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Modern pollen-vegetation relationship from the tropical forest of eastern buffer zone of Manas National Park, Assam, northeast India

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ABSTRACT

Fifty surface sediment samples from Manas National Park, the gateway of the Indo-Burma hotspot region, were analyzed palynologically in order to explore the relationship between the pollen assemblage in sediments and contemporary vegetation patterns. The study reveals the occurrence of tropical mixed deciduous forest with major arboreals, namely *Terminalia bellirica*, *Dillenia pentagyna*, *Emblica officinalis*, *Sterculia villosa*, *Lagerstroemia parviflora*, *Salmalia malabaricum* and *Careya arborea* along with a patch of semi-evergreen forest consisting of *Mesua ferrea*, *Schima wallichii*, *Cinnamomum bejolghota* and *Elaeocarpus rugosus* under warm and humid climatic condition. This combination of deciduous and semi-evergreen floral elements suggests a strong monsoonal activity in and around the region. The presence of marshy (Cyperaceae, *Polygonum* and *Impatiens*) and aquatic taxa (*Myriophyllum*, *Nymphoides* and *Nymphaea*) suggests perennial water logged condition in and around the area. Pollen transport in the study area is largely affected by distant sediment load through river tributaries and frequent roaming of wild fauna from Bhutan Himalaya to foothills and associated flood plains. The presence of shrubby elements like *Melastoma malabathricum* and *Clerodendron viscosum* as a significant ingredient signifies the deterioration and encroachment of natural forest vegetation especially in the river bank. *Pinus*, *Rhododendron*, *Betula*, *Corylus*, *Alnus* and *Ulmus* occur in low frequencies and are exclusively transported by wind and water from the eastern Himalayas. Anthropogenic activity is in continuous pace as reflected by the higher frequencies of cereal pollen (7.9%). The present pollen database will be helpful in tracing the past vegetation succession and climatic alterations in and around this remote and biologically rich ecosystem of northeast India.

Key-words: Pollen rain, Vegetation, Surface samples, Manas National Park, Northeast India.

INTRODUCTION

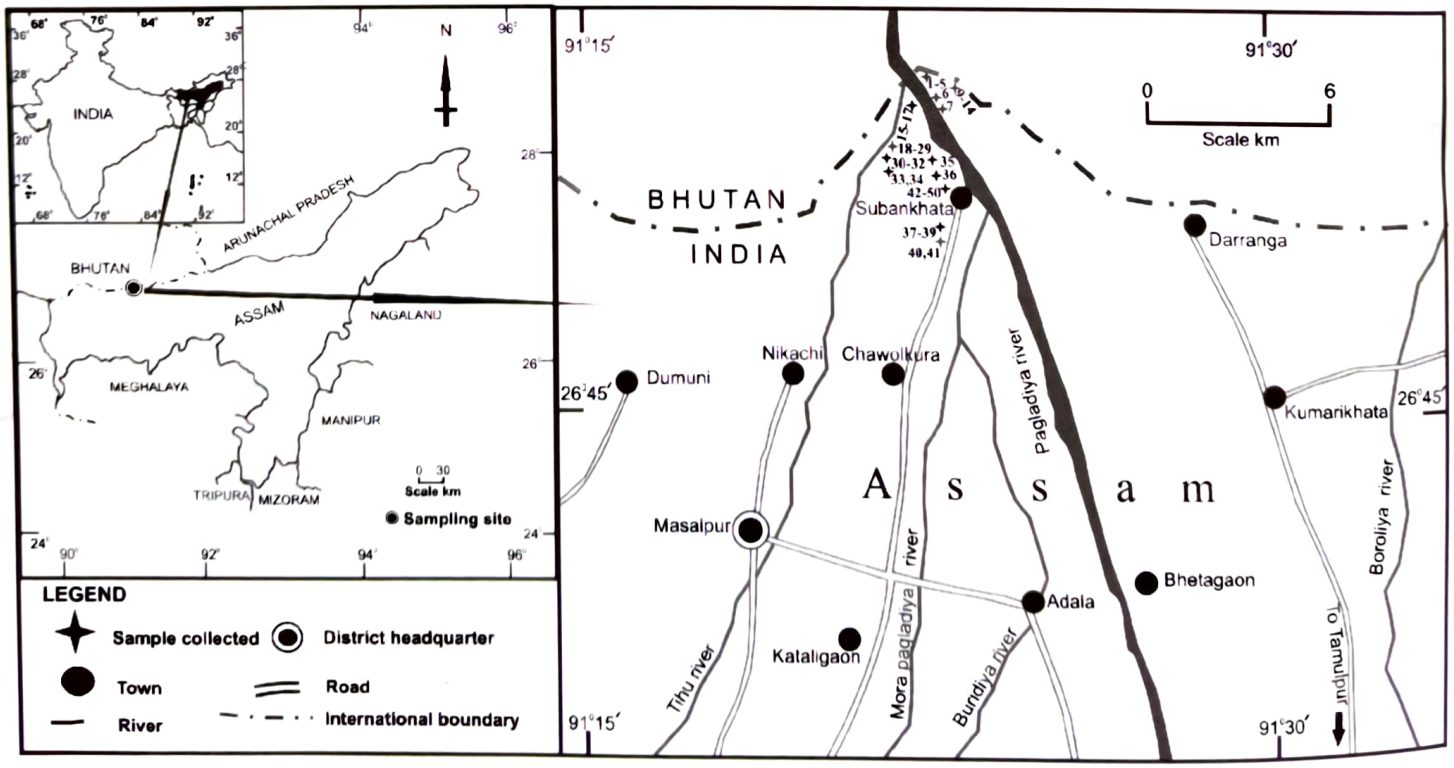
Studies of modern pollen deposition in surface soil are an important source of information for the Quaternary reconstructions. Many surveys have shown a strong relation between pollen rain and vegetation (Janssen 1967, Wright 1967, Birks & Birks 1980, Bradley 1985, Overpeck et al. 1985). This will be instrumental in better understanding of fossil samples, as there is no direct way of reconstructing past vegetation and climate. The dispersal, deposition and preservation pattern of pollen grains may vary in a particular area, resulting in over-representation and under-representation of certain pollen taxa (Prentice 1985, Prentice et al. 1987, Jackson & Lyford 1999). The mode of pollination (mainly anemophily and entomophily) plays an important role in the

