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RESEARCH ARTICLE

Changes in plant diversity and community attributes of coal mine affected forest in relation to a community reserve forest of Nagaland, Northeast India

Khikeya Semy[1,2] · **Maibam Romeo Singh**[1]

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Abstract
This study assessed changes in herb, shrub and tree composition of Coal mining-affected forest (CMAF) area in relation to a community reserve forest designated as Non-affected forest (NAF) of Changki village, Nagaland, Northeast India. In all the three plant life forms, Shannon-Wiener index, Simpson's diversity index and Margalef richness index showed higher species diversity and richness in NAF compared to CMAF while Sorenson's index reveals a low species similarity between the sites. Pielou's evenness was higher at NAF and a contiguous pattern was prominently distributed in both the forest. The family Poaceae, Asteraceae and Cyperaceae dominated the CMAF while Euphorbiaceae, Rubiaceae and Poaceae dominated NAF. The NAF has greater plant density compared to CMAF and the IVI shows the dominant status of native tree *Terminalia myriocarpa* in the Northeastern tropical forest. Weeds like *Ageratum conyzoides, Bidens pilosa* and *Drymaria cordata* were prominently distributed in CMAF while *Abarema clypearia*, *Inula cappa* and *Strobilanthes coloratus* has been obstructed by mining. The result imparted that the plant diversity of Nagaland tropical forests are under threat due to coal mining which has reduced the vegetation diversity and induce the loss of dominant plant species. As such, regulation of mine waste, land reclamation projects, robust forest management and bioremediation can be scientifically integrated to reduce the mining repercussion effects. Moreover, the result emphasizes the need to impart the tribal knowledge of preserving natural forest to the upcoming generations and develop conservation strategies to prevent further degradation or loss of biodiversity in this part of the Indo-Burma hotspot region.

Keywords Biodiversity indices · Coal mining · Nagaland · Species composition · Tropical forest

Introduction

Tropical forest covers approximately 44% of the earth's land surface (FAO 2015). It sustains the most species-diverse terrestrial ecosystems and serves as a storehouse for the biological and genetic diversity, along with more than half of the world's life form thriving under these forests (May and Stumpf 2000; Keenan et al. 2015). The species diversity is an essential component of a forest as it represents the overall forest health and offers valuable knowledge that serves as the primary information for the conservation and protection of the ecosystem (Roy et al. 2004; Sharma and Kant 2014). Plant composition, diversity and their spatial distribution in a forest ecosystem are largely influenced by the geographical location of the region, soil, climate, regeneration pattern of species (Sarkar and Devi 2014; Siregar et al. 2019), niche requirement and disturbances (Huang et al. 2003). Over the years, vegetation cover under natural forests has been rapidly declining worldwide, particularly in tropical areas and secondary forests are rising in dominance (Devi et al. 2018). In South and Southeast Asia, the net forest loss was estimated to be around 25% higher between 2010 and 2015 compared to the 1990's (Keenan et al. 2015). It is estimated that an alarming percent of 0.8–2.0% of these forests gradually disappear per year (Sagar et al. 2003). Vast area of forest cover are impaired by multiple anthropogenic actions such as clearing of forest for agricultural

✉ Khikeya Semy
khikeyasemy@gmail.com

1 Department of Botany, Nagaland University, Lumami 798627, India

2 Don Bosco College, Kohima, Nagaland 797001, India

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land, industrial built-ups, dams, highways and extensive mining. Environmental factors including soil erosion, heavy rain, lightning, forest fire and other harsh climatic condition can also alter the composition of the standing forest structure. However, primary causes of forest destruction are attributed mainly to man-made sources. Therefore, it is critical to understand the human impact on the ecosystem to prioritize the conservation of tropical forests (Devi et al. 2018). External anthropogenic pressures alter the soil, water and air quality and affect the environmental gradient of the individual plant species and their population via various mechanisms of reaction, and thus, influence the plant community structure. As such by the selection pressures of the environment, the plant community structure of an area tends to become established. The superimposition of severe pressures on the plant community sometimes occurs to allow feedback mechanisms to operate for the selection of resistant and dominant species (Pandey et al. 2014). Coal mining is an environmental degrading activity that initially involves clearing of a large area of forest which gradually changes the forest landscape affecting the forest ecosystem while the repercussion effect of it stays for decades spreading over a vast area of land. In India, workers such as Singh et al. (1994), Sarma et al. (2010), Sarma and Barik (2011) and Pandey et al. (2014) reported the negative effects of coal mining on plant community structure which resulted in the loss of species, reduction in forest cover and alteration of the landscape.

