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Research article

# Lichen diversity in coal mining affected areas of Makum coalfield, Magherita, Assam

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**Abstract:** The coal mining industry in Assam was started by the British in 1884. Coal mining activities are considered hazardous to the sustenance of biodiversity of the region, which is under Eastern Himalayan province, the richest bio-geographical province of the Himalayan zone and also falls in one of the mega biodiversity hotspots of the world. Makum Coalfield of North Eastern Coalfields in Margherita of Tinsukia district of Assam was surveyed and lichen diversity of different sites was studied. Sites with active mining had very low diversity of lichens. Reclamation sites have an intermediate number of lichen species; rocks were under the process of lichenization. Reserve forests near the mining sites had maximum lichen diversity; understorey plants were abundant with follicolous lichens.
**Keywords:** Coal mining - Biodiversity - Lichenization - Follicolous.

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## INTRODUCTION

Any sort of developmental activity in forests usually initiate a series of changes in the status quo and disrupt the natural forest dynamics. Mining tends to make a notable impact on the environment, the impacts varying in severity depending on whether the mine is working or abandoned, the mining methods used, and the geological conditions (Bell *et al.* 2001). Natural plant communities get disturbed and the habitats become impoverished due to mining, presenting a very rigorous condition for plant growth. The unscientific mining of minerals poses a serious threat to the environment, resulting in the reduction of forest cover, erosion of soil in a greater scale, pollution of air, water and land and reduction in biodiversity (UNESCO 1985). The problems of waste rock damps become devastating to the landscape around mining areas (Goretti 1998).

Coal mining by both opencast and underground method affects the environment of the area (Dhar 1993). In the process of mining, huge amounts of water are discharged to the surface to facilitate the mining operation. The discharged water often contains a high load of Total Suspended Solids (TSS), Total Suspended Solids (TDS), hardness and heavy metals, which contaminate the surface and groundwater (Tiwary & Dhar 1994). Sometimes it is acidic in nature and pollutes the water regime (Tiwary *et al.* 1997).

Coal contains a significant amount of ferrous sulphate in the form of pyrites. The exposure of pyrite to atmospheric oxygen during mining oxidizes it to produce ferrous sulphate and sulphuric acid. The sulphuric acid thus formed, lowers the pH of the soil and water in the terrestrial and aquatic environments, respectively, which affects the organisms inhabiting those environments. Chemicals released from the coal mines, overburden and tailings also contain a high concentration of metals such as Cu, Cd, Fe, Hg and Zn, which also affect the organisms adversely. Large-scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural lands are some of the conspicuous environmental implications of coal mining (Swer & Singh 2004).

Just as canaries provide warnings of toxic gases to coal miners, so can the investigation of lichen communities provide information on potential deterioration of ecosystems stressed by air pollutants (Nash 2008). Lichens have sensitivity, both physiological and ecological, to pollutants and therefore have been employed almost exclusively to monitor the extent or spread of air pollution particularly $SO_2$ (Gries *et al.* 1997).


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Due to lack of cuticle, lichen absorbs both gases and dissolved substances through their surface. Reduction in air pollution has been reported to result in recovery of lichen abundance (Showman 1990, Kirschbaum *et al.* 1996). Murphy *et al.* (1999) used lichen abundance to indicate whether a rural, coal burning, electrical generating station in the northern USA has measurable impacts on the surrounding forest. Charak *et al.* (2009) studied lichens growing around the Moghla Coal mines, Kalakote, Jammu & Kashmir and revealed that pollutants released by the open coal mining activities not only effected qualitative distribution but also have an effect on the quantitative parameters.

The coal mining industry in Assam is more than a century old, started by British in 1884 when huge deposits of bituminous coal were discovered in this part of the country. Few collieries are operational and huge loads of coal are recovered every day, however, the impact of coal mining on plant vegetation has not been studied till date. This study intends to assess the lichen diversity of coal mining sites in Margherita, Assam and draw some useful inferences.

