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Vegetation vis á vis climate change around Bhogdoi swamp in lower Brahmaputra flood plain of Assam, Northeast India since Late Holocene

SWATI DIXIT* AND S.K. BERA

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.
**Corresponding author: swatidixit26@gmail.com*

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ABSTRACT

Dixit S & Bera SK 2013. Vegetation vis á vis climate change around Bhogdoi swamp in lower Brahmaputra flood plain of Assam, Northeast India since Late Holocene. The Palaeobotanist 62(1): 19–27.

Pollen records from 1.8 m deep sedimentary profile cored from Bhogdoi swamp, Kamrup District, lower Brahmaputra flood plain of Assam, Northeast India have revealed enrichment of tropical mixed deciduous forest elements including *Shorea robusta*, *Syzygium cumini*, *Dillenia pentagyna* and *Acacia catechu* indicating warm and humid climatic regime during 3,795–2,530 years BP. Subsequently during 2,530–680 years BP relative increment in proliferation of tropical mixed deciduous elements namely *Lagerstroemia parviflora*, *Lannea coromandelica*, *Terminalia bellirica*, Sapotaceae and *Emblica officinalis* occurred resulting into final settlement of tropical mixed deciduous forest under increased warm and humid climatic regime attributable to active Southwest Monsoon. However, from 680 years BP onward gradual deterioration of mixed deciduous forest occurred as evidenced by sudden decline in Sal and its associates under warm and relatively drier climate. Drastic increment in *Melastoma*, *Ziziphus* and *Areca* implying forest clearance at this phase. The occurrence of degraded pollen–spore along with adequate fungal remains especially *Xylaria*, *Diplodia*, *Nigrospora* and Microthyriaceous fruiting body is suggestive of aerobic microbial digenesis of rich organic debris during sedimentation.

Key–words—Palynology, Late Holocene sediment, Flood plain, Assam.

विलंबित होलोसीन से असम, पूर्वोत्तर भारत से अधःब्रह्मपुत्र बाढ़ के मैदान भोगडोइ दलदल के चारों ओर वनस्पति बनाम जलवायु परिवर्तन

स्वाति दीक्षित एवं एस.के. बेरा

सारांश

भोगडोइ दलदल, जनपद कामरूप, अधःब्रह्मपुत्र असम बाढ़ के मैदान, पूर्वोत्तर भारत में क्रोडित 1.8 मीटर गहरी अवसादी परिच्छेदिका से प्राप्त पराग अभिलेखों से 3,795–2,530 वर्षों पूर्व के दौरान कोष्ण एवं आर्द्र जलवायवी प्रवृत्ति इंगित करते हुए *शोरिया रोबस्टा, सायज़ीजियम, कुमिनि, डिल्लेनिया, पेंटागायना* और *एकासिया कटेचु* सन्निहित उष्णकटिबंधीय मिश्रित पतझड़ी वन तत्वों के संवर्धन मिले हैं। इसके अनुगामी 2,530–680 वर्षों पूर्व के दौरान उष्णकटिबंधीय मिश्रित पतझड़ी तत्वों नामतः *लेजरस्ट्रोमिया पर्विफ्लोरा, लन्निया कोरोमंडेलिका, टर्मिनेलिया बेल्लिरिका,* सपोटेसी एवं *एम्बिलिका ऑफीसिनेलिस* के क्रमप्रसरण में सापेक्षिक वृद्धि हुई परिणामतः सक्रिय दक्षिण पश्चिम मानसून को उत्तरदायी वृद्धित कोष्ण एवं आर्द्र जलवायु प्रवृत्ति के अंतर्गत उष्णकटिबंधीय मिश्रित पतझड़ी वन का अंतिम स्थिरीकरण हुआ। फिर भी, 680 वर्षों पूर्व से मिश्रित पतझड़ी वन का अल्प ह्वास हुआ जैसा कि कोष्ण एवं सापेक्षतया शुष्कतर जलवायु के अंतर्गत साल एवं इसके सहयोगियों ने आकस्मिक अवनति से प्रमाणित है। इस प्रावस्था में *मेलास्टोमा, ज़िज़ीफस* एवं *ऐरिका* में प्रबल वृद्धि वनोन्मूलन बयां कर रही है। पर्याप्त कवक अवशेषों विशेषतया *जायलेरिया, डिप्लोडिया, निग्रोस्पोरा* एवं माइक्रोथायरीसियस फलन काय सहित निम्नकोटिकृत पराग बीजाणु की प्राप्ति अवसादन के दौरान प्रचुर कार्बनिक कचरा के वाई जी बी सूक्ष्मजैविक पीढ़ी एकांतरण को सुझावित है।

संकेत-शब्द—परागाणुविज्ञान, विलंबित होलोसीन अवसाद, बाढ़ के मैदान, असम।

INTRODUCTION

Pollen and spores form the basis of an important aspect of palaeoclimatic reconstruction. Accumulated pollen and spores preserve a record of past vegetation of an area which may have changed with climate. Pollen and spores analysis may lead to strong inferences about the past climate (Bradley, 1985) and have great role to reflect the vegetation due to their extreme resistant sporoderm and high production with wide distribution.