Northeast India is a part of the Indo-Burma mega biodiversity hotspot which includes an immense variety of plant species and is one of the richest in terms of biological wealth and endemism in the Indian subcontinent (Tynsong and Tiwari 2011). However, the primary forest of this region are disappearing at an alarming rate due to a number of human activities including shifting cultivation, deforestation, forest fragmentation (Upadhaya et al. 2003), coal mining (Rai 2002; Sarma and Barik 2011; Barik et al. 2006) and urbanization. Quantitative plant diversity studies in northeast Indian forests are very limited and mainly confined to the tropical forests of Arunachal Pradesh (Bhuyan et al. 2003), Meghalaya (Kumar 2006; Upadhaya et al. 2003), lowland primary and secondary moist deciduous forests of Tripura (Majumdar 2012), subtropical forests of Manipur (Khumbongmayum et al. 2005), tropical forest stands of Mizoram (Singh et al. 2015) and Nagaland (Ao et al. 2020; Ao et al. 2021). In concern with the growing awareness and need for biodiversity conservation, quantification of plant species distribution and its abundance is vital. However, Northeast India and in particular Nagaland, when compared to the rest of the country is understudied. One major challenging factor and hurdle for enthusiast researchers or scientist could be the topography of the area itself, which are often not easily accessible, as most states in this part of the country have a hilly terrain resulting in a cost and time-intensive study (Nohro and Jayakumar 2020). For the present study, we assume that the plant community structure in the coal mining area and the community forest is strongly differentiated owning to contrasting anthropogenically disturbed and undisturbed conditions and the site far away from coal mining areas will support greater plant diversity. Therefore, the hypothesis stated for the research was "The community protected forest will have higher plant composition, species richness and diversity than the coal mine disturbed forest". The objectives of this study are as follows: (1) To assess herb, shrub and tree composition in a coal mining-affected and community protected tropical forest of Changki. (2) To determine changes in species diversity and richness in two forests of Nagaland. Quantitative analysis of plants will provide baseline information on the effects of anthropogenic disturbance on forest species distribution and diversity. The findings will initiate necessary steps to reiterate traditional norms in conserving forests to the upcoming younger generations, improve their knowledge for identifying important ecological species of special concern and enable different stakeholders to take appropriate decisions and measures for sustainable forest management.

Materials and methods

Study area

Nagaland lies in the North-eastern part of India, extending from 25°6′ N to 27°4′ N Latitude and 93°20′ E to 95°15′ E Longitude. The state is bounded by the neighbouring state of Arunachal Pradesh and Myanmar in the east, Manipur in the south and Assam in the north-west. Annual average rainfall ranges from 1,800 to 2,500 millimeters (70–100 inches). The maximum temperature is observed during the summer months (21 to 36 °C) while in winter, temperature generally drops from 21 to 4 °C. Frost is common at high elevations and strong northwest wind blows across the state during the months of February and March. Agriculture covers over 70% of the state's economy and other significant economic activities include forestry, tourism and miscellaneous cottage industries. About one-sixth of the state is under tropical and sub-tropical evergreen forests including palms, bamboo, timber and mahogany forests (DEFCC 2018). The present study was carried out in a Northern tropical semi-deciduous forest at Changki, Mokokchung district of Nagaland, India. The Non-affected forest (NAF) which is a community forest under the traditional protection of the Naga tribal is geographically located at 26°24′40″N 94°23′31″E at an altitude of 598 m above msl while the Coal mining-affected forest

(CMAF) is located 45 m away from the Merayim coal fields and lies at 26°26′18″N and 94°22′48″E at an altitude of 248 m above msl (Fig. 1). Coal mining was initiated in this region by the Ao Nagas in collaborations with major stakeholders from Assam and other neighbouring states for over 20 years. The Merayim coal fields are active mines operated for over 15 years covering an area of approximately 52,000 m^2 and annually on average, 250 tons of overburdened mine spoils are dumped at the CMAF. Apart from mining other anthropogenic activities along the stretch of forest belt includes stone quarries, plantation, agriculture, collection of fodder for livestock, foraging and the passage of national highway "Mokokchung-Mariani Road (NH 702D)". The study area is directly influenced by the South-west monsoon causing heavy rainfall from July to September. The soil is characterized by the deep dark brown to yellowish-brown, clay loam surface and clay sub-surface soils which are strongly acidic in nature (Semy and Singh 2021).

Vegetation analysis and identification of species

The phytosociological studies of herbs, shrubs and trees from the CMAF and NAF were conducted during the period of January, 2019 to December, 2019. In each site, from a one-hectare area (1-ha) plot, the Nested quadrate sampling method was applied to acquire the utmost representative composition of the samples. An area of 1×1 m^2 (60 quadrates), 5×5 m^2 (50 quadrates) and 10×10 m^2 (25 quadrates) plots for herbs, shrubs and trees were demarcated and subdivided. The circumference of trees at each girth classes (11–20, 21–30, 31–40, 41–50, 51–60, 61–70, 71–80, 81–90 cm) were recorded at breast height (dbh at 1.37 m above ground level). Whereas, diameter for shrub and herbs were measured at 10 cm above ground and at the base of stem, respectively, using diameter tape and a screw gauge (Pande et al. 1988). The representative taxa collected during the field survey were processed for herbarium following Jain and Rao (1977) and identified with the help of standard literature and regional floras (Bentham and Hooker 1862–1883; Prain 1903; Kanjilal et al. 1934; Kanjilal et al. 1936; Kanjilal et al. 1938; Kanjilal et al. 1940; Bor 1940; Bennet 1987; Dey 2018). The voucher herbarium specimens were then deposited in the Department of Botany, Nagaland University, Lumami Campus.