## MATERIALS AND METHODS

### *Study area*

The study was confined to the Makum Coalfield of North Eastern Coalfields in Margherita (Fig. 1) and its 10 km buffer area in Tinsukia district of Assam. The area of the buffer zone is approximately 484.8 km$^2$. The extent of the study area is from 95° 36′ 12″ E to 96° 01′ 55″ E and 27° 12′ 20″ N to 27° 26′ 27″ N. As many as 16 reserve/proposed reserve forests in four forest ranges fall in this buffer zone. Broadly, the area comes under Assam Valley Tropical Wet Evergreen Forests (*Dipterocarpus- Mesua* formation) with interspersed Semi-Evergreen Forests and scattered Bamboo Brakes (Champion & Seth 1968). Moderately Dense Forests (forests with the crown cover 40–70%) cover the maximum area followed by Open Forests (crown cover 10–40%) and Very Dense Forests (crown cover >70%), covering 16,256.1 ha, 7043.8 ha and 2070.4 ha, respectively. Bio-geographically, the study site is situated in the Eastern Himalayan province, the richest bio-geographical province of the Himalayan zone and also falls in one of the mega biodiversity hotspots of the world (Myers *et al.* 2000).

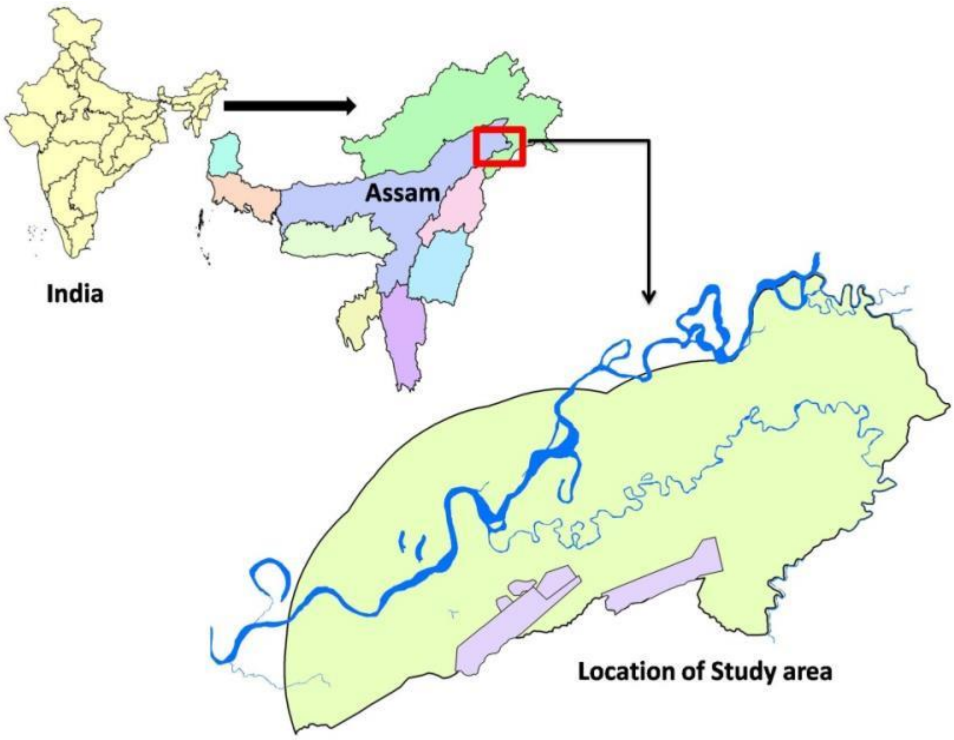


**Figure 1.** Location map of the study sites.

The Makum Coalfield covers forest areas amongst hilly terrains within Digboi forest division, Assam (Fig. 2). Coal mining activities of North Eastern Coalfields, Coal India Limited (CIL) are at present confined to Makum Coalfields with four coal mines under operation, covering an area of 2688.16 hectares. Tirap, Ledo and Tikak collieries are open cast coal mines, while the Tipong colliery is underground (Anonymous 2008, 2009). Among the land uses, Agriculture with an area of 9470.2 ha is the dominant land use followed by Scrub Land (2994.1 ha), Tea Gardens (2940.5 ha), Open Land (2400), major Settlement (1705.0 ha), Sandy Area (1574.4

ha) Agriculture-Crop (903.2 ha), Mine Area (568.2 ha) and major water body (555.9 ha). The present study area falls in watersheds of River Tirap and Burhi-Dihing flowing across the area.

