Most of the local people (about 92%) depended on the Sundarbans for fuelwood and 80% on aquatic resources (Table 3). Fuelwood and aquatic resources were their daily need and they can not think of a single day without fuelwood or small timber. They collected honey (27%) from the deep forest and sold this to the nearby markets. The percentage of collected Goran (*Ceriops decandra*) and Golpata (*Nypa fruticans*) were 8% and 6%, respectively for their house shade. Islam et al. (2020) stated that the percentage of fish, golpata, fuelwood, honey, and goran collection were 56.67%, 43.33%, 23.33%, 14.14%, and 0.33% respectively. Sources of drinking water in the study areas

Due to high salinity, local people in the Shymnagar Upazila used pond (33%) and deep tube-wells (28%) water for drinking. Other water utilization rates were filter (2%), PSF (Pond Sand Filter) (18%), pond and rainwater (3%) and pond and filter water (16%). Especially in the summer season locals suffered more and have to collect water from far away.

Health treatments types

Good and balanced health of the people indicates developed livelihood (Frankenberger and McCaston 1998). In this study area, most of the respondents were poor and about 50% of the respondents took treatment from village doctors. Only 33.85% of the respondents had capacity to go to private clinics, while 7% of people took treatments from government hospitals, which was due to fewer available government hospitals (Table 4). In addition, modern treatment was often not affordable to them due to high cost so the village doctors, homeopaths, general health practitioners and kabiraz (a person traditionally practicing Ayurveda in Eastern Indian subcontinent) were less expensive alternatives. The results obtained from the present study indicated that most of the rural people received inadequate health treatment, possibly associated with ignorance, social constraints and cost of treatment, and lack of facilities.

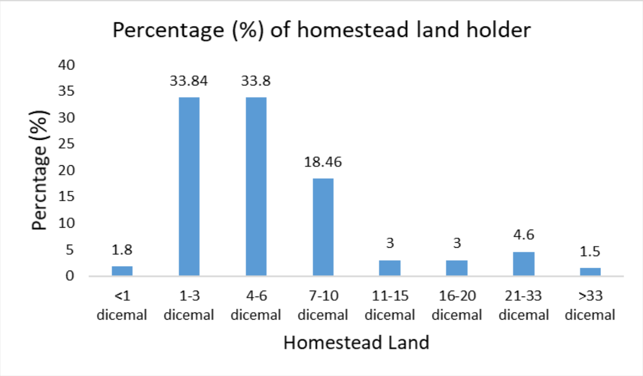

Figure 2. Percentages of local respondents having homestead land in decimal

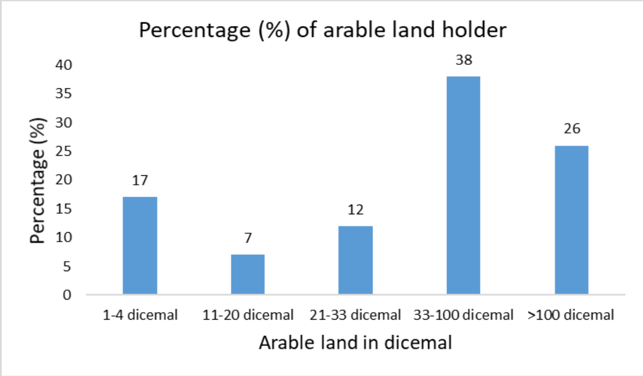

Figure 3. Percentages of local people having arable land in decimal

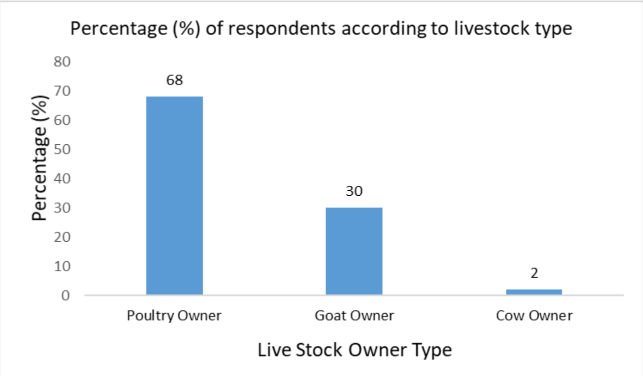

Figure 4. Percentages of respondents with various livestock

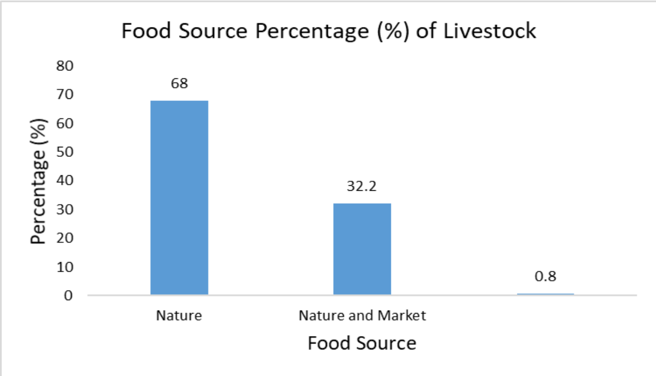

Figure 5. Percentages of food sources of livestock in the study areas

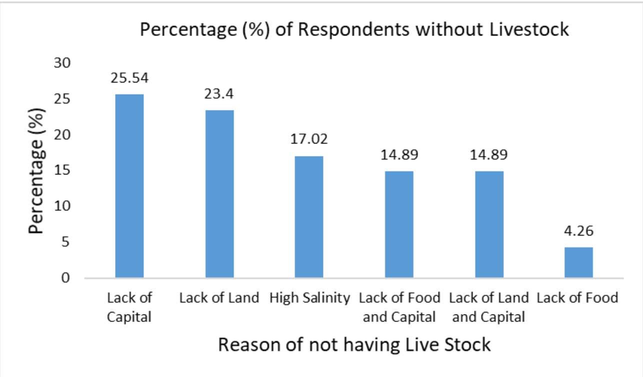

Figure 6. Percentages of respondents without livestock due to some reasons

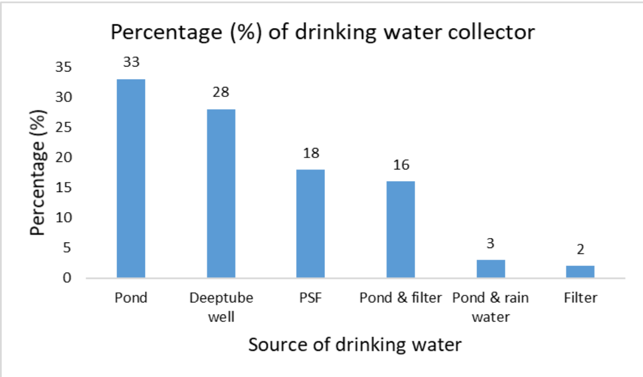

Figure 7. Percentages of the respondents with drinking water collection from various sources

Table 3. Percentages of collector respondents of Sundarbans products

Products collected from Sundarbans	Percentages (%) of collector respondents
Fuelwood	92%
Aquatic resources	80%
Small timber	54%
Honey	27%
Goran (*Ceriops decandra*)	8%
Golpata (*Nypa fruticans*)	6%