representation of pollen grains in the sediments. In India, Quamar & Bera (2014, 2016) and Tripathi et al. (2015) have already reported the different representation of pollen taxa caused by variable characteristics, including pollen production and dispersal ability among taxa. A relatively good correspondence between vegetation types and surface pollen assemblages in Assam has been observed in a transect from centre, margin and open-land areas of tropical deciduous forests (Dixit & Bera 2013). Dixit et al. (2012) suggested that by comparing multiple points of pollen data, variations among taxa and sites would help us to understand the vegetation structure. Qualitative studies of the pollen-vegetation relationship in several vegetation types on the Indian subcontinent have been carried out (Singh et al. 2011; Basumatary et al. 2013). However, only a few studies were concerned with the quantitative relationship between pollen and vegetation (Barboni & Bonnefille 2001).

Earlier, a study on modern pollen rain and reconstruction of palaeovegetation and past climate has been made in the Keoladeo National Park and Bharatpur Bird Sanctuary, Rajasthan using pollen proxy records (Sharma & Chatterjee 2007, Sharma et al. 2011). However, no such palynological research was carried out in national parks of northeast India. Only few scattered work on modern pollen rain have been carried out in Mikir hills (Bera 2000) and lower Brahmaputra valley, Assam (Dixit & Bera 2011). The generated palynological data will prove as a baseline for deciphering palaeovegetation and climate in northeast India. Correlation of the generated regional data with other parts of the country is one of the objectives.

Regional Setting

The Subankhata reserve forest (lat. 26°48´N and long. 91°25´E), the richest biodiversity region in the Indo-Burma hotspot, holds a key geographical position for palaeoecological study (Text Figure 1). It is commonly known as the eastern buffer zone of Manas National Park in Assam and was declared a world heritage site by The United Nations Educational, Scientific and Cultural Organization (UNESCO) in December 1985. It is contiguous with the Royal Manas National Park (65,800 ha) of Bhutan within the Indo-Burma hotspot range. The reserve forest is a junction between the plains and hills of India and Bhutan, and is traditionally known as 'Duar' (door). It represents the transition zone between the Himalayan Mountains and Peninsular India (Rao 1994). The main Pagladia River,



Text Figure 1. Location map showing the sampling sites of the eastern buffer zone, Manas National Park, Assam.

along with many small tributaries originates from the higher Himalaya flows through the reserve forest towards the mighty Brahmaputra River. The region is already identified as one of the most threatened biodiversity hotspots of the world and, therefore, special care is required for proper conservation.

Climate and type of vegetation

The climate in the district is subtropical with semi dry summers and cold in winter. Rain makes its first appearance in the month of April with occasional and irregular light showers and at times heavy downpour followed by cyclonic storm. The irregular rainfall continues up to the end of May. The rain occurs due to the influence of southwest and northeast wind. Monsoon rain normally begins from the early part of June and heavy to excessive rains occur in the district till the month of October. Annual rainfall ranges between 34 cm to 560 cm. The maximum temperature attains 36°C during July and August and the minimum temperature dips down to 3°C in the month of January.

However, this area has still not been properly explored botanically. From the present study area, there are very few plant collections in the herbarium of Botanical Survey of India (BSI), Eastern Circle, Shillong (Jain & Hazra 1975). In general, five forest types occur in the region, as described in Champion & Seth (1968) which are as follows: Sub-Himalayan alluvial semi-evergreen forest, East Himalayan mixed moist and dry deciduous forest, Low alluvial savanna forest, Open land/Crop land and Degraded forest. The arboreal taxa in the semi-evergreen and deciduous forests are represented by *Aphanamixis polystachya*, *Cinnamomum bejolghota*, *Mesua ferrea*, *Syzygium cumini*, *Mallotus philippensis*, *Albizia lebbeck*, *Careya arborea*, *Dillenia pentagyna*, *Lagerstroemia parviflora* and *Terminalia bellirica* (Pl. 1, fig. 1). The savanna forest is comprised of grasses viz., *Imperata cylindrica*, *Saccharum naranga*, *Phragmites karka* and *Arundo donax*, along with trees such as *Salmalia malabaricum*, *Dillenia pentagyna* and *Emblica officinalis*. The shrubs here are comprised of *Clerodendron viscosum*, *Melastoma malabathricum*, *Ziziphus mauritiana* and *Leea crispa*. The open and crop land of the forest area includes plant families like Cyperaceae, Polygonaceae, Ranunculaceae, Commelinaceae and Onagraceae. The aquatic taxa are represented by *Nymphoides indica*, *Potamogeton pectinatus*, *Nymphaea nouchali*, *Trapa bispinosa*, *Myriophyllum indicum*, *Lemna minor* and *Eichhornia crasipes*. The cultivated taxa are mainly comprised of Poaceae and Brassicaceae. The common pteridophytic taxa in the periphery of the swamp are mainly represented by *Marsilea quadrifolia*, *Pteris vittata*, *Dryopteris flix-mas*, *Adiantum caudatum*, *Lycopodium cernuum*, *Selaginella biformis* and *Lygodium japonicum*. The degraded forest is constituted by scattered trees and shrubs, along with some common herbaceous taxa. Illegal deforestation and encroachment are the major reasons for the deterioration of forest land (Pl. 1, fig. 2).