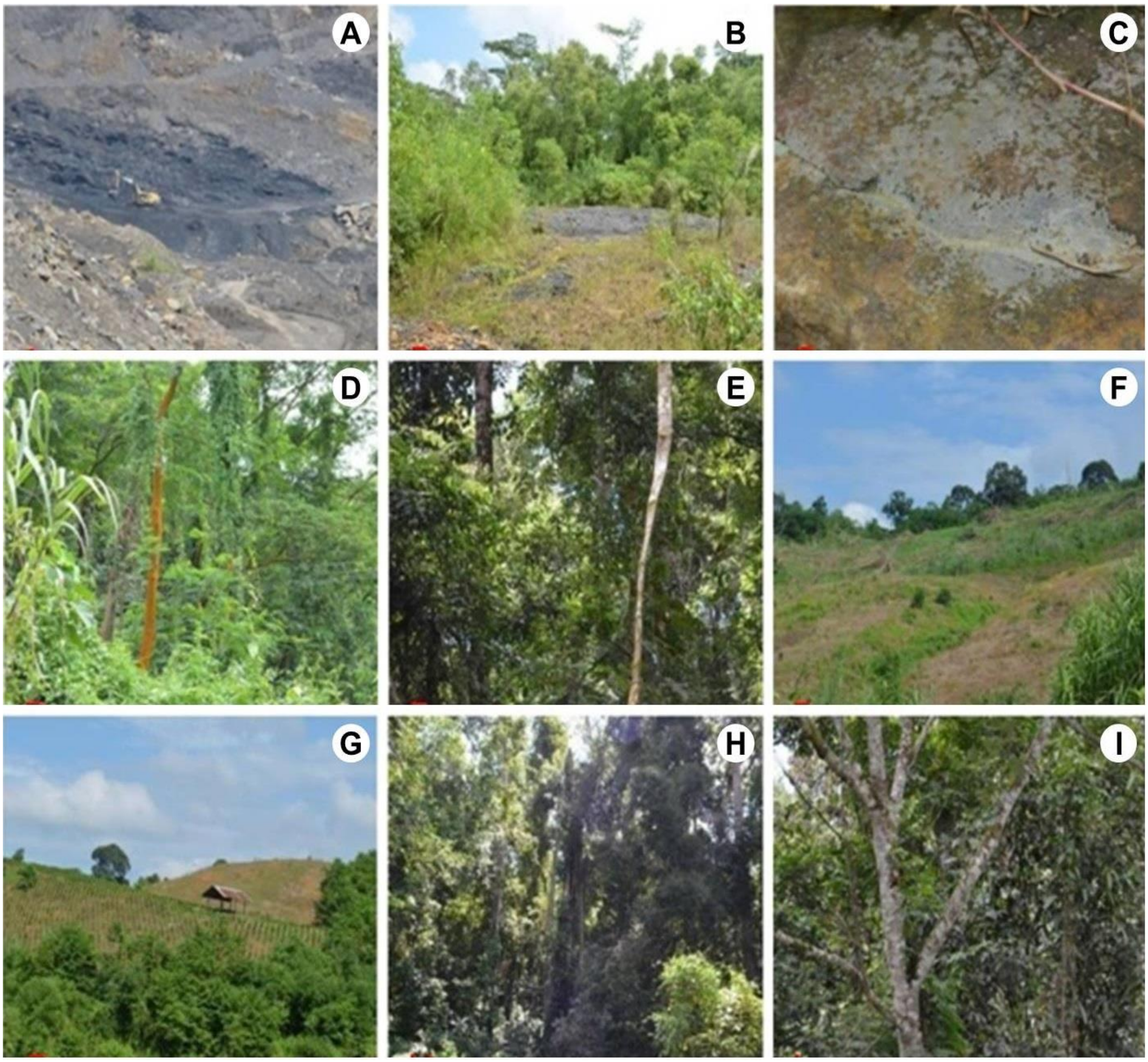


**Figure 2. A**, Active Coal mining at location 5 of Tikak colliery; **B**, Reclamation site at location 4 of Tikak colliery; **C**, Boulders in the initial stage of Lichenization at location 4 of Tikak colliery; **D**, Tree at reclamation site are covered with algae *Trentopholia* sp.; **E**, Reserve forest at Tipong Charlie at Location 1, 2, and 3; **F**, Salaki Hills at Location 6; **G**, Tea and turmeric garden at Salaki hills; **H**, Tinkupaani Reserve forest at location 7, 8, 9, and 10; **I**, Rich abundance of corticolous lichens at Dehing-Patakai at location 11 and 12.

The Study area falls under the humid zone, characterized by high precipitation. High humidity and heavy rainfall are significant features of evergreen forests in this region. The relative humidity is generally high during most part of the year, touching about 90 percent during monsoon. Heavy downpour takes place during the monsoon months of May, June, July & August. The average rainfall recorded from 2010–11 to 2016–17 in this region shows that highest rainfall occurs during the month of July (428.86 mm) whereas the lowest average rainfall was recorded during November (17.11 mm).

*Data collection*

Around 150 lichen specimens were collected from rocks, soil, twigs and barks of different trees from 12 different sites in Makum Coalfield. The collected specimens were investigated morphologically (by Leica EZ4 HD Stereo microscope), anatomically (by Leica DM 750 compound microscope) and chemically (by Thin Layer Chromatography). The specimens were identified following the publications of Coppins & James (1984), Awasthi (1991, 2000 & 2007) and Harris (1995). The colour tests were performed with the usual reagents, *i.e.* K (5% potassium hydroxide), C (Aqueous solution of calcium hypochlorite) and P (paraphenylenediamine). Lichen substances were identified with thin layer chromatography (TLC) in solvent system A (toluene: dioxane: acetic acid; 180:60:8 ml) using the technique of Walker & James (1980).