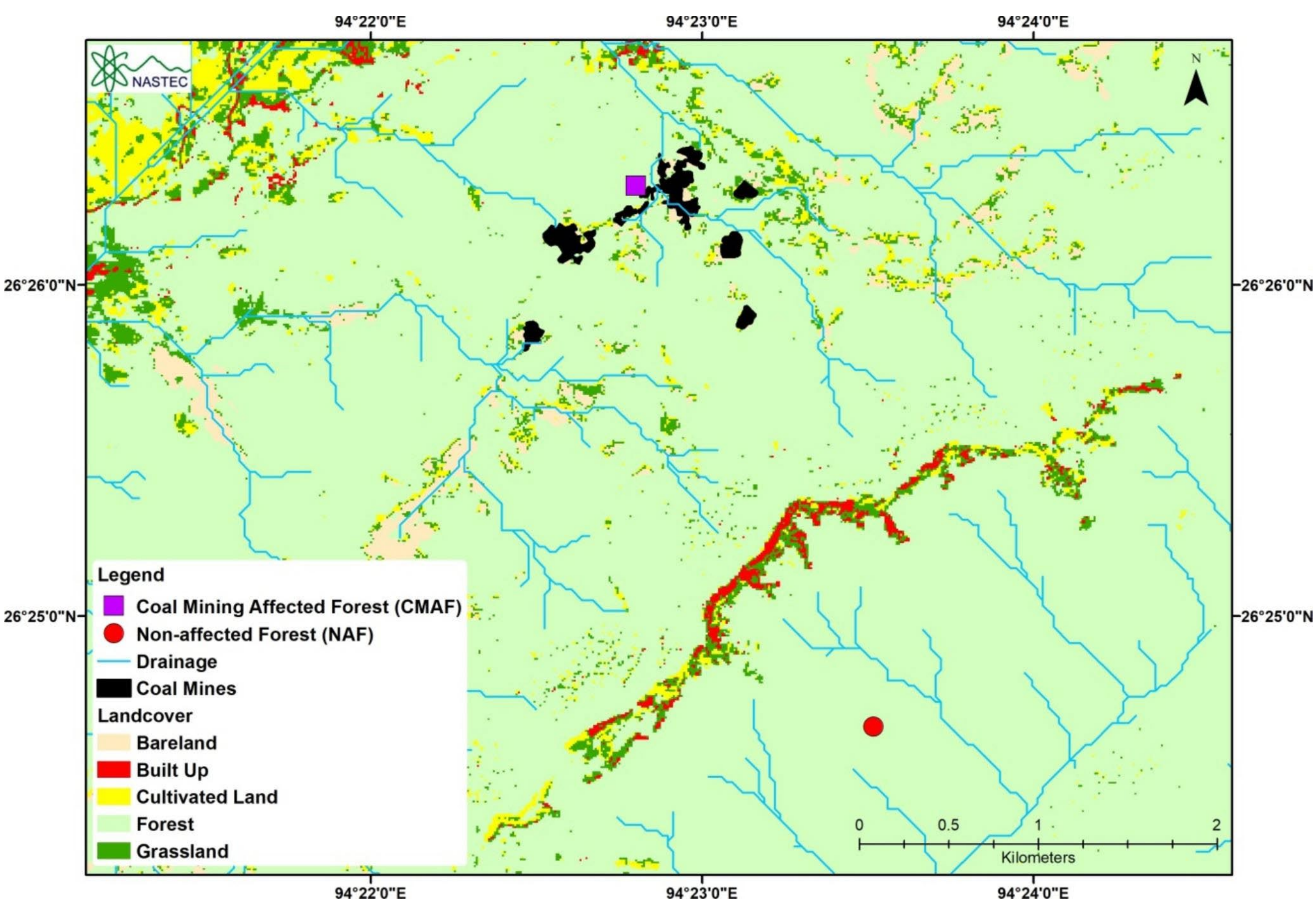

Fig. 1 Landuse and landcover map of the study area

Data analysis

The value of density, frequency and abundance was calculated as per Curtis and Mclntosh (1950). The Important value index (IVI) for each species was calculated by summing the relative values of frequency (RF), density (RD) and dominance (RD) following Curtis (1959). Abundance to Frequency ratio (A/F) of each species was calculated to study the population dispersion pattern. The values for determining dispersion range pattern were categorized as: regular ($<$0.025), random (0.025–0.05), contiguous (0.05-1.00) and clump ($>$1.00) proposed by Cottam and Curtis (1956). Diversity indices were estimated following Shannon-Wiener index (H') by Shannon and Weaver (1963), Simpson's diversity index (D) formulated by Simpson's (1949), Margalef's richness (R) index by Margalef (1958), Evenness index (J) given by Pielou (1969) and both similarity and dissimilarity index was analyzed following Sorenson (1948).