STUDY AREA

The study site is enriched with three main vegetation types: sub-Himalayan alluvial semi-evergreen forest, east Himalayan mixed moist and dry deciduous forests, the commonest type, and grasslands. Much of the riverine dry deciduous forest is an early successional stage, being constantly renewed by floods. It is replaced by moist deciduous forest away from water courses, which is succeeded by semi-evergreen climax forest in the northern part of the reserve forest. Two types of alluvial grasslands cover almost 42.84% of the park: low alluvial savanna and semi-evergreen alluvial grassland. These are created and maintained by burning, and on a smaller scale, by elephants. The riparian grasslands are the best tiger habitat in India, and also well suited to the unique wild buffalo herds, Indian bison and swamp deer, elephants and water birds. There are 43 different grass species of which *Imperata cylindrica*, *Saccharum narenga*, *Phragmites karka* and *Arundo donax* predominate in eight major associations (Menon 1995). There are also a variety of tree and shrub species such as *Dillenia pentagyna*, which dominates the swamp forest. The silk cotton tree *Salmalia malabarica* is dominant in the savanna woodland. The shrub species are represented by *Eupatorium*, *Clerodendrum*, *Leea*, *Grewia*, *Premna*, *Mussaenda*, *Sonchus*, *Osbekia* and *Blumea*. There is

presence of a wide variety of aquatic flora along the riverbanks and in the numerous pools (Jain & Sastry 1983). Some 374 species of dicotyledons, including 89 trees, 139 species of 6 monocotyledons and 15 species of orchid have been identified. The soil of the region is throughout alluvium with sandy loam and rich in organic matter. The area is built mainly of metamorphic rocks but with a distinct calcareous component. The tributaries of the Brahmaputra River are characterized by very sharp rises and falls of discharge several times even during a single rainy season. Their braided channels undergo frequent avulsions over the extensive alluvial fans.