## RESULTS

The identification of the specimens collected from study sites (Table 1) reveals the occurrence of 31 lichen species belonging to 26 genera and 21 families (Table 2; Fig. 3–4). In all of the sites studied, lichens exhibited a high abundance of low diversified communities. Sites with good forest cover such as location 7 and 10 of Tinkupaani reserve forest harboured a high number of lichens including species such as *Coccocarpia palmicola* and *Cladonia coniocrea*.

**Table 1.** Study sites of Makum coalfield.

| S.N. | Sampling Site | Location (Code) | Altitude (m) | GPS |
|---|---|---|---|---|
| 1. | Tipong Charlie no. 8 | Location 1 (L1) | 175 | N 27° 17' 42.9"<br>E 095° 51' 17.2" |
| 2. | | Location 2 (L2) | 376 | N 27° 17' 21.7"<br>E 095° 50' 47.4" |
| 3. | | Location 3 (L3) | 476 | N 27° 17' 02.4"<br>E 095° 50' 32.6" |
| 4. | Tikak Colliery | Location 4 (L4)<br>(Reclamation site) | 483 | N 27° 16' 02.8"<br>E 095° 43' 08.2" |
| 5. | | Location 5 (L5)<br>(Active mining) | 530 | N 27° 16' 15.6"<br>E 095° 43' 30.7" |
| 6. | Salaki Hills (proposed extension site) | Location 6 (L6) | 300 | N 27° 18' 04.4"<br>E 095° 47' 53.0" |
| 7. | Tinkupaani Reserve Forest | Location 7 (L7) | 186 | N 27° 22' 10.8"<br>E 095° 57' 48.0" |
| 8. | | Location 8 (L8) | 183 | N 27° 22' 28.6"<br>E 095° 57' 52.6" |
| 9. | | Location 9 (L9) | 200 | N 27° 21' 55.7"<br>E 095° 58' 00.2" |
| 10. | | Location 10 (L10) | 180 | N 27° 21' 20.5"<br>E 095° 58' 01.2" |
| 11. | Dehing – Patakai | Location 11 (L11) | 141 | N 27° 21' 23.2"<br>E 095° 31' 46.0" |
| 12. | | Location 12 (L12) | 114 | N 27° 21' 05.6"<br>E 095° 30' 34.4" |
| 13. | Saraingpung Range | Location 13 (L13) | 106 | N 27° 20' 41.2"<br>E 095° 28' 28.4" |