Results

A total of 769 tree individuals belonging to 60 genera, 64 species and 37 taxonomically well-represented families from the two forests were enumerated. The tree species richness was higher at NAF (44) compared to CMAF (36). At NAF, a total of 421 tree individuals representing 44 genera constituting 29 families were identified whereas at CMAF, a total of 348 individual trees belonging to 35 genera and 12 families were recorded. Based on the IVI obtained in NAF, *Terminalia myriocarpa* contributed the highest IVI (15.7) followed by *Litsea monopetala* (14.78). At CMAF, *T. myriocarpa* had the highest IVI (22.98) followed by *Phoebe lanceolata* (17.83), while *Ficus obscura* imparted the lowest IVI (2.03). The family Euphorbiaceae occupied the highest (5) number of species followed by Anacardiaceae (4), Lauraceae (4), Apocynaceae (2), Phyllanthaceae (2), Fagaceae (2), Malvaceae (2) and Burseraceae (2) in NAF. In CMAF, Fabaceae (7) dominated the forest followed by Euphorbiaceae (3), Phyllanthaceae (2), Poaceae (2), Moraceae (2), Rubiaceae (2) and Lauraceae (2). The rest of the families in both the forest represent 1 species each. It was observed that the family Araliaceae, Salicaceae, Ebenaceae, Junglandaceae, Gnetaceae, Sabiaceae, Rutaceae, Magnoliaceae, Bignoniaceae and Caprifoliaceae were absent in CMAF but present in NAF. While the family Poaceae, Lythraceae, Verbenaceae, Rubiaceae, Primulaceae, Theaceae and Meliaceae were present in CMAF but absent in NAF. In terms of dominance, *T. myriocarpa*, *Mesua ferrae* and *Lannea coromandelica* were found to be the most dominant tree species at NAF while *Aporosa octandra, Croton persimilis, T. myriocarpa* and *Styrax serrulatus* dominated the CMAF. The CMAF and NAF tree basal area range from 1.13 to 52.78 m^2 ha^{-1} and 0.94 to 51.50 m^2 ha^{-1} respectively. In both the forest, *T. myriocarpa* contributed the highest basal area cover. In CMAF, *Croton persimilis* had the highest density of 132 individual ha^{-1} followed by *A. octandra* (124 individual ha^{-1}), *S. serrulatus* (100 individual ha^{-1}) and *T. myriocarpa* (100 individual ha^{-1}). In NAF, *Gnetum gnemon* (132 individual ha^{-1}) contributed the maximum species density followed by *L. monopetala* (92 individual ha^{-1}) and *Castanopsis indica* (84 individual ha^{-1}). The total tree density cover in CMAF and NAF was 1392 trees ha^{-1} and 1684 trees ha^{-1} respectively. In both the sites, the lower girth classes 11–20 > 21–30 > 31–40 cm represented higher number of individuals and density ha^{-1} while the middle girth classes 31–40 > 41–50 > 51–60 cm covers maximum basal area ha^{-1} (Fig. 2). The A/F ratio ranged from 0.07 to 0.75 at NAF and 0.07 to 1.5 at CMAF. The species in the two sites followed the contiguous pattern of distribution except for *Bambusa pallida* and *Dendrocalamus giganteus* in CMAF showing a clumped pattern of distribution. Shannon-Wiener index showed that NAF (1.55) has higher diversity than CMAF (1.40) which was also observed in the Simpson's diversity index at NAF (0.97) and CMAF (0.95). A Margalef index of 5.98 and 7.11 while species evenness of 0.39 and 0.41 was recorded in CMAF and NAF (Table 1). Sorenson's index shows a low similarity (40%) and higher dissimilarity (60%) between the tree species of NAF and CMAF.

The shrub species richness was higher at NAF (22) compared to CMAF (13). At NAF, a total of 291 shrubs comprising 21 genera and 12 families were recorded whereas, in CMAF, a total of 239 shrubs belonging to 12 genera and 9 families were identified. *Mussaenda roxburghii* contributed the highest IVI (19.85) followed by *Schefflera bengalensis* (18.84) and *Morinda augustifolia* (18.47) at NAF. Whereas in CMAF, *Melastoma malabathricum* had the highest IVI (44.50) followed by *Cassia hirsuta* (36.69) and *M. roxburghii* (33.03). At NAF, Rubiaceae (5) presented the maximum number of species followed by Fabaceae (4), Lamiaceae (3), Melastomataceae (2), Primulaceae (1), Phyllanthaceae (1), Capparaceae (1), Asteraceae (1), Acanthaceae (1), Urticaceae (1), Caprifoliaceae (1) and Araliaceae (1). Rubiaceae (3) dominated CMAF followed by the family Fabaceae (2), Melastomataceae (2), Phyllanthaceae (1), Lamiaceae (1), Vitaceae (1), Caprifoliaceae (1), Solanaceae (1) and Verbenaceae (1). Some of the family like Primulaceae, Capparaceae, Asteraceae, Acanthaceae, Urticaceae and Araliaceae were present in NAF but not in CMAF while Vitaceae and Solanaceae were present in CMAF but absent in NAF. The shrub basal area of CMAF ranges from 0.11 to 0.72 m^2 ha^{-1}. *Breynia retusa* occupies the lowest basal