MATERIAL AND METHODS

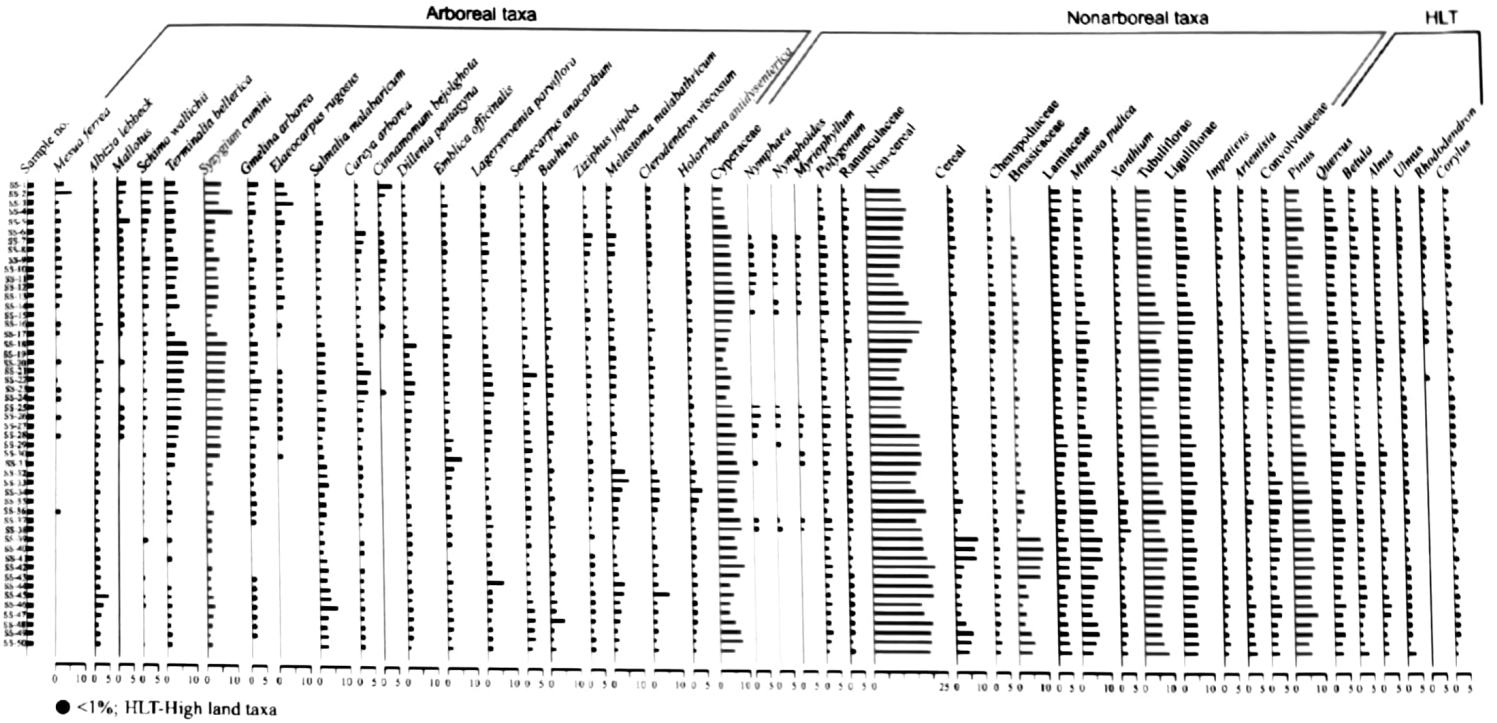
The material for the present study includes 50 surface soil samples that were procured randomly at 100-m intervals from the centre to periphery of the forest with the help of a trowel (Faegri & Iverson 1964). The samples were procured from different vegetation types (semievergreen, dry and moist deciduous, savanna, crop land, open land and degraded forest) of Subankhata reserve forest. The soil samples were processed employing standard acetolysis method (Erdtman 1954). The samples were treated with 10% aqueous KOH solution to deflocculate the pollen/spore from the sediments followed by 40% HF treatment to dissolve silica content. Thereafter, the conventional procedure of acetolysis was followed using acetolysis mixture (9:1 acetic anhydrite and conc. H_2SO_4). Finally the material was kept in 50% glycerine solution for microscopic examination. A few drops of phenol were also added to the glycerine solution to protect the processed material from microbial decomposition. A total of 250 to 400 pollen grains per sample were counted to make pollen spectra. For the precise identification of fossil palynomorphs in the sediments, the reference pollen slides available at Birbal Sahni Institute of Palaeosciences (BSIP) herbarium as well as the pollen photographs in the published literature (Chauhan & Bera, 1990; Nayar, 1990; Bera et al., 2009) were consulted and photodocumentation of palynomorphs was made using Olympus BX-61 light microscope with DP-25 digital camera under 40x magnification (Pl. 2). The pollen spectra were made using Microsoft Excel programme and modified in Corel Draw-12 software. The percentages of the recovered palynomorphs were calculated in terms of total plant pollen count. Poaceae (grasses) in the text are categorized into Non-Cereal (wild grass) with pollen<45µm and Cereal (cultivated grass) with pollen >45µm (Joly et al. 2007). The palynoassemblages have been categorized as arboreals (trees and shrubs), non-arboreals (marshy and terrestrial herbs) and High land taxa (conifers and other broad leaved taxa). Ferns (monolete and trilete spores) and fungal remains are excluded from the total pollen sum to avoid over-representation of these groups over regional plant constituents (Text Figure 2). Characteristic plant taxa growing in respective vegetation type of study area are mentioned in Table 1.

RESULTS OF POLLEN RAIN FROM DIFFERENT FOREST TYPES

The Indo-Burma biodiversity hotspot, with an area of 2,20,60,000 km^2, comes next only to the Mediterranean basin among the 25 hotspots identified globally (Myers 1988). The region represents about 50% of the floristic wealth of India diversity-wise, containing about 8000 species of flowering plants, including several representatives of primitive or ancient angiosperms (Takhtajan 1969). The distribution data across multiple flora and fauna indicate that the biological similarities of the region are closest to Southeast Asia (Hooker 1905; Mani 1974; Rodgers & Panwar 1988). The study region is dominated by an intense monsoon rainfall regime, a fragile geophysical framework, an active seismicity and a fabulously rich biological diversity (Goswami 1985) and therefore has experienced a wide range of vegetation shifts. The pollen assemblages reported from different vegetation types are discussed below:

Semi-evergreen forest

(Surface sample no. 1-17): The major semi-evergreen arboreals viz., *Mesua ferrea*, *Mallotus*, *Schima*, *Elaeocarpus* and *Cinnamomum* are recorded with in the value of 0.5–6.0%. The other deciduous elements like *Albizia*, *Terminalia* and *Dillenia* are also recovered up to 4.8%. However,



Text Figure 2. Frequency analyses of pollen rain spectra from eastern buffer zone of Manas national park, Assam. The values are expressed as percentage of the total land pollen count.

Syzygium occurred in slightly higher value of up to 7.2%. The shrubby elements like *Holarrhena* and *Melastoma* are recorded at the average value of 1.2% and 2.0% respectively. The grasses are recorded within maximum value of 18.8%. Similarly other terrestrial herbs like Tubuliflorae, Convolvulaceae, *Artemisia*, etc. are represented within the value of 0.5–8.9%. The aquatic taxa like *Nymphaea*, *Myriophyllum* and *Nymphoides* are recorded at the value of 0.5–1.7% in the sample number 6–14. The marshy taxa are represented by Cyperaceae, *Polygonum* and Ranunculaceae within frequency of 0.5-7.0%. The high land taxa like *Pinus*, *Betula*, *Rhododendron, Quercus* and *Alnus* are represented at the value of 0.5–6.0%.