Table 4. Scenario of health treatment's types in the study areas

Health treatment providers	% of rural people
Village doctors	49.23%
Private clinic	33.85%
Government hospital	7.69%
Govt. hospital and village treatment	3.08%
Kabiraz (traditionally practicing Ayurveda)	5.38%
Kabiraz and private clinic	0.77%

Table 5. Names of the desirable trees/grasses on the dike of shrimp farm

Local name of trees	Scientific name
Dhundul	*Xylocarpus granatum*
Goran	*Ceriops decandra*
Sundri	*Heritiera fomes*
Keora	*Sonneratia apetala*
Peyara	*Psidium guajava*
Sofeda	*Populus ciliata*
Geowa	*Excoecaria agallocha*
Narikel	*Cocos nucifera*
Tal (Palm tree)	*Borassus flabellifer*
Dhonce	*Sesbania bispinosa*
Durba	*Cynodon dactylon*
Samna	*Albizia saman*

VGF/VGD support

Vulnerable Group Feeding (VGF) and VGD (Vulnerable Group Development) are the citizens right for the helpless or poor people from the Government of Bangladesh. But only 11% of the respondents got this support, whereas 89% of the respondents were poor and did not get the support, which was a great concern.

Disaster warning & shelter facilities

It was found that about 70% of people got disaster warnings during natural disasters, unfortunately, about 80% of people did not have their shelter from natural disasters. During these natural disasters, the local people were badly affected and became helpless. Their crops, livestock, and homes were damaged by storms and cyclones. It is needed by the Government and different NGOs to establish enough shelter centers for the victims.

Co-management on Sundarbans

Different co-management activities on Sundarbans were being run by different Governments and NGOs. But in this study area, about 91% of the respondents had no knowledge and only 9% knew about co-management.

About 84% of respondents were connected with different NGOs for financial support but still, their socio-economic condition is at minimum level. Structures loan and technical support for livelihood development from NGOs are needed.

Shrimp farm (Gher)

Except for the homestead land, most of the arable land in this study area were used for shrimp farm (gher), and a little amount of the total land was used for agricultural purposes. About 63% of the respondents had shrimp farms and 37% had no gher because of land scarcity. USAID (2006) estimated that nearly 1.2 million people were directly involved in shrimp production and made $625 million in exports in 2010-11 in Bangladesh (Parvez 2011). Many studies revealed that unabated expansion of shrimp culture caused the loss of mangrove areas and biodiversity (Hoq et al. 2001; Shahid and Islam 2003; Hoq 2007; Hossain et al. 2013;), loss of soil fertility, and increase salinity (Wahab 2003; Ali 2006; Choudhury et al. 2011; Rahman et al. 2011; Rahman et al. 2013), loss of livestock (EJF 2004; Karim 2006) and changes in land use pattern (Ali 2006; Azad et al. 2009). Most of the respondents (87%) who had gher, were eager to diversify the income and wanted to plant trees and grasses on gher dike which would also protect their farm dike from erosion and also provide shade for the shrimps. Following trees and grasses were suggested by the local shrimp farm owners (Table 5).

To conclude, most of the local people adjacent to Sundarbans are directly or indirectly dependent on Sundarbans for their livelihood. In addition, the major physical risks are associated with the people through their poor communicative networks. The livelihoods analysis based on findings in Shymnagar Upazila reflects a legible picture of the life of poor households in the polder areas. Co-management on Sundarbans and other income-generating activities (IGAs) training is rare here. If there are enough facilities for this training, it may facilitate to improve the income of the local people. The government and different NGOs should provide various easy loans and technical support so that they can start alternative occupations and their dependencies on the Sundarbans may be reduced significantly. Further, livelihood pattern of the local people with seasonal changes is a cause of concern and the concerned authorities may urgently ponder upon necessary steps to be taken in the future.

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Plant species diversity and crown cover response to vegetation regeneration in community-managed forest in Makawanpur District, Nepal

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Abstract. *Ghimire P, Lamichhane U. 2020. Plant species diversity and crown cover response to vegetation regeneration in community-managed forest in Makawanpur District, Nepal. Asian J For 5: 36-41.* Community forestry is considered as a win-win solution for forest conservation and livelihood provision of forest-based communities. Yet, limited knowledge is available regarding the status of vegetation regeneration in community forests. The study was carried out to assess plant species diversity and crown cover response to regeneration composition in Nawalpur Saraswati (Basamadi) Community Forest of Hetauda Municipality, Makawanpur District, Nepal in November 2020 to December 2020. A stratified random sampling method with a total of 94 sample plots was applied in the study. In total, 44 species belonging to 26 families were recorded in the study site, of which 23 species were represented in tree category, 14 in shrub, and 7 in herb category. Both Shannon-Weiner and Simpson's diversity indices indicated good floral species diversity in the study area. The forest was dominated by *Shorea robusta* with 396 stem ha^{-1}, followed by *Terminalia bellerica* 29 stem ha^{-1}, *Lagerstroemia parviflora* 25 stem ha^{-1}, and *Terminalia tomentosa* 21 stem ha^{-1}, respectively. Both seedling and sapling were found in good numbers with seedlings 11,583 number $ha^{-1}$and saplings were 1,896 number ha^{-1}. Both seedling and sapling density was recorded higher in open crown coverage (seedlings=32625 number ha^{-1}; saplings=5033 number ha^{-1}) than in close crown coverage (seedlings=13,708 number ha^{-1}; saplings=2,550 number ha^{-1}). Therefore, the study concluded that crown opening facilitates the growth and development of regeneration density in *Shorea robusta* and its associated forests. Furthermore, the information generated could be useful to predict future trends in species composition and stand structure in order to optimize the possible forest management strategies.

Keywords: Community forest, crown cover, diversity, regeneration

INTRODUCTION

Biodiversity or biological diversity refers to the variety of life forms on Earth, or to the property of living systems to be distinct. It includes plants, animals, microorganisms, ecosystems, and ecological processes associated with them. (CBD 2010; MoFSC 2014). Biodiversity is a central theme of ecological theory and has been the topic of many discussions. The Convention on Biological Diversity (1992) states that the assessment and documentation of biodiversity as one of the most prioritized tasks by the world (CBD 2010). The documentation of biological resources is possible through extensive exploration of biological resources including in-depth floristic and faunal studies (Chalise et al. 2018; Ghimire 2019). Floristic study refers to the identification and documentation of all plant species in a given geographical area (Simpson 2006). Such study helps in botanical inventory and adds herbarium specimens in the existing herbaria which can facilitate the updating of taxonomical nomenclature (Chalise et al. 2018). Moreover, it could provide the basis for protection and wise use of floristic resources and to evaluate the effectiveness of conservation measures.