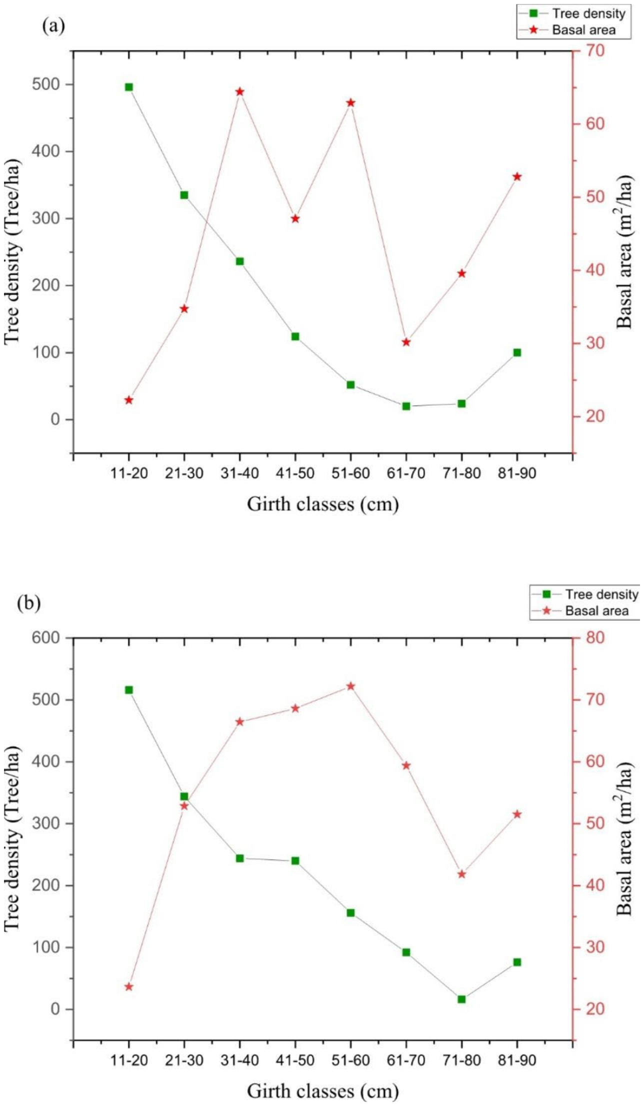

Fig. 2 Tree density (tree/ha) and basal area (m^2/ha) distribution graph based on girth classes: **a** Coal mining-affected forest (CMAF) **b** Non-affected forest (NAF)

area cover and *Clerodendrum infortunatum* had the highest basal area. In NAF, the basal area ranges from 0.13 to 1.17 m^2 ha^{-1}. The basal area of *Tephrosia candida* was lowest while *Pterolobium hexapetalum* constituted the highest basal area cover. The total shrub density in CMAF (1912 shrub ha^{-1}) was considerably lower than NAF (2328 shrub ha^{-1}). *Melastoma malabathricum* (392 individual ha^{-1}) contributed the highest density followed by *C. hirsuta* (312 individual ha^{-1}) and *M. roxburghii* (296 individual ha^{-1}) in CMAF. While In NAF, *Phlogacanthus thyrsiflorus* contributed the highest density (208 individual ha^{-1}) followed by *Sarcochlamys pulcherrima* (184 individual ha^{-1}) and *M. roxburghii* (168 individual ha^{-1}). Contiguous pattern of distribution was observed in both the sites which ranged from 0.17 to 0.75 (NAF) and 0.08 to 0.78 (CMAF). In NAF and CMAF, the Shannon-Wiener index was 1.30 and 0.99 while Simpson's diversity value was 0.95 and 0.88 respectively. The evenness index value of 0.43 and 0.37 and Margalef index of 3.70 and 2.37 were recorded in NAF and CMAF. A Sorenson's index between the shrubs of the two forests shows a similarity of 40% and a dissimilarity of 60%.