Understorey plants in Tipong and Tinkupaani reserve forests were colonized by follicolous lichens such as *Mazosia phyllosema*, *Strigula antillarum*, *Strigula smaragdula*, *Calopadia fusca* etc. Sites nearby active mining such as Location 5 of Tikak Colliery showed a minimum number of genera. Sites near reclamation land such as Location 4 of Tikak Colliery exhibited less number of lichens indicating disturbed condition; however, many of the rocks in this area were in the initial process of lichenization. Trees at Saleki Hills (which included the proposed coal mining extension sites) had already been felled down by local tribal and replaced with tea and turmeric gardens, and therefore, exhibit a low diversity of lichen communities. The complete list of lichens found in the study area is given in table 2.

**Table 2.** List of lichens studied in Makum coalfield.

| S.N. | Botanical name | Family | Growth form | Substratum | Abundance |
|---|---|---|---|---|---|
| 1. | *Bacidia incongruens* (Stirt.) Zahlbr. | Ramalinaceae | Crustose | Bark | Rare |
| 2. | *Buellia alboatra* (Hoffm.) Th. Fr. | Caliciaceae | Crustose | Bark | Rare |
| 3. | *Calopadia fusca* (Mull. Arg.) Vezda | Ectolechiaceae | Crustose | Leaves | Common |
| 4. | *Caloplaca bassiae* (Willd. Ex Ach.) Zahlbr. | Teloschistaceae | Crustose | Bark | Rare |
| 5. | *Chiodecton leptosporum* Mull. Arg | Roccellaceae | Crustose | Bark | Common |
| 6. | *Chrysothrix chlorina* (Ach.) laundon | Chrysothricaceae | Leprose | Bark | Rare |
| 8. | *Cladonia coniocraea* (Florke) Spreng | Cladoniaceae | Fruticose | Soil and rocks | Rare |
| 9. | *Coccocarpia palmicola* (Spreng.) Arvidss& D.J. Galloway | Coccocarpiaceae | Foliose | Bark | Rare |
| 10. | *Collema pulcellum* Ach. var. *subnigrescens* (Mull. Arg.) Degel. | Collemataceae | Foliose | Bark | Rare |
| 11. | *Cryptothecia striata* G. Thor | Arthoniaceae | Crustose | Bark and rocks | Common |
| 12. | *Dirinaria aegialita* (Afzel.) B.J. Moore | Caliciaceae | Foliose | Bark and rocks | Common |