Floristic diversity refers to the variety of plants occurring in a specific geographical region (Simpson 2006). It is strongly associated with forest crown cover which can be described as the proportion of the forest floor covered by the vertical projection of the crowns of live trees (Jennings et al. 1999). The structure, composition, and vegetative functions are the most significant ecological features of a particular ecosystem, which show variations in response to environmental as well as human-induced variables (Shaheen et al. 2012; Timilsina et al. 2007). Likewise, analyses of diversity of forest components, natural regeneration, and crown cover are important variables in the assessment of forest status in terms of growing stock, dynamics, forest, and sustainable management. Such information would help facilitate the development of a forest management strategy (Spies 1998; Sarkar and Devi 2014). Therefore, timely and accurate assessment of floral diversity dynamics is important for their sustainable management, utilization, and biodiversity conservation.

Natural regeneration of forests is the most important process to maintain and expand the population of plant species in a community with time and space (Bharali et al. 2012). A healthy forest ensures good future regeneration (Awasthi et al. 2015). The regenerating and productive character of a forest is determined by various age groups of seedlings, saplings, and trees (Chauhan et al. 2008). Floral structure in a forest can convey its regeneration behavior, particularly the reproductive strategy (Singh and Singh

1992) which in turn demonstrates the development trend of the community (Zhang et al. 2007), species composition and stability in the future (Napit 2015). Crown cover also influences plant regeneration and survival, thus governing the nature of the vegetation (Zollner and Crane 2003; Baral and Ghimire 2020). Therefore, it is considered an important ecological parameter of forest ecosystem for its relationship with natural regeneration and species richness (Ganey and Block 1994; Zollner and Crane 2003; Baral and Ghimire 2020).

Community forestry (CF) has been accorded the highest priority of Nepal's forestry sector and has been widely acclaimed as a successful forest management approach. The program successfully rehabilitates degraded hills and thereby increases biodiversity (Shrestha et al. 2010; Gilmour 2016; Ghimire and Lamichhane 2020). During the last 40 years of community forestry implementation, about 40% of the national forest area has been handed over to more than 22,266 community forest user groups (Ghimire and Lamichhane 2020). While forest user groups have been protecting community forests for about the last 40 years, yet studies on the assessment of regeneration and growth performance of forest species in community-managed forests have not received much attention, except few similar studies (Paudyal 2016; Cedamon et al. 2018). In this regard, this study was conducted to assess plant species diversity and crown cover response to forest regeneration in community-managed forest of Makawanpur District, Nepal.

MATERIALS AND METHODS

Study area

The study was carried out in the Nawalpur Saraswati (Basamadi) Community Forest (27°25'N, 85°02' E) of Hetauda Municipality, Makawanpur District, Nepal, covering an area of 234.21 ha which was handed over in July 1995. The study area is characterized by upper tropical climate with average temperature ranging from 18° C to 28° C and rainfall of 220 mm. It is situated at an altitude between 510-950 m above mean sea level. It has good forest condition with the dominant stage of forest is tree and has 80 percent coverage of *Shorea robusta* forest. Other associated plant species are *Terminalia alata, Terminalia bellerica, Terminalia chebula, Syzygium cumini, Lagerstroemia parviflora,* etc. (NSBCFUG 2015).

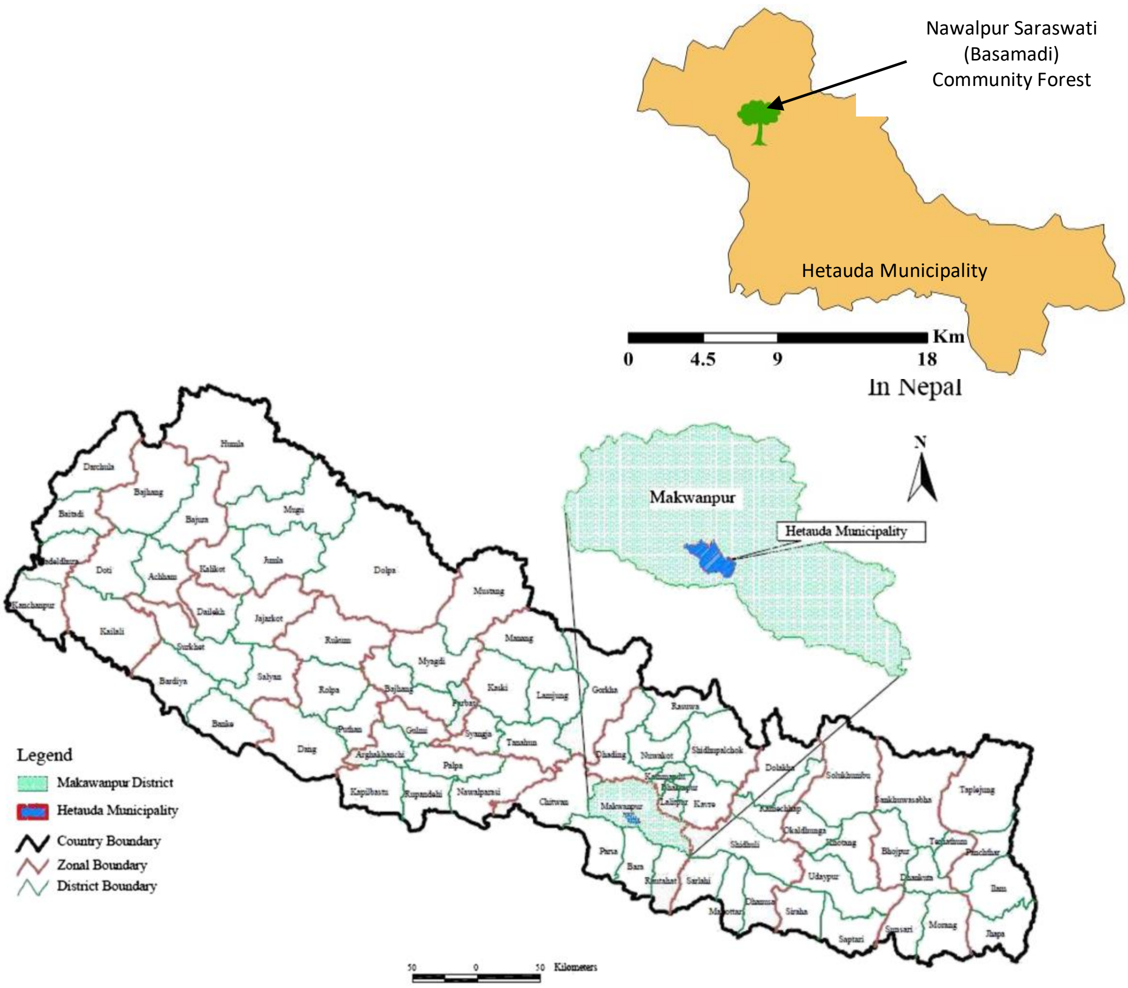

Figure 1. Map of the study area in Nawalpur Saraswati (Basamadi) Community Forest of Hetauda Municipality, Makawanpur District, Nepal

Forest sampling

A stratified random sampling method was applied in the study. Individual plants were categorized into tree (dbh> 30 cm), saplings (dbh < 10 cm and height > 1.0 m) and seedling (height < 1.0 m). A total of 96 sample plots (with 0.5% intensity) were established to collect plant species diversity and regeneration status following the Forest inventory guideline as recommended by Government of Nepal (DoF 2004). The quadrants of 5m x 5m for sapling and 5m x2m for seedling were laid out. Furthermore, of the total 96 plots, as many 24 plots were stratified into four crown cover classes namely: 0-25%, 25050%, 50-75%, and 75-100% to analyze the crown response to regeneration status. Diameter tape and GPS were used for the measurement of plots. Densitometer was used to determine the crown cover percentage.