Table 1. Characteristic plant taxa growing in respective vegetation type of study area.

Major Vegetation types	Marker plant taxa	Main associated taxa
Sub-Himalayan alluvial semi-evergreen forest	*Neolamarckia chinensis*, *Aphanamixis polystachya*, *Schima wallichii*, *Ilex sulcata*, *Tetrameles nudiflora*, *Cinnamomum bejolghota*, *Michelia champaca*	*Mallotus philippensis*, *Mesua ferrea*, *Syzygium cumini*, *Artocarpus chaplasha*, *Symplocos racemosa*, *Elaeocarpus rugosus*, *Terminalia myriocarpa*
East Himalayan mixed moist and dry deciduous	*Albizia lebbeck*, *Dillenia pentagyna*, *Lagerstroemia parviflora*, *Terminalia bellirica*, *Semecarpus anacardium*	*Gmelina arborea*, *Duabanga sonneratioides*, *Lannea coromandelica*, *Adina cordifolia*, *Careya arborea*, *Barringtonia acutangula*
Low alluvial savanna forest including: crop/open land, swamp and degraded forest)	*Arundo donax*, *Imperata cylindrica*, *Phragmites karka*, *Saccharum spontaneum*, *Ludwigia octavalvis*, *Colocasia esculenta*, *Andrographis paniculata*, *Impatiens balsamina*, Cyperaceae, Polygonaceae, *Nymphaea nouchali*, *Typha latifolia*, *Eichhornia crassipes*	Asteraceae (*Mikania micrantha*/*Eupatorium cannabinum*), *Syzygium cumini*, *Dillenia indica*, *Salmalia malabaricum*, *Ziziphus mauritiana*, *Melastoma malabathricum*, Oleaceae (*Jasminum sambac*, *Ligustrum robustum*), *Mimosa pudica*, *Bauhinia purpurea*, *Nymphoides indica*, *Lemna minor*, *Nelumbo nucifera*, *Potamogeton pectinatus*, *Myriophyllum indicum*, *Trapa bispinosa*

Mixed moist and dry deciduous forest

(Surface sample no. 18-29): The deciduous tree elements like *Albizia*, *Terminalia*, *Syzygium*, *Dillenia* and *Salmalia* are recovered at the value of 0.5–7.3%. The semi-evergreen arboreals, namely *Mesua ferrea*, *Schima*, *Elaeocarpus* and *Cinnamomum* are also recorded at the value of 0.4–2.7%. The non arboreal taxa like grasses, Tubuliflorae, Convolvulaceae, *Artemisia*, etc. are represented up to a value of 17.5%. The marshy taxa are represented by Cyperaceae, *Polygonum* and Ranunculaceae within frequency of 0.4-6.0%. The aquatic taxa, namely *Nymphaea*, *Myriophyllum* and *Nymphoides* are recorded within the value of 1.8%. Cereals are also recorded at the range of 0.6–3.0%. The high land taxa like *Pinus*, *Betula*, *Corylus*, *Quercus* and *Rhododendron* are represented at the value of 0.4–4.9%.

Savanna forest

(Surface sample no. 30–36): The major shrubby elements like *Melastoma*, *Bauhinia* and *Holarrhena* occupied the maximum value of up to 5.9%. The deciduous elements like *Albizia*, *Terminalia*, *Emblica*, and *Dillenia* are also recovered at the value of 0.5–4.5%. The semi-evergreen arboreals, namely *Mesua ferrea* and *Schima* are also recorded in trace value of up to 1.1%. *Mallotus* and *Cinnamomum* were not recovered in the sediments of the area. The non arboreal taxa like grasses, Tubuliflorae, Convolvulaceae, *Artemisia*, etc. are represented at the value of 0.5–19.5%. The marshy taxa are represented by Cyperaceae, *Polygonum* and Ranunculaceae within frequency of 0.2-6.0%. The aquatic taxa like *Nymphaea*, *Myriophyllum* and *Nymphoides* are recorded within the range of 1.5%. The Cereals are also recorded at the value of 0.6–3.3%. The high land taxa like *Pinus*, *Betula*, *Quercus*, *Ulmus* and *Alnus* are represented at the value of 0.5–6.5%. *Rhododendron* pollen is absent in the sediment.

Cropland

(Surface sample no. 37–39): The deciduous elements like *Albizia*, *Syzygium*, *Dillenia*, *Salmalia*, *Melastoma* and *Bauhinia* occupied the value of 0.5–2.5%. The semi-evergreen arboreal, namely *Schima* is only recorded in sporadic value. The grasses are recorded up to a maximum value of 17.8%. The other herbaceous associates like Tubuliflorae, Convolvulaceae, *Artemisia* and Chenopodiaceae are represented at the value of 0.5–8.3%. The marshy taxa are represented by Cyperaceae, *Polygonum* and Ranunculaceae with maximum frequency of up to 8.0%. The aquatic taxa like *Nymphaea*, *Myriophyllum* and *Nymphoides* are recorded within the value of 0.5–1.0%. The cereals are also recorded at the maximum value of 7.9%. The high land taxa like *Pinus*, *Betula*, *Corylus*, *Ulmus* and *Quercus* are represented at the