| | | | | | |
|---|---|---|---|---|---|
| 13. | *Glyphis duriuscula* Stirton | Graphidaceae | Crustose | Bark | Common |
| 14. | *Graphis duplicata* Ach | Graphidaceae | Crustose | Bark | Common |
| 15. | *Graphis scripta* (L.) Ach | Graphidaceae | Crustose | Bark | Common |
| 16. | *Haematomma puniceum* (Sw.) A. Massal. | Haematommataceae | Crustose | Bark | Common |
| 17. | *Heterodermia diademata* (Taylor) D.D. Awasthi | Physciaceae | Foliose | Bark and rock | Rare |
| 18. | *Lecanora indica* Zahlbr. | Lecanoraceae | Crustose | Bark | Common |
| 19. | *Leptogium azureum* | Lecanoraceae | Crustose | Bark | Common |
| 20. | *Mazosia phyllosema* (Nyl.) Zahlbr. | Roccellaceae | Crustose | Leaves | Common |
| 21. | *Parmotrema crinitoides* J. C. Wei | Parmeliaceae | Foliose | Bark and rock | Common |
| 22. | *Pertusaria quassiae* (Fee) Nyl. | Pertusariaceae | Crustose | Bark | Common |
| 23. | *Phaeographina caesioradians* (Leighton) Redinger | Graphidaceae | Crustose | Bark | Common |
| 24. | *Phaeographis platycarpa* Müll. Arg. | Graphidaceae | Crustose | Bark | Common |
| 25. | *Pseudopyrenula pupula* (Ach.) Mull. Arg | Trypetheliaceae | Crustose | Bark | Common |
| 26. | *Strigula antillarum* (Fee) Mull. Arg. | Strigulaceae | Crustose | Leaves | Common |
| 27. | *Strigula elegans* (Fee) Mull. Arg. | Strigulaceae | Crustose | Leaves | Common |
| 28. | *Strigula smaragdula* Fr. | Strigulaceae | Crustose | Leaves | Common |
| 29. | *Tricharia vainioi* R. Sant. | Gomphillaceae | Crustose | Leaves | Common |
| 30. | *Trichothelium annulatum* (Karst) R. Sant. | Trichotheliaceae | Crustose | Leaves | Common |
| 31. | *Trypethelium eluteriae* Spreng | Trypetheliaceae | Crustose | Bark | Rare |