Data analysis

There are many indices that are available for measurement of species diversity and richness. For this study, diversity indices including Shannon-Wiener's index (H), Simpson's diversity index (D), and Species evenness index (E) were analyzed following Shannon and Wiener (1963) and Simpson's (1949) respectively. Empirical data were analyzed with the help of Statistical Package for Social Science (SPSS). In addition, Correlation analysis was performed to assess the response of crown cover on regeneration composition of the forest.

Density = Total number of a species in all the quadrats/ Total number of quadrats

Shannon-Wiener index (H) (For the analysis of species diversity)

$$H = -\sum pi \ln pi$$

Shannon's measure of evenness (E) (For the analysis of species evenness)

$$E = H / \ln S$$

Simpson's index (D) (For analysis of species diversity)

$$D = 1/ (\sum p^2_i)$$

Where, Pi is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), and S is the total number of species(=species richness), E= evenness, and H= Shannon-Wiener index respectively.

RESULTS AND DISCUSSIONS

Abundance and species composition

In total, 44 plant species belonging to 26 families were reported in the study area, of which 23 species were represented in the tree group, 14 in the shrub group, and 7 in the herb group. *Shorea robusta* was the most dominant species of tree category followed by *Terminalia bellerica*, *Lagerstroemia parviflora*, *Terminalia alata*, *Mallotus philippensis*, *Terminalia chebula*, and *Schima wallichii* (Table 2). *Clerodendron infortunatum, Lyonia ovalifolia, Woodfordia fruticosa,* and *Eupatorium odorata* were dominant species in the shrub category. Among herbs, *Thysanolaena maxima* and *Eulaliopis binata* were most dominant. Occasionally, *Rauwolfia serpentina,* and *Asparagus officinalis* were also reported in the study area. Paudyal (2011) observed 58 plant species in the *Shorea robusta* dominated Lamindanda Community forest of Tanahu District. The result is in line with Mishra and Garkoti (2014) who reported 51 floral species including 15 tree species, 20 shrub species, and 9 herb species in Sabaiya Collaborative forest in Bara district of central Nepal. Similarly, Paudel (2016) documented 32 plant species in Pragatisil Community forest in Kaski District of western Nepal. In the two *Shorea robusta* Forests in Western Nepal, Gautam (2001) observed 94 and 120 plant species respectively. Pandey and Shukla (2003) also recorded a total of 208 plant species representing 165 genera and 72 families in a *Shorea robusta* forest in Gorakhpur, India.

This study revealed that the index of dominance was 0.55 (S*horea robusta* representing 55% in the stand). The Shannon Diversity Index (H) for tree, shrub and herb was 1.59, 1.32 and 0.52 respectively, while Simpson's Diversity Index was 0.79, 0.51 and 0.27 for tree, shrub and herb, respectively (Table 1), showing higher floral diversity in the forest. Dhakal et al. (2011) reported Shannon Diversity Index and Simpson's Diversity Index of 3.01 and 0.87, respectively, in Satkanya CF of Chitwan district. Similarly, the result of this study is consistent with Mishra and Garkoti (2014) who documented Shannon Diversity Index for tree, shrub and herb was 1.34, 2.09 and 0.56 respectively and Simpson's Diversity Index of 0.52, 0.57 and 0.21 for tree, shrub and herb, respectively, in Sabaiya Collaborative forest in Bara district of Nepal.

Plant density and regeneration status

In the study area the highest tree density was recorded for *Shorea robusta* (396 stem ha^{-1}), followed by *Terminalia bellerica* (29 stem ha^{-1}), *Lagerstroemia parviflora* (25 stem ha^{-1}), *Terminalia tomentosa* (21 stem ha^{-1}) and *Mallotus philippensis* (20 stem ha^{-1}). Accordingly, in shrub category *Clerodendrum infortunatum* was dominant with density of 25 stem ha^{-1}. In the regeneration composition (both seedling and sapling), the highest density was reported for *Shorea robusta* (10,908 number per ha), followed by *Terminalia bellerica* (950 number per ha), *Terminalia alata* (700 number per ha) and *Terminalia chebula* (279 number per ha) (Table 2). Both, seedlings and saplings of *Shorea robusta* was recorded in good number than other species.

Regeneration status of forests in terms of number per hectare determines the condition of the forest ecosystem. In this study regeneration structure (both seedling and sapling) of *Shorea robusta* (seedling=8,552 ha^{-1} and sapling=1,683 ha^{-1}) shared a major portion in the study area, which was followed by other 22 different tree species such as *Terminalia bellerica*, *Terminalia*. Compared to *Shorea robusta*, the regeneration status of other species was very poor (less than 1,000 seedling ha^{-1} to even 0). Shrestha (2005) reported 909 trees ha^{-1} in Community forest of Gorkha district, Nepal. Mishra and Garkoti (2014) reported *Shorea robusta* was found to be the dominant tree species with 430 trees ha^{-1} in Sabaiya Collaborative forest of Bara district. The findings of this study are in line with Paudyal (2016) who reported *Shorea robusta* with higher density 291 stems ha^{-1} and with 6,126 seedlings ha^{-1} in the Pragatisil Community forest of Kaski district. Baral and Ghimire (2020) also reported a good number of regeneration (seedling 29,251 ha^{-1} and sapling 4,800 ha^{-1}) in Buddha-Shanti Collaborative forest of Paris district in western Nepal.

Table 1. Plant species diversity and evenness in the Nawalpur Saraswati (Basamadi) Community Forest, Nepal

Biodiversity indicators	**Plant category**		
	Tree	**Shrub**	**Herb**
Species richness (number of species)	23	14	7
Shannon diversity index (H)	1.59	1.32	0.52
Simpsons diversity index (D)	0.79	0.51	0.27
Species Evenness index (E)	1.17	1.15	0.48

Table 2. Density and regeneration per ha of plant species in Nawalpur Saraswati (Basamadi) Community Forest, Nepal

Species/category	**Family**	**Density (trees/ha)**	**Regeneration (individuals/ha)**		
			Seedling	**Sapling**	**Total**
Shorea robusta (T)	Dipterocarpaceae	396	8,552	1,683	10,235
Terminalia bellerica (T)	Combretaceae	29	979	13	992
Terminalia alata (T)	Combretaceae	21	677	75	752
Terminalia chebula (T)	Combretaceae	17	271	8	279
Schima wallichii (T)	Theaceae	13	198	29	227
Clerodendrum infortunatum (S)	Lamiaceae	25	125	12	137
Mallotus philippensis (T)	Euphorbiaceae	20	94	17	111
Syzygium operculata (T)	Myrtaceae	4	83	8	91
Lagerstroemia parviflora (T)	Lythraceae	25	73	13	86
Holarrhena antidysenterica (T)	Apocynaceae	6	73	0	73
Syzygium cumini (T)	Myrtaceae	4	62	4	66
Bombax ceiba (T)	Malvaceae	4	0	0	0
Phyllanthus emblica (T)	Phyllanthaceae	12	21	4	25
Miscellaneous		143	315	34	349
Total		719	11,583	1,896	13,479