An absolute total of 2730 individual herbs belonging to 83 genera, constituting 88 species and 46 families were recorded from the two forests. In NAF, the species richness accounts for 62 species which was comparatively higher than CMAF (54). NAF had a total of 1440 individual herbs representing 58 genera and 37 families whereas CMAF had a total of 1290 individual herbs belonging to 51 genera and 30 families. In NAF, *Chromolaena odorata* contributed the highest IVI (15.57) followed by *Pteridium esculentum* (13.29) and *Alpinia malaccensis* (9.82). At CMAF, *C. odorata* had the highest IVI (31.86) followed by *P. esculentum* (29.01) and *Thysanolaena latifolia* (24.53). Poaceae (6) dominated the NAF followed by Zingiberaceae (5), Cyperaceae (4), Acanthaceae (4) and Asteraceae (3). In CMAF, Poaceae occupied the maximum (10) number of families followed by Asteraceae (9) and Cyperaceae (4). It was observed that the NAF herb families such as Araceae, Zingiberaceae, Begoniaceae, Adiantaceae, Fabaceae, Balsaminaceae, Hypoxidaceae, Urticaceae, Selaginellaceae, Marantaceae, Asparagaceae, Melastomataceae, Chloranthaceae, Linderniaceae, Smilacaceae, Urticaceae and Araliaceae were absent in CMAF whereas Thelypteridaceae, Cryophyllaceae, Euphorbiaceae, Ranuculaceae and Phyllanthaceae were present in CMAF but not in NAF. Basal area cover in CMAF ranges from 0.07 to 2.54 m^2 ha^{-1} with the lowest cover by *Cyperus iria* and *Drymaria cordata* and the highest by *Pteridium esculentum*. The NAF basal area ranges from 0.07 to 3.14 m^2 ha^{-1}. Basal area cover of *Cheilanthes tenuifolia, Eragrostis amabilis, Kyllinga brevifolia, Odontosoria chinensis, Torenia violacea* were recorded

Table 1 Diversity indices of CMAF and NAF at Changki

Diversity indices	CMAF			NAF		
	Herb	Shrub	Trees	Herb	Shrub	Trees
Species richness (S)	54	13	36	62	22	44
Shannon-Weiner index (H′)	1.34	0.99	1.40	1.61	1.30	1.55
Simpson's diversity index (D)	0.92	0.88	0.95	0.97	0.95	0.97
Margalef richness index (R)	7.40	2.37	5.98	8.40	3.70	7.11
Pielou's evenness index (J)	0.34	0.37	0.39	0.39	0.43	0.41

minimum and *Alpinia malaccensis* as maximum. In CMAF, *C. odorata* (30,833 individual ha^{-1}) contributed the highest density followed by *Dicranopteris linearis* (23,000 individual ha^{-1}) and *T. latifolia* (16,833 individual ha^{-1}). The NAF density stand of *C. odorata* (24,000 individual ha^{-1}) was recorded maximum followed by *Strobilanthus coloratus* (14,666 individual ha^{-1}) and *D. linearis* (13,500 individual ha^{-1}). The A/F ratio ranged from 0.35 to 5.70 (NAF) and 0.34 to 5.40 (CMAF) which constituted the contiguous and clumped pattern of distribution. Shannon-Wiener index showed that the diversity value in NAF (1.61) was higher than CMAF (1.34). The NAF and CMAF Simpson's diversity value was 0.97 and 0.92 while species evenness was 0.39 and 0.34 respectively. A Margalef index value of 7.40 and 8.40 was recorded in CMAF and NAF. Sorenson's index shows a similarity of 48% and a dissimilarity of 52% between the two forests.

Discussion

The present study conducted at the CMAF and NAF of Changki, Nagaland elucidated a high floristic diversity of the area. Floristic composition of plant species in mine disturbed area provides insight into the environmental and ecological potential of these sites in the process of biological recultivation including the primary and secondary succession (Gajic and Pavlovic 2018). In this study, the absolute species from one hectare area including herbs, shrubs and trees of NAF was comparatively higher than CMAF which represents a rich source of species diversity in the undisturbed area. Due to extensive coal mining, large forest areas of CMAF have been degraded and resulted in unfavorable habitat conditions for plants growth while the prevailing environmental quality has also limited the regeneration rate of many species, thereby reducing the number of species in the forest. IVI value of any species indicates their dominant nature in a mixed population and provides a comprehensive picture of the social arrangement of species in a group (Parthasarathy and Karthikeyan 1997). The higher IVI value of *C. odorata, M. malabathricum, T. myriocarpa, A. octandra, P. lanceolata* and *C. persimilis* species shows their pollution-tolerant nature at the coal mining polluted site. Sarma et al. (2010) has reported the dominance of *Pinus kesiya*, *Paspalum orbiculare* and *Schima wallichii* in the coal mine disturbed forest of Jaintia Hills district, Meghalaya, North East India. Although different dominant plants were recorded in the present study sites due to varying geographical layouts and species distribution compared to Meghalaya, similar inductive results can be reasoned. Such as the dominant nature of plants in mining areas suggest their resilient ability to grow in the disturbed forest as they multiply rapidly and subjugate other species irrespective of the environmental conditions (Mondal et al. 2020) including low nutrient, acidic soil, high bulk density, low moisture and reduced organic carbon (Semy et al. 2021). Similar tolerant species like *Eleusine indica, Pteridium aquilinum* (Chu 2008), *Euphorbia* sp. (Jimenez et al. 2011) and *Rumex crispus* (Randjelovic et al. 2014) has also been reported to survive in adverse mine affected areas due to their high ecological potential. Moreover, these species act as pioneers as they begin the process of revegetation by providing erosion control, improving the physico-chemical composition of mine spoil, retaining moisture and vitalizing nutritional substances that will be later used by spontaneous colonizers (Gajic et al. 2016). The prominent population of *C. odorata*, *P. esculentum*, *M. roxburghii* and *T. myriocarpa* in CMAF as depicted by IVI shows that man-made intrusion pressures have created an environment for these species to flourish over the other populations. However, considering this phenomenon such as selective integration or elimination of some species would affect forest species composition, stand structure and also create a more subtle impact on that region (Brandl et al. 2002).