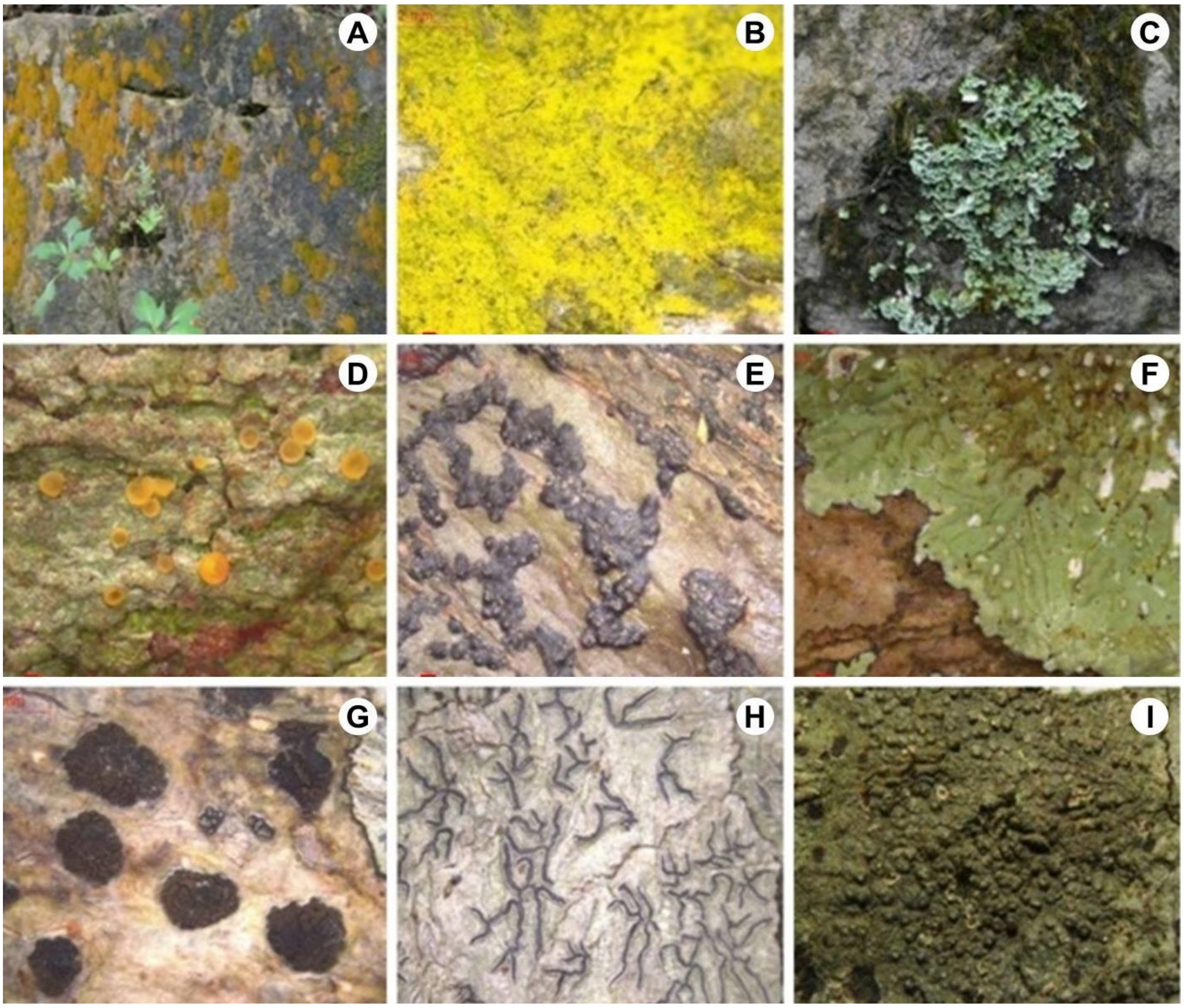


**Figure 3. A**, *Trentopholia* sp., a terrestrial alga, was of common occurrence in the reclamation sites; **B**, Leprose thallus of *Chrysothrix chlorine*; **C**, *Cladonia coniocraea* growing on rock at Tipong Charlie reserve forest; **D**, Corticolous thallus of *Bacidia incongruens*; **E**, Corticolous thallus of *Chiodecton leptosporum*; **F**, Corticolous thallus of *Dirinaria aegialita*; **G**, Corticolous thallus of *Glyphis duriuscula*; **H**, Corticolous thallus of *Graphis duplicate*; **I**, Corticolous thallus of *Pertusaria quassiae*.