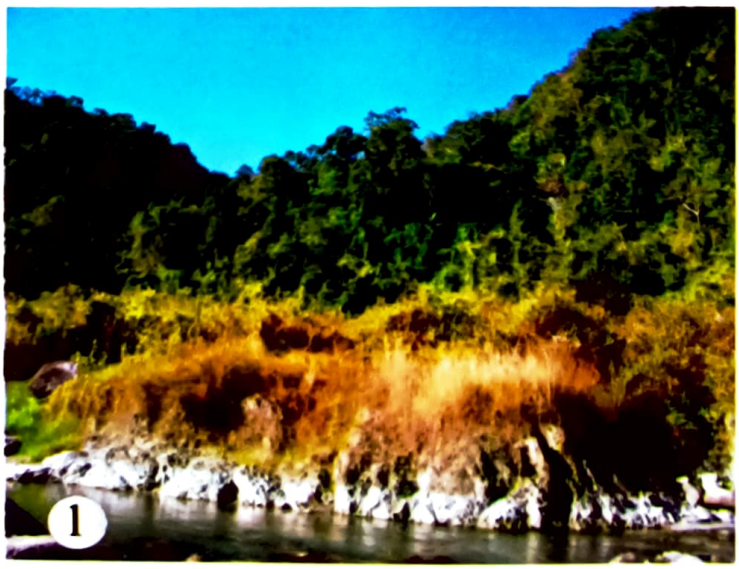


Plate 1

Field photographs: 1. View of dense semi-evergreen forest along with Pagladia river of Subankhata reserve forest, Assam. 2. View of degraded forest under the Subankhata reserve forest, Assam.

value of 0.5–6.9%, whereas *Rhododendron* pollen is absent in the palynoassemblage.

Open land

(Surface sample no. 40–41): The major shrubby elements like *Clerodendron*, *Melastoma*, *Bauhinia* and *Holarrhena* occupied the value of 0.5–2.0%. The deciduous elements like *Salmalia*, *Terminalia*, *Syzygium* and *Dillenia* are also recovered at the value of 0.5–1.0%. The semi-evergreen arboreals are absent in the palynoassemblage. There is a distinct rise in the average value of grasses (18.1%) and their maximum value is noted as 22.2%. The cereals are recorded at a maximum value of 7.4%. However, the other herbaceous taxa like Tubuliflorae, Convolvulaceae, Lamiaceae and *Xanthium* are represented at the value of 7.9%. The marshy taxa are represented by Cyperaceae, *Polygonum* and Ranunculaceae with maximum frequency of up to 9.0%. Aquatic taxa are not found in the palynoassemblage. There is an isolated rise of *Mimosa pudica* at the average value of 6.0%. The high land taxa like *Pinus*, *Quercus*, *Betula*, *Alnus* and *Ulmus* are represented at the value of 0.5–7.1%. *Rhododendron* pollen is not encountered in the sediment.

Degraded forest

(Surface sample no. 42–50): The major deciduous arboreal taxa like *Salmalia*, *Semecarpus*, *Syzygium*, *Terminalia*, *Lagerstroemia* and *Dillenia* are recovered within the value of 0.5–6.1%. The lone semi-evergreen arboreal, *Schima* is recorded in trace value of 0.9%. The shrubby elements especially *Melastoma* and *Clerodendron* have fairly increased their frequency. The average value of grasses relatively inclined (21.4%) along with increase in herbaceous associates like Tubuliflorae, Convolvulaceae, *Artemisia*, etc. represented at the value of 0.5–8.2%. The marshy taxa are represented by Cyperaceae, *Polygonum* and Ranunculaceae with maximum frequency of up to 6.5%. Aquatic taxa are not found in the palynoassemblage. The cereals are recorded within the value of 1.4–5.9%. The high land taxa like *Pinus*, *Betula*, *Alnus*, *Corylus* and *Ulmus* are represented at the value of 0.6–7.8%. However, *Rhododendron* is not recovered in the sediment.

DISCUSSION

The presence of arboreal composition of *Mesua ferrea*, *Elaeocarpus rugosus*, *Cinnamomum bejolghota*, *Mallotus* and *Schima wallichii* in the surface samples procured from semi-evergreen forest implies that the modern pollen rain in semi-evergreen forest coheres with the extant vegetation. However, the moist and dry deciduous elements like *Terminalia*, *Dillenia*, *Syzygium*, *Lagerstroemia* and *Careya* are also associated in reasonable values, attributable to their long range of climate acclimatization. The shrubby elements like *Melastoma*, *Holarrhena* and *Bauhinia* are represented in low frequencies due to dense canopy of forest which restricts the further growth of these roadside shrubs. The non-arboreals like grasses, Tubuliflorae, Liguliflorae and Lamiaceae are represented in moderate frequencies. The presence of high land taxa like *Pinus*, *Quercus*, *Betula*, *Corylus*, *Ulmus* and *Alnus* are probably derived from the long distance transport through strong wind and water activity from Eastern Himalaya (Tripathi et al. 2014). The presence of *Rhododendron* pollen in the surface sediment is signifying its luxuriant growth in the Bhutan Himalaya suggesting, high rainfall with strong water flowing system in the study region. In the succeeding moist and dry deciduous forest, the semi-evergreen elements like *Cinnamomum*, *Mesua* and *Elaeocarpus* progressively declined due to climate variability. However, the deciduous taxa, chiefly *Salmalia*, *Syzygium*, *Gmelina*, *Lagerstroemia*, *Semecarpus* and *Terminalia* show the distinct rise in their frequencies. The values of non-arboreal taxa like grasses, Cyperaceae, Convolvulaceae, *Xanthium*, etc. do not show any significant change. Aquatic taxa, namely *Nymphoides* and *Myriophyllum* suggest water logged condition in and around the study area. The continuous presence of high land taxa supports speedy wind and water activity. In terms of frequencies, the pollen spectra from semievergreen and deciduous forest shows dominance of non-arboreals (terrestrial and marshy/aquatic herbs) and relatively lower frequencies of arboreals (trees and shrubs), whereas in factual composition of the forest the arboreals are much better represented than non-arboreals (Text Figure 2). The