Note: T=tree, S=Shrub, H=herb

Table 3. Crown coverage and regeneration density per ha of study area in Nawalpur Saraswati (Basamadi) Community Forest, Nepal

Crown cover (%)	**Species**	**Regeneration count**		**Regeneration density (per ha)**	
		Seedling	**Sapling**	**Seedling**	**Sapling**
0-25	*Shorea robusta*	343	157	14292	2617
	Terminalia alata	22	5	917	83
	Terminalia bellerica	35	1	1458	17
	Others	44	14	1833	233
	Total			18500	2950
25-50	*Shorea robusta*	228	107	9500	1783
	Terminalia alata	26	8	1084	133
	Terminalia bellerica	38	1	1583	17
	Others	47	9	1958	150
	Total			14125	2083
50-75	*Shorea robusta*	146	84	6083	1400
	Terminalia alata	15	5	625	84
	Terminalia bellerica	17	0	708	0
	Others	32	2	1334	33
	Total			8750	1517
75-100	*Shorea robusta*	104	56	4333	933
	Terminalia alata	2		83	0
	Terminalia bellerica	4		167	0
	Others	9	6	375	100
	Total			4958	1033

Response of crown covers to forest regeneration

The study found that crown cover has a notable role in regeneration density of plant species, particularly in regeneration structure of *Shorea robusta* species (Table 3). This study found the regeneration density (both seedling and sapling) was recorded higher in open crown cover strata (i.e. 0-25% and 25-50% crown cover) than in dense crown cover strata (i.e. 50-75% and 75-100% crown cover) (Table 3). Higher regeneration density was recorded in 0–25% crown cover strata with seedlings 18,500 and saplings 2,950 per ha, respectively, and a lesser regeneration number in 75–100 % crown cover strata with seedling 4,958 and sapling 1,033 number per ha respectively.

Opening of crown is one of the important factors in the study of plant growth and development which influences phenology of plant communities (Cook et al. 1995; Zollner and Crane 2003; Baral and Ghimire 2020). This study found that both seedling and sapling density was lower in dense crow cover strata than in open crown cover strata. Baral and Ghimire (2020) also reported higher regeneration density in open crown closure than dense crown closure in community-managed forest in western Terai, Nepal. Comparing the regeneration structure of *Shorea robusta* species with the increasing crown cover, the regeneration number decreased remarkably, which indicates that crown opening and light intensity is important for the regeneration of *Shorea robusta* and other associated species (Table 3). Gautam and Devoe (2006); and Awasthi et al. (2015) reported that the regeneration performance of *Shorea robusta* and other associated species was found better in open space than under shade. Similarly, the finding of this study is consistent with Sapkota and Oden (2009); and Baral and Ghimire (2020) who reported that regenerations of *Shorea robusta* better grow and survive on open canopy as compared to those under dense or closed canopy. This also exemplifies that the regeneration of *Shorea robusta* and its associated species better grow and survive on open canopy or in presence of light intensity. Furthermore, the study shows that the regeneration density has a strong negative correlation (seedling: r=-0.961; sapling: r=-0.935) with dense or close crown coverage. Baral and Ghimire (2020) also reported a negative correlation between regeneration density and increased crown cover in *Shorea robusta*-dominated community managed forest in western Terai, Nepal.

In conclusion, Nawalpur Saraswati (Basamadi) Community Forest supports 23 species of tree, 14 species of shrub and 7 species of herb belonging to 26 families. Both Shannon-Weiner and Simpson's diversity indices indicated good floral species diversity in the study area. Both the seedling and sapling density was recorded for *Shorea robusta* species (seedlings=8,552 number ha^1; saplings=1,683 number ha^{-1}). A higher number of both seedling and sapling densities were recorded in the open space than in the indicating crown opening. The presence of light is crucial for growth and development of regeneration of *Shorea robusta* and its associated species. The study also revealed a strong negative correlation between increasing number of regeneration densities and increased crown coverage, i.e. increase in regeneration density with a decrease in crown coverage.

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The use of DNA barcoding to avoid adulteration in olive plant leaf products

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Abstract. *Partovi R, Iranbakhsh A, Sheidai M, Ebadi M. 2020. The use of DNA barcoding to avoid adulteration in olive plant leaf products. Asian J For 5: 42-47.* The leaves of olive plant species, either the cultivated (*Olea europaea*) and the wild (*O. europaea* var. *Cuspidata*) have been used for medicinal uses in Iran. The first species leaves have been used to control the blood pressure, while the leaves of wild olive have been used for abortion by locals. Our preliminary inspection of the medicinal plant market revealed that the leaves of these two olive species were sold mistakenly to the consumers and their health might be at risk. Therefore, we performed this investigation to produce DNA barcodes for correct identification of these two olive species and also identify the potential adulteration in our local market. We used Internal transcribed spacer (ITS) as well as plastid genome *trnL-F* intergenic spacer and ribosomal protein L16 (rpL16) sequences. These sequences after alignment and curation produced DNA barcodes that can differentiate the two olive species from each other. The phylogenetic trees constructed also separated the samples of these olive species and confirmed the potential use of these short DNA sequences for olive barcoding. The present study revealed that some of the local shops mistakenly sell the wild olive leaves instead of the cultivated olive leaf to be used for blood pressure. This mistake endangers the health of pregnant women consumers if they carry a child. We suggest using a combination of nuclear ITS and plastid intergenic spacer (*trnL-F* and rpL16) regions for DNA barcoding of olive plants to avoid leaf product adulteration.

Keyword: DNA barcoding, medicinal market, *olive*, rpL16,trnL-F

INTRODUCTION

The olive plant (*Olea europaea* L.) complex occurs in the Canary Islands, the Mediterranean region, south-west Asia, Sino-Himalayan region, eastern as well as southern Africa (Green 2002). While African olive is a tropical wild olive, which is geographically isolated from its Mediterranean relatives (Zohary 1995). In the recent revision of *Olea* (Green 2002), the name *Olea europaea* subsp. *cuspidata* is proposed for the wild olive occurring in South to North-East Africa and southwest Asia.