The dominance of tree families Euphorbiaceae, Moraceae, Lauraceae, Anarcardiaceae, Malvaceae, Fagaceae and Fabaceae indicates the type of Northern tropical semi-deciduous forest in Nagaland (Leishangthem and Singh 2018). The present study reciprocates to the floristic findings in neighbouring states of Assam and Manipur such as the dominance of Asteraceae and Poaceae among the herb population recorded by Devi et al. (2014) in their floristic diversity of Sangla valley in Indian Himalaya. The dominance of Rubiaceae, Fabaceae, Anacardiaceae, Malvaceae and Apocynaceae were also reported from Barail Wildlife Sanctuary, Assam (Bora and Bhattacharyya 2017). From Western Ghats, the dominance of Poaceae, Euphoriaceae, Acanthaceae and Fabaceae was reported by Palanisamy and Arumugam (2014) at Madukkarai hills. Donggan et al. (2011) presented the presiding nature of Asteraceae, Cyperaceae and Caprifoliaceae in the coal mine area which were also dominant in CMAF. The pre-potent nature of Lythraceae, Verbenaceae, Primulaceae, Theaceae, Vitaceae, Solanaceae, Meliaceae, Thelypteridaceae and Cryophyllaceae in the disturbed coal mine area could represent its presiding nature and of a habitat that is conducive to more typical tolerant families, which suggest that biased habitat loss is exerting a selective influence on the population and that the increased number of a particular family could be a response to that selection. Higher basal area was recorded at NAF in all three basis of plant forms which was in conformity with Sarma and Barik (2011). This result, however, contradicts the findings of Sarma et al. (2010) where the basal area was comparatively greater in the mined areas than the unmined area at Jaintia hills district of Meghalaya, India. *Terminalia myriocarpa* the East Indian almond or Hollock which is native to India and Southeast Asia contributed the highest overall basal area cover in both the forest. The difference in density and basal area cover of the two forests apart from mining activities may be attributed to altitudinal variation, species composition, age structure, successional stage of the forest and degree of disturbances (Sundarapandian and Swamy 2000). Tree density at NAF (1684 trees ha^{-1}) was higher than CMAF (1392 trees ha^{-1}) and consonant with reports of Pandey et al. (2014) in mining areas. The tree density measured in this study can be compared to tree density values reported in tropical forest by Adekunle et al. (2013) and Akash et al. (2018). The A/F ratio generates the distribution pattern analysis which shows species dispersion across a span of time at any given site. This pattern may depend on the environmental variables exhibiting in the area as well as reflect on the biological peculiarities of the organisms themselves. In all three basis of plant life forms, the analysis of distribution patterns along the two forests indicates that contiguous distribution was the most common, which according to Odum (1971) is a result of small but significant variations in the ambient environmental conditions. A similar observation was made by Sarma (2002) and Sarma et al. (2010) in the mined areas where majority of the species showed contiguous pattern of distribution. In India, several workers (Majumdar and Datta 2015; Shameem et al. 2017; Saravanan et al. 2019) have reported similar distribution patterns in the forest vegetation.