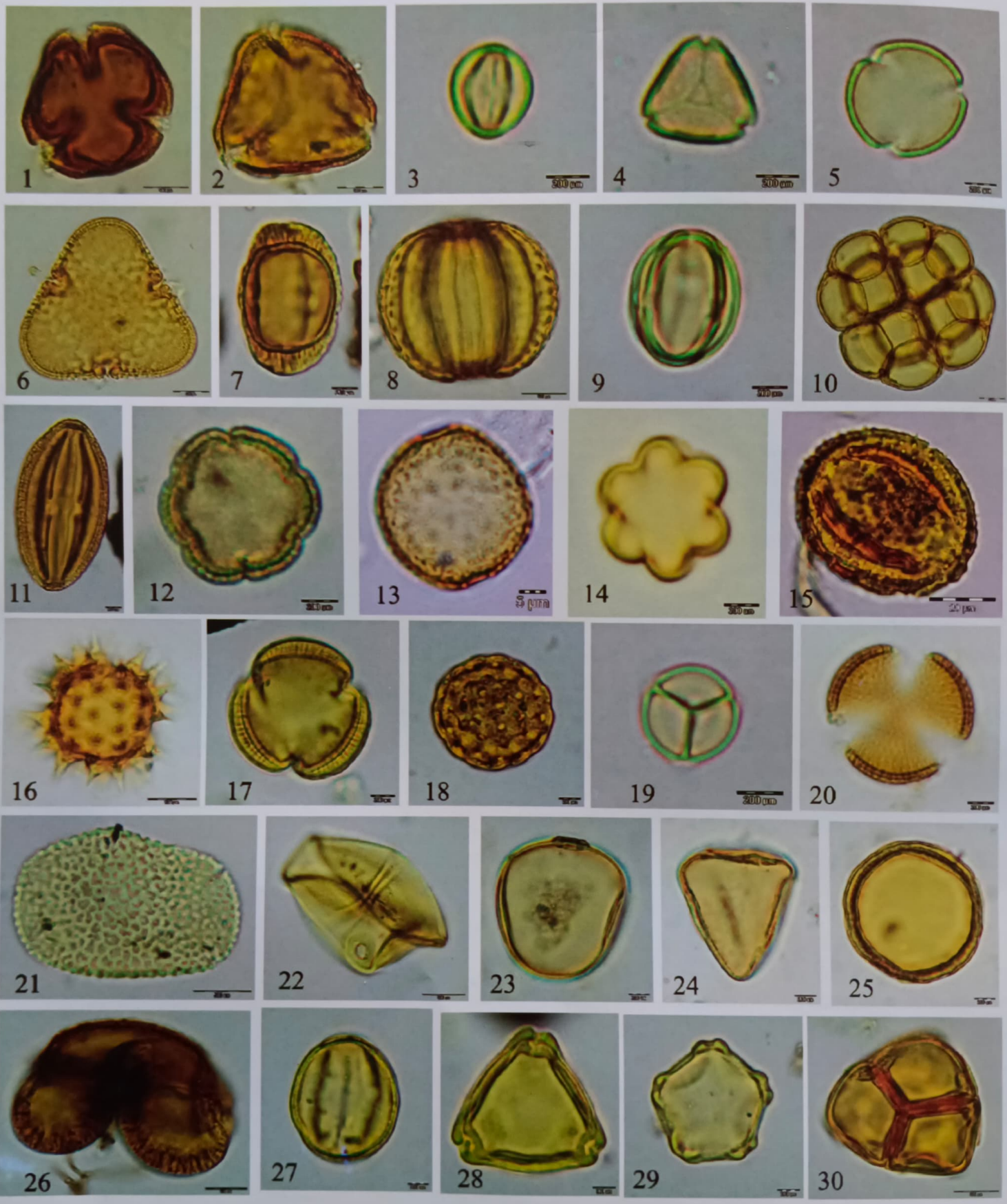


Plate 2

Palynoassemblage recovered from the modern surface samples of eastern buffer zone, Manas National Park, Assam: 1. *Mesua ferrea*, 2. *Schima wallichii*, 3. *Elaeocarpus* sp., 4. *Syzygium* sp., 5. *Dillenia pentagyna*, 6. *Salmalia malabaricum*, 7. *Lagerstroemia* sp., 8. *Careya arborea*, 9.*Terminalia* sp. 10. *Albizia* sp., 11. *Semecarpus anacardium*, 12. *Emblica officinalis*, 13. *Holarrhena antidesynterica*, 14. *Melastoma malabathricum*, 15. *Clerodendron* sp., 16. Tubuliflorae, 17. *Artemisia* sp., 18. Cheneopodiaceae, 19. *Mimosa pudica*, 20. Brassicaceae, 21. *Impatiens* sp., 22. Cereal, 23. Non-Cereal, 24. Cyperacaeae, 25. *Nymphaea* sp., 26. *Pinus* sp., 27. *Quercus* sp., 28. *Betula* sp., 29. *Alnus* sp., 30. *Rhododendron* sp.

reason could be due to under-representation of some arboreals attributed to differential pollen dispersal and preservation of their pollen taxa, depending on the plant species and climatic conditions.