In Iran, the olive plant occurs in both cultivated (*Olea europaea* subsp. *europaea*), and wild (*Olea europaea* subsp. *cuspidata* (Wall. & G. Don) Cif.). The wild *Olea europaea* subsp. *cuspidata* is naturally distributed in southern parts of Iran. Both cultivated and wild olive plants have edible and/or medicinal values. The cultivated olive (*O. europaea* subsp. *europaea*) is mainly used for olive oil, but also its leaves have been used to reduce blood pressure (Lockyer et al. 2017). Similarly, the wild olive (*O. cuspidata*) has medicinal properties like antibacterial, antifungal and antioxidant activity (Masoko and Makgapeetja 2015). The plant leaves are usually used as a remedy for eye infections, sore throat, urinary tract infections, kidney problems and backaches or headaches (Masoko and Makgapeetja 2015). The leaves are also recommended as hypotensive, emollient, febrifuge and styptic (Somova et al. 2003), and utilized for the treatment of malaria in 1854 (Altinyay et al. 2011). The leaves of both cultivated olive *O. europaea*, as well as wild olive *Olea cuspidata* are important medicinal plant product in Iran that is used for several disorders. The leaves of *O. europaea* are used to reduce blood pressure, while leaves of *O. cuspidata* are used in the form of tea to avoid pregnancy among our local people (Abaza et al. 2015; Hashmi et al. 2015).

Our preliminary inspection of these plant products in local medicinal plant market noticed that both plant species products were sold with the same name, i.e. olive, and were given for blood pressure control. This urges for attention since it might cause unintended effects, particularly regarding the adulteration of medicinal plants. Adulteration of medicinal plant products is a dangerous act that can endanger the consumer’s health. This might happen due to substitution or addition of another substance in the genuine medicinal product (El Beyrouthy and Abi-Rizk 2013), or due to careless plant collection, mislabelling or presence of high level of morphological similarity of the plant species in the field (El Beyrouthy and Abi-Rizk 2013). Irrespective of the reason for adulteration, this phenomenon seems to occur frequently in medicinal plant market of developing countries (Srirama et al. 2017). Medicinal plant product adulteration can result in various and extensive harm to the people using them. For example, cases of kidney failure were reported (Srirama et al. 2017), as a result of adulteration of the roots in *Stephania tetrandra* with that of

Aristolochia fangchi. Similarly, hepatotoxicity occurred due to mixing of the *Cinnamomum verum* bark with *C. cassia* and *C. malabatrum* (Srirama et al. 2017).

It is suggested to utilize integrative methods for authentication of the medicinal plants and investigating the cases for adulteration. A combination of various approaches and disciplines have been considered for such investigations such as physical and chemical methods like thin-layer chromatography (TLC) and high-performance liquid chromatography (HPLC), external morphological features, DNA sequence similarity, and phylogenetic analyses using both tree-based criteria or character-based methods (Pasqualone et al. 2016; Ghorbani et al. 2017; Yu et al. 2018). Recently, determination of the genetic distance among the studied samples and with the correct plant specimens as well as BLAST approach and DNA barcoding have also been used (Sheidai et al. 2019). A DNA barcode is unique short DNA sequences that different plant species, cultivars or races from each other and the closely related plant taxa (Sheidai et al. 2019). It enables the researchers to correctly identify the target species. This approach has been utilized to identify the medicinal plants and distinguish the original products from adulterated species/DNA (Heubl 2010; Sheidai et al. 2019).

The present study was conducted with the following aims: (i) to use different DNA regions to differentiate wild versus cultivated olive plants; (ii) to provide proper barcodes for either species, (iii) to check the potential adulteration/ or misidentification of these plant products by the local medicinal plant markets based on different barcoding approaches. For these, we first used ITS (Internal Transcribed Spacer DNA), and the chloroplast intron sequences of rpL16 and *trnL-F*, for distinguishing the two plant species of *O. europaea*, and *O. cuspidata*. We finally used rpl16 sequences to identify the local market plants and investigate the potential adulteration or mistakes in these products.

MATERIAL AND METHODS

Plant materials

The wild olive (*Olea cuspidata*) leaf samples (four different trees) were collected in Southern Iran, where the local people collect the same plant leaves for consumption (Table 1). For ITS, six wild specimens were compared with four cultivated specimens (Table 2). For trnL-F, six wild specimens and five cultivated specimens gathered from NCBI were compared with each other (Table 3). The accession numbers of *Olea* species have been provided. For rp16, we also applied two out-groups, six cultivated specimens collected from different shops in Tehran, Iran, and one wild specimen (Table 4).

DNA extraction and PCR reactions

Fresh leaves were put to dry in silica gel powder. We used CTAB activated charcoal protocol (Krizman et al. 2006). The extracted DNA was examined in terms of quality and quantity by running on 0.8% agarose (Sheidai et al. 2013).

ITS sequences investigation

The complete ITS region was amplified using forward ITS5 (5′- GGA AGT AAA AGTCGTAAC AAG G- 3′) and reverse primers ITS4 (5′- TCC GCT TAT TGA TAT GC- 3′) (White et al. 1990). The following program was used for amplification of nuclear region in a PCR reaction: 5 min initial denaturation step 94°C, followed by 40 cycles of 1 min at 94°C; 1 min at 53.5°C and 2 min at 72°C. The reaction was completed by a final extension step of 7 min at 72°C.

Cp- DNA study

The intergenic spacer of chloroplast genome rpL16 was amplified and sequenced with universal primers following the methodology of (Shaw et al. 2005; Timme et al. 2007). Each 20 µl of PCR tube contained 10 µl of 2x PCR buffer, 0.5 mM of each primer, 200 mM of each dNTP, 1 unit of Taq DNA polymerase (Bioron, Germany), and 1 µl of template genomic DNA at 20 ng µl-1.

The following program was used for amplification of nuclear region in a PCR reaction: 5 min initial denaturation step 94°C, followed by 35 cycles of 1 min at 94°C; 1 min at 54°C and 1 min at 72°C. The reaction was completed by a final extension step of 6 min at 72°C.

Data analysis

DNA regions investigated were first aligned by MUSCLE program as implemented in MEGA 7 Program (Tamura et al. 2012). They were then cured and investigated for the nucleotide difference and also to find out those nucleotides which were unique for either wild or cultivated olive plants.

Different phylogenetic trees were constructed by using PAUP ver. 4. Followed by 1000 times bootstrapping (Swofford 2002). The TCS network and related sequence statistics were obtained by using POPART program (http://popart.otago.ac.nz).