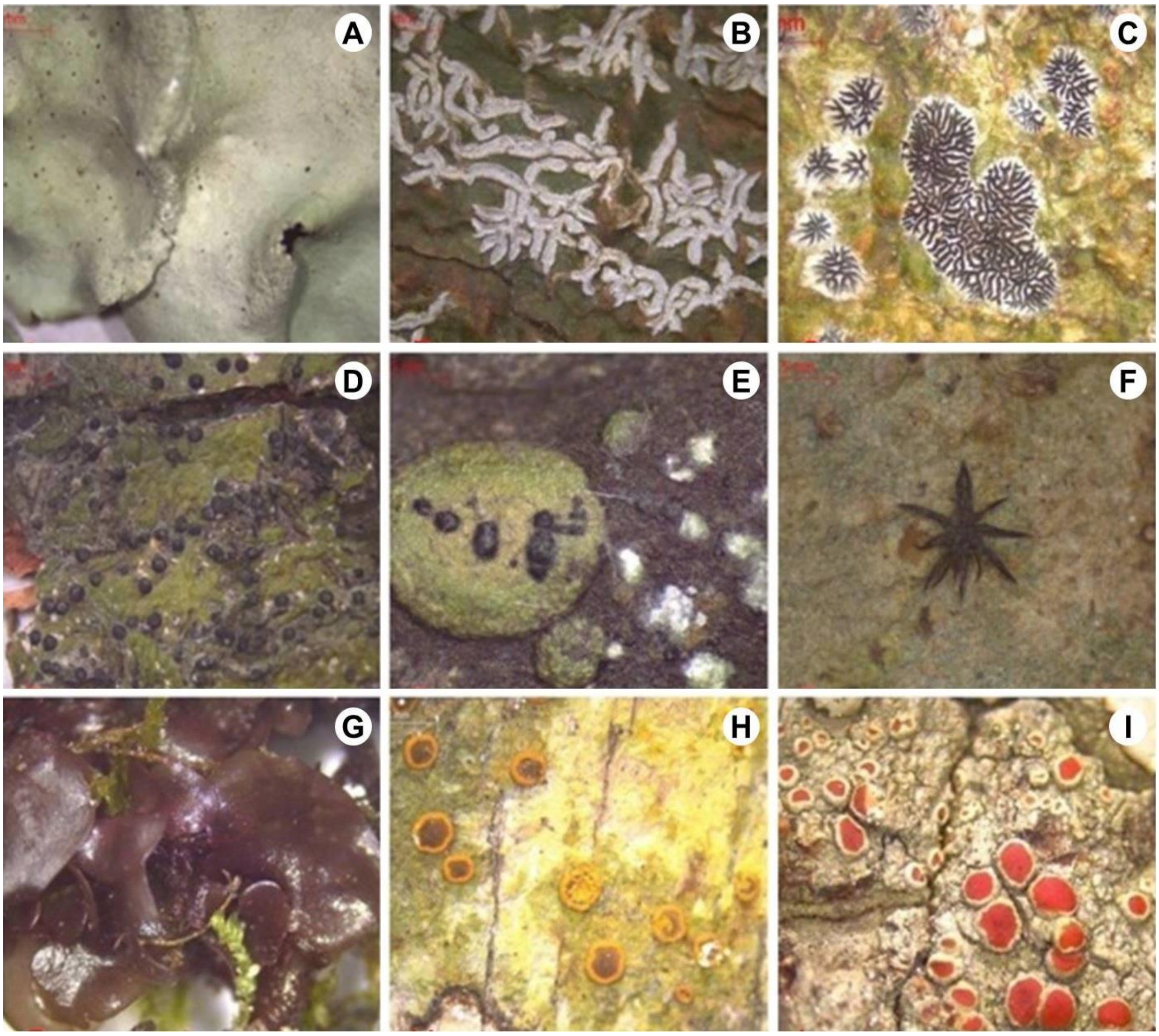


**Figure 4. A**, Foliose thallus of *Parmotrema crinitoides*; **B**, Corticolous thallus of *Phaeographina caesioradians*; **C**, Corticolous thallus of *Phaeographis platycarpa*; **D**, Corticolous thallus of *Pseudopyrenula pupula*; **E**, Follicolous thallus of *Strigulaelegans*; **F,** Follicolous thallus of *Trichothelium annulatum*; **G**, Corticolous thallus of *Collema pulcellum*; **H**, Corticolous thallus of *Letroutia transgressa*; **I**, Corticolous thallus of *Haemotomma puniecium*

## CONCLUSION

Biodiversity may be considered as a non-renewable resource that needs to be managed for its conservation and sustainable utilization. As far as biodiversity is considered, Makum Coalfield, Assam is situated within a vivacious habitat that is famous for quite rich flora and fauna. However, biotic interference in this fertile region over the years has resulted in forest degradation, fragmentation and deforestation and evolution of secondary forests in place of the primary virgin forest. The direct impacts of mining disturbances to land surfaces are usually significant, with the likelihood of destruction of biodiversity within natural ecosystems through the removal of natural soil, plants and animals.

In the open cast mining sites, phorophytes are uprooted and therefore, lichen communities are adversely affected. Lichen diversity in sites with active or past mining is found to be considerably low, because of the prevailing harsh and disturbed environmental conditions. On the other hand, sites with good forest reserve cover have a high abundance of lichen communities. It had been noticed that in reclamation sites, while the vegetation had successfully been established, lichens were only restricted to the initial process of colonization of rocks (pioneer stage of Lithosere). The bark of trees of reclamation sites was devoid of lichens and was inhabited by terrestrial algae, *Trentepholia* sp. This indicates that coal mining activities are more detrimental for lichens as compared to other vegetation. A conglomeration of both nitrophylic and oligotrophic species at the sites of active mining and reclamation sites reveals that the land use is the guiding factor in community dynamics. However, the presence of terricolous and cyanolichens such as *Coccocarpia palmicola* and *Cladonia coniocrea* in the reserve areas near to the collieries points towards the low atmospheric pollution output and stable substrate indicating a lichen growth supporting habitat.

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