In the savanna forest, the shrubby elements are dominant in comparison to the deciduous and semi-evergreen forest. The semi-evergreen taxa are almost not visualized except for *Mesua ferrea* and *Schima*. There is a general fall in the frequency of deciduous trees like *Albizia*, *Syzygium* and *Lagerstroemia* as compared to the preceding forest. The frequency of non-arboreals, chiefly Tubuliflorae, Liguliflorae and Convulvulaceae are over-dominant in comparison to the preceding two forest types. High abundance of terrestrial herbaceous taxon, *Mimosa pudica* is signifying the encroachment towards the forest vegetation. The high land taxa especially *Pinus*, *Corylus* and *Betula* are over-represented supporting an open exposed area for high wind activity.

In the cropland, there is a total absence of semi-evergreen elements. However, the trace frequencies of deciduous tree taxa like *Salmalia*, *Albizia* and *Dillenia* are noticed. The shrubby elements, mainly *Melastoma* and *Clerodendron* are represented in moderate frequencies supporting their scattered growth towards the margin area. The non-arboreal taxa, namely grasses, Cyperaceae, Ranunculaceae and Convulvulaceae are dominant, whereas the aquatic taxa like *Nymphaea* and *Myriophyllum* are encountered in low values. The good presence of cereal pollen signifies the pastoral activity by the local people. In an open-land area, the non-arboreals like grasses, Cyperaceae, Tubuliflorae and *Artemisia* are over-dominant. The palynospecies of Tubuliflorae averaged 7% pollen depict the intense pastoral activities in the open-land area, as members of this family escape grazing because of their unpalatable nature for cattle and goats (Mazier et al. 2006). The deciduous tree taxa, namely *Dillenia* and *Salmalia* indicate their scattered abundance in the study area. The absence of aquatic pollen is suggestive of unavailability of perennial water logged condition in the area.

The pollen spectra of degraded forest show that the deciduous arboreal taxa, chiefly *Albizia*, *Syzygium*, *Careya* and *Dillenia* drastically declined, whereas the shrubby elements like *Holarrhena* and *Clerodendron* are fairly increased. The occurrence of pollen grains of *Melastoma* and *Mimosa pudica* is significantly higher than that of semi-evergreen and deciduous forest, supporting the forest clearance and invasion of secondary forest elements (Basumatary et al. 2015). The values of grasses and other herbaceous associates like Tubuliflorae, *Xanthium* and *Artemisia* remain fairly high in the palynoassemblage. The absence of aquatic taxa especially *Nymphaea* and *Myriophyllum* is indicative of dryness and deterioration in local water bodies. The increased value of cereal pollen, along with Brassicaceae and Lamiaceae is strongly signifying the anthropogenic activity through time.

The present palynological study demonstrates that pollen-assemblage richness does reflect extant floristic in different vegetation types. However, this relationship is not a simple or exact 1:1 relationship (Birks et al. 2016). This relationship involves many natural and human induced factors like high rainfall, soil erosion, wind activity, soil pH, low sporopollenin content of pollen and spore wall, entomophily, anthropogenic impact, etc., which resulted in the under-representation of certain pollen taxa. These factors need to be observed in more detail for the precise deciphering of past vegetation and climate through the fossil pollen in sedimentary sequences.

CONCLUSION

The modern pollen deposition in and around Subhankhata reserve forest primarily reflects a tropical semi-evergreen, deciduous and savanna forest in response to the high rainfall under warm and humid climate in the region. It is confirmed that the depositional pattern at the centre and margin of the forest mainly depends on the growth of nearby parent plant taxa, pollen production, pollination mode, rainfall and wind speed. The semi-evergreen and deciduous elements, especially *Mesua ferrea*, *Elaeocarpus*, *Semecarpus*, *Dillenia* and *Syzygium* in the reserve forest strongly support acceleration in monsoonal activity. The presence of *Rhododendron* pollen in the surface sediment is signifying its luxuriant growth in the Bhutan Himalaya supporting the high rainfall in the region. The occurrence

of degraded forest patches in the forest is due to severe anthropogenic pressure, mainly of large scale deforestation and encroachment of the reserve forestland. The enhancement of *Melastoma malabathricum*, *Mimosa pudica*, cereals and Brassicaceae indicate the forest clearance affecting forest wealth and wildlife habitation. Thus, the generated pollen database from surface soil coheres with the extant vegetation of Subhankhata reserve forest, Assam and will be significant in the interpretation of past vegetation and climate change in this region through pollen sequences with corresponding radiocarbon dates.

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