Table 1. List of three specimens of *Olea europaea* subsp. *cuspidata* L. along with the information regarding altitude, latitude, longitude and herbarium number

Localities	Altitude	Latitude	Longitude	Voucher no.
Chaharmahal and Bakhtiari Province, Dehedz – Lordgan, Iran	1713	31°31'18"	50°28'26"	HSBU2018700
Kohgiluyeh and Boyer-Ahmad Province, Khersaan Road, Iran	1380	31°26'59"	50°28'57"	HSBU2018705
Chaharmahal and Bakhtiari Province, Lordgan, Monj, Gachahan, Iran	1151	31°26'48"	50°32'19"	HSBU2018711
Chaharmahal and Bakhtiari Province, Lordgan, Monj, Gachahan, Iran	1592	35°55'41"	57°41'53"	HSBU2018712

Table 2. The comparison between six wild specimens and four cultivated specimens applied for ITS

Species	Accession number
Olea europaea	KY313879.1
Olea europaea	AF231866.1
Olea europaea	KY313880.1
Olea europaea subsp. cuspidata	HQ117893
Olea paniculata	AF231867.1
Olea europaea subsp. *cuspidata*	AY040810.1
Olea europaea subsp. *cuspidata*	AM933049.1
Olea europaea subsp. *cuspidata*	AM933048.1
Olea europaea subsp. *cuspidata*	AM933047.1
Olea europaea subsp. *cuspidata*	AM933046.1

Table 3. The comparison between six wild specimens and five cultivated specimens applied for trnl-F

Species	Accession number
Olea europaea subsp. *cuspidata*	AY040810.1
Olea europaea subsp. *cuspidata*	AM933043.1
Olea europaea subsp. *cuspidata*	AM933045.1
Olea europaea subsp. *cuspidata*	AM933047.1
Olea europaea subsp. *cuspidata*	AM933048.1
Olea europaea subsp. *cuspidata*	AM933049.1
Olea europaea	AY040811.1
Olea europaea	FJ490798.1
Olea europaea	KY313879.1
Olea europaea	HQ117895.1
Olea europaea	AF231866.1

Table 4. Two out-groups applied for rpl16 sequencing

Species	Accession number
Olea europeaea cultivar Frantolo	GU931818.1
Olea europeaea cultivar Bianchera	NC 013707.2

RESULTS AND DISCUSSION

ITS sequences obtained after curation produced 377 bp long sequences, which could differentiate wild and cultivated olives from each other. The preliminary statistics of the ITS sequences produced the nucleotide diversity (Pi)= 0.26, the number of nucleotide differences between wild and cultivated olive samples was 174, and Tajima's D test (D) = 2.82. Short sequences were identified which were specific for either plant species which can be used as DNA barcodes (Figure 1).

Maximum likelihood (ML) phylogenetic tree based on ITS sequences (Figure 2) separated the studied plant samples of the two species in separate clades with 100% bootstrap value.

CP-DNA trnL-F region

TrnL-F region sequences obtained in the wild and cultivated olive samples after curation produced 73 bp long sequences. The two olive species studied differed in 35 nucleotides, with nucleotide diversity (Pi) = 0.27, and Tajima's D statistic: D = 1.48 (p = 0.16). Some of the short sequences of *TrnL-F* chloroplast inter-genie region also could differentiate the two plant species from each other and can act as barcodes (Figure3). Maximum likelihood (ML) phylogenetic tree based on trnL-F sequences (Figure 4). separated the studied plant samples of the two species in separate clades with 100% bootstrap value.

Chloroplast rpL16 sequences

Chloroplast rpl16 region sequences after curation produced a total length of 583 bp DNA segment with 229 polymorphic sites, Pi = 0.067. The two olive species differed in 218 nucleotides, few of which were unique in either species and can be used in olive species barcoding (Figure 5). The ML phylogenetic tree was obtained with dual purposes. First to differentiate the wild olive (denoted in Figure 6) from the cultivated samples studied (Samples A1), and second, to check the local medicinal plant products (Samples A2-A6, in Figure 6).

The result showed that wild olive is separated from the cultivated olive samples and is placed in a distant clade. Therefore, based on rpL16 sequences these two olive species can be differentiated. Out of 5 plants from the medicinal shops investigated, four samples were placed closer to the wild olive plant and only 2 samples (A2 and A6) were placed close to the cultivated olive plant. Therefore, it seems that misidentification of these two different plant species by the local shops can cause potential abortion problems for the consumers (Kadam and Gaykar 2018). As stated before, usually, the consumers purchase the cultivated olive leaves for controlling the blood pressure, but instead the leaves of wild olives have been sold to them which is used for abortion.

The result of the present study indicates that using a combination of molecular barcodes present in ITS, *trnL-F* and rpL16 sequences can help to differentiate the two olive species *O. europeae*, and *O. cuspidata*, and can improve the correct marketing of these medicinal plant taxa.

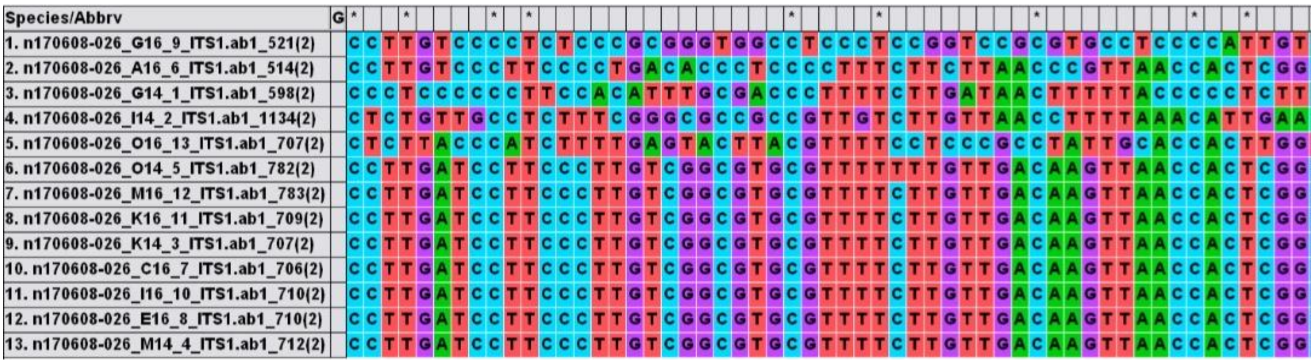

Figure 1. Representative barcoding nucleotides in ITS region of wild and cultivated olive studied

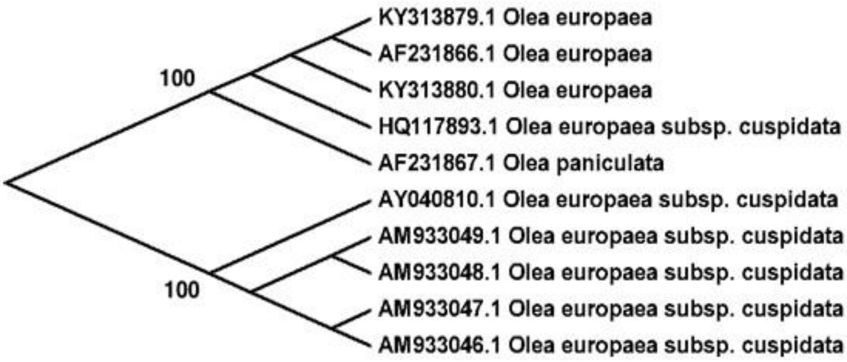

Figure 2. ML phylogenetic tree of wild and cultivated olives based on ITS sequences showing the species differentiation. (Numbers on the branches are bootstrap value).