Plant diversity indices are generated to bring the diversity and abundance of species in different habitats to a similar scale for comparison and assess ecosystem health and ecological processes (Naidu and Kumar 2016). The high value of Shannon-Wiener index at the NAF represents a diverse community which was in conformity with Pandey et al. (2014) at an undisturbed site compared to Raniganj and Jharia coalfield both for the herbaceous and woody vegetation. The diversity value in NAF and CMAF were similar with an observation value of 1.43–1.84 by Bachan (2003). However, the diversity index of tree species in the two forests is comparatively lesser than the tropical forest of Eastern Ghats, Andhra Pradesh ranging between 3.76 and 3.96 (Naidu and Kumar 2016; Sahu et al. 2012; Sundarapandian and Swamy 2000) stated that the diversity value for Indian forests is in the range of 0.8 to 4.1. In the present study, the diversity values of herb, shrub and trees obtained in both the forests falls under the reported range of Indian tropical forests. Simpson diversity index value of the three plant forms represents higher diversity at NAF than CMAF. Sarma (2002) has also reported low species diversity in the mined areas as compared to unmined areas from Nokrek biosphere reserve, Meghalaya. NAF harbors greater biodiversity value than CMAF due to balanced vegetation composition as it provides sustenance on habitat suitability, ecosystem productivity and successional pathways while lower species diversity in CMAF imparts information on the forest susceptibility to anthropogenic disturbances and altered trophic structures. The Pielou's evenness index of all three plant forms did not significantly vary between the sites suggesting that the equability of the NAF and CMAF forest located in one region is influenced by similar weather patterns which could have its impact on their evenness. Evenness in the study area was quite low compared to Shameem et al. (2017) in Kashmir Himalaya, India where they reported a high evenness index of 0.90. Species composition and richness vary widely according to the frequency of disturbances. NAF harbors diverse vegetation and presented a higher Margalef richness value in all three plant forms compared to CMAF. The community stability is coherently related to the species diversity, greater the diversity index, higher will be the stability of community structure and function. Evidently, the species richness had a greater influence over species diversity than evenness as observed in this study. Sorensen's index which was used to compare the associations between the two forests shows the percentage of similarity is lower than the dissimilarity index. Since CMAF and NAF are located in one geographical region, coal mining activities had reflected a more pronounced effect on species composition apart from the influence of microclimate, soil properties, species compositions, productivity and competition which might also have contributed to the variation in species similarity between the study sites (Criddle et al. 2003). Lower tree girth classes were annotated with higher total number of individual species and density while middle girth classes have higher basal area in both the forest which was in conformity with Basyal et al. (2011). Sarma and Barik (2011) reported that in the un-mined areas, the young and middle-size trees were higher than the old trees, indicating a stable tree population structure that was relevant to the NAF stands. The existing tree population structure in the two sites is represented by a normal case and suggests that the forest is growing and would continue to exist and stabilize. However, in the disturbed areas of CMAF, extensive coal mining could cause rampant changes in the forest landscape over a period of time which may affect the tree population structure if measures are not taken.

Since the NAF and CMAF areas were located at similar climatic, edaphic and physiographic features, the changes and the differences in species composition could be attributed to the land-use patterns. NAF depicts a community structure that is heterogeneous because of the low pollution load at the forest which favors the growth, survival and regeneration of natural vegetation. However, in case of CMAF over a period of time the habitats in close proximity with mining areas may subsequently lose their sensitive plant species and create a niche that will favor the dominance of more tolerant species. The dominant nature of some species at CMAF showed resistance to the impact of mining pollutants and other man-made disturbances and suggests that species gets acclimatized to stress conditions. Moreover, the changes in species diversity observed at CMAF indicated an increase in the proportion of resistant herbs and grasses of the family Poaceae, Asteraceae and Cyperaceae presenting a positive tendency towards a definite selection strategy of an ecosystem in response to the prevailing environmental conditions. As variations in environmental factors impose the adaptive abilities of organisms, only those species which are resilient to new conditions or those which can become accustomed to the changing forest structure, participate in the community formation (Agrawal and Agarwal 2000). The regional patterns of species richness and its succession to stabilization as a community are a collaborative effect of different interacting factors, species dynamics as well as species pool. Such processing effect was observed in the study as the total numbers of individual species and families participating in the community structure as dominants or co-dominants were higher at NAF compared to CMAF. Even though the degree of environmental pollution in the CMAF has not been analyzed, the biodiversity indices obtained from the study has indicated that anthropogenic stress associated with intermittent small scale folds were pervasive in the forest due to the open cast mining, rat-hole mining, logging of trees, collection of fodders, grazing of cattle, stone quarries, passage of national highway and Jhum cultivations. So, if the trends of dumping overburden mine spoils and other anthropogenic activities continue, detrimental environmental changes will affect the survivability, reproductive potential and hamper the growth of the existing species composition.

Conclusion

The critical assessment on the plant community structure in the Coal mining-affected forest (CMAF) and Non-affected forest (NAF) at Changki has provided insight on the interpretation of plant diversity in the Northern tropical semi-deciduous forest of Nagaland, India. The plant diversity indices points out the variation in species diversity and richness of the two forests induced by mining activities. The decade long dumping of coal spoils into the forest has thwarted the normal plant populations' upto an extent where the influence is observed in the CMAF. While the community protected NAF accounts for very few anthropogenic activities; it has a rich species diversity providing a balanced ecosystem for a sustaining habitat. The changes in the dominance of the plant species at CMAF indicate their acclimatization state being susceptible due to the mining effects. However, few species are resilient to the coal mining stress and adapt by enhancing their colonization rate in the disturbed forest. Through the study, it can be stated that consistent quantitative and qualitative information of floristic data and their records are required to understand the regional forest biodiversity affected by anthropogenic activities. Overall, the database collected in this research can be an important source for the local authorities as well as researchers and environmentalists working on the Indo-Burma biodiversity hotspot to promote the use of the botanical records as part of conserving biological diversity and promoting sustainable development.

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Conflict of interest The authors declare that they have no conflict of interest.

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