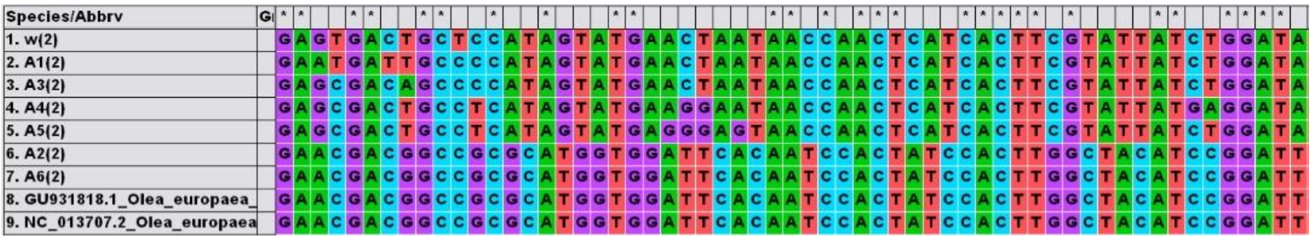

Figure 3. Representative chloroplast *trnL-F* sequences in wild and cultivated olives studied

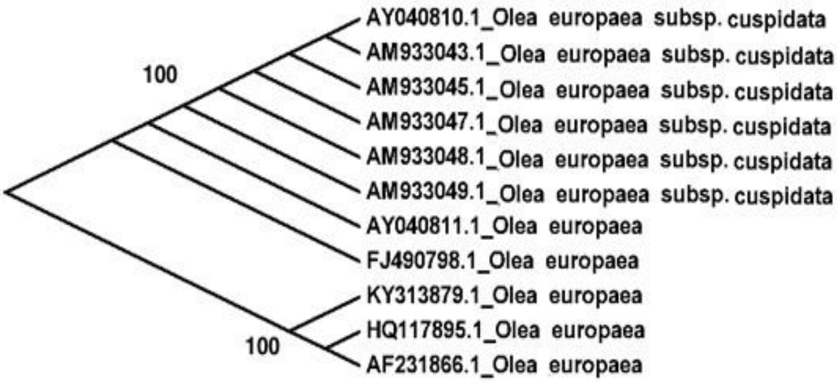

Figure 4. ML phylogenetic tree of wild and cultivated olives based on *trnL-F* sequences. (Numbers on the branches are bootstrap value)

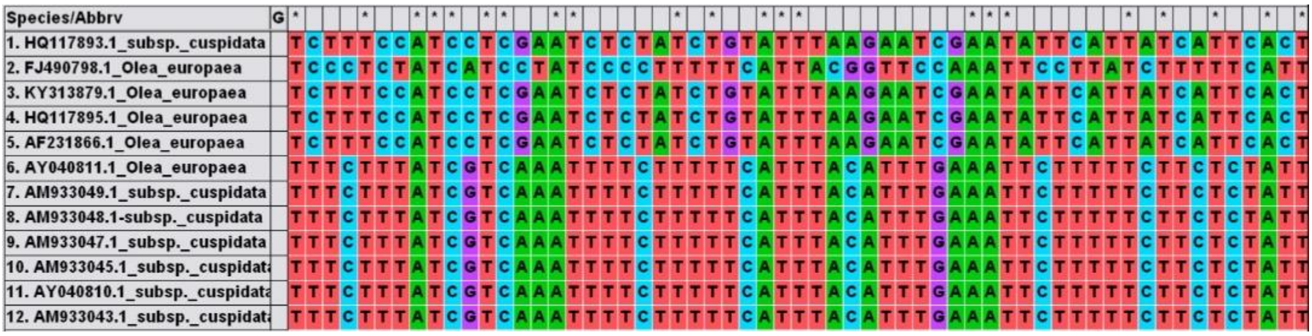

Figure 5. Representative rpL16 sequences in wild and cultivated olive plants

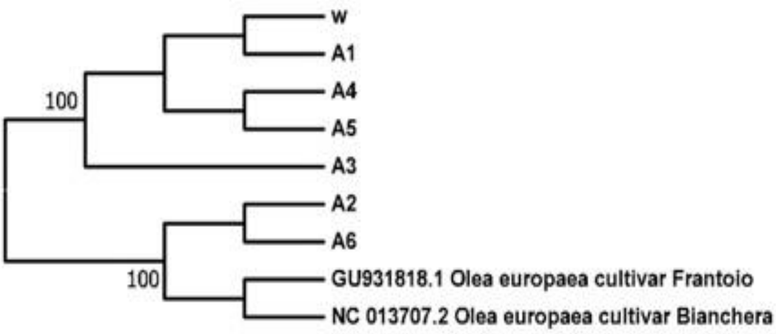

Figure 6. ML phylogenetic tree of the wild and cultivated as well as market sold olive samples based on rpL16 sequences. (w = wild olive, A1-A6 = Market sold samples). (Numbers on branches are bootstrap value)

Discussion

The medicinal plant products and the consumers health can be improved by scientific and regular monitoring of the local markets. Nowadays advanced approaches can be utilized for market product control. DNA barcoding is one of the recent molecular approaches for such product marketing improvement which in turn improves the consumers' health (Sheidai et al. 2019).

DNA barcoding allows the correct identification of the biological species. Although these barcodes are comprised of short sequences and represent only a small fraction of the total DNA, they can provide adequate nucleotide variability as well as species/ varietal sequence peculiarity which can differentiate most of the species from each other (Barcaccia et al. 2016; Sheidai et al. 2019). Therefore, in recent days, DNA barcoding approach has been practiced in the food industry and medicinal plant products marketing to avoid food piracy and adulteration of the products (Barcaccia et al. 2016).

Recent investigations concerned with the olive tree are mainly focused on screening adulteration in olive oil by using different methodologies, including DNA barcodes (see, for example, Kumar et al. 2011; Barcaccia et al. 2016). Due to nutritional value of the olive (*Olea europaea*), it has a high demand and therefore, is subjected to adulteration and fraud. This is usually done through the mixing of lower-cost plant oils like soya, canola, maize, sunflower, and sesame, with olive oil (Barcaccia et al. 2016).

The use of a combination of barcodes obtained from psbA-trnH and partial coding region of matK of the plastid genome was able to identify the presence of canola and sunflower in olive oil samples (Kumar et al. 2011).

The present investigation was concerned with olive leaf product misidentification/adulteration in Iran local medicinal plant market as these plant products have different properties. The cultivated olive is utilized for blood pressure control, but the leaves of wild olive in the form of tea have been used for abortion. We showed that a combination of nuclear ITS region along with short sequences in *trnL-F* and rpL16 chloroplast can differentiate the two olive species and uncover adulteration in the local markets.

Besnard et al. (2001) utilized molecular markers to study the cp-DNA variation in cultivated and wild Mediterranean olive trees. The discriminating power of cp-DNA variation was particularly low for the cultivated olive tree with one predominating haplotype, but more diversity was detected in wild populations.

Besnard et al. (2011) and Pérez-Jiménez et al. (2013) suggested that cp-DNA markers will have applications for a comparative study of the dynamic of wild olive tree populations in different environments, such as archipelagos and Saharan mountains. These data altogether suggest that we can use barcode sequences of both nuclear and plastid genomes to avoid olive plants' misidentification for the medicinal plant market.

In conclusion, the present study emphasizes the use of modern molecular barcoding to improve olive leaf marketing in medicinal local shops. This approach can avoid misidentification of the closely related species of olive which have different medicinal properties. This, in turn, avoid harm to human health.

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