Late Holocene (3,795 yrs BP onwards) development and history of tropical mixed deciduous forests distributed in lower Brahmaputra flood plain of Assam have not received any attention, except a few scattered publications from Upper Assam, Mikir Hills and lower Assam (Bhattacharya & Chanda, 1982, 1992; Bhattacharya *et al*., 1986; Bera, 2003; Bera & Dixit, 2010; Dixit & Bera, 2011). Here, based on pollen proxy records, an attempt has been made to deduce the succession stages involved in the development of tropical mixed deciduous forest under different climatic regimes since Late Holocene through the investigation of a sedimentary profile cored from Bhogdoi swamp, Kamrup District, lower Brahmaputra flood plain of Assam, Lat. 26°10'12.6" N, Long. 91°29'28.7" E (Fig. 1). This is the first comprehensive study regarding development of tropical mixed deciduous forest vis à vis climatic changes since Late Holocene in Northeast India.

The present communication also aims at finding signals of global climatic events like Medieval Warm Period and Little Ice Age in this climatically sensitive region. It is well established that the climate during the Holocene is unstable (Bond *et al*., 1997; Mayewski *et al*., 2004). However, the regulation of climate change, regional characteristics, abrupt

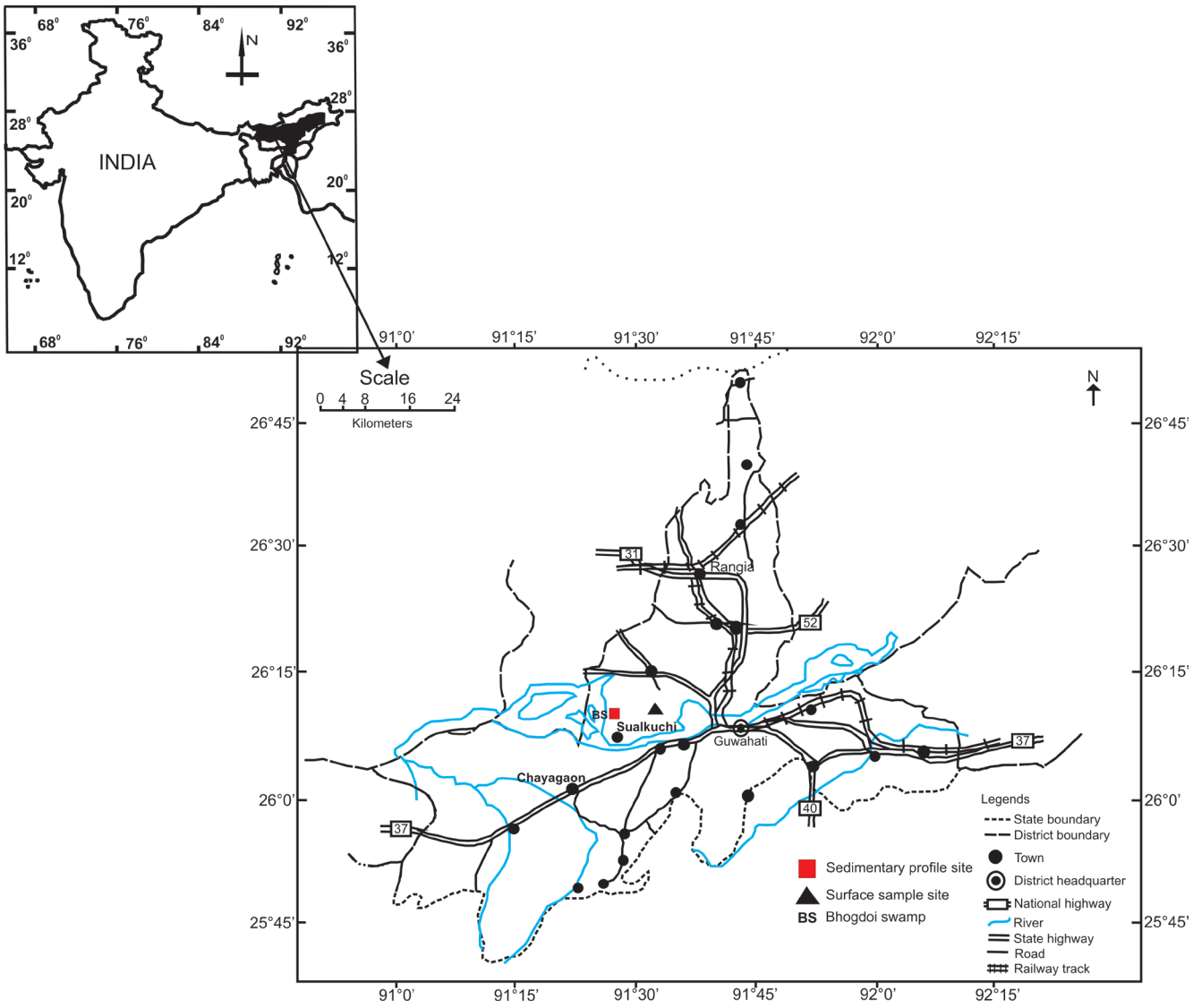

Fig. 1—District map of Kamrup, Assam showing sampling site.

change and its relation to human activities are also not clear (Street–Perott & Perott, 1990; Lamb *et al*., 1995). But it is strongly suggested from our study that acceleration in human activities is one of the factors for the abrupt change in climate from increased warm and humid to warm and relatively dry since 680 years BP.

STUDY SITE

Bhogdoi swamp is situated at Sualkuchi Block of Kamrup District, about 35 km west of Guwahati City, Assam. The swamp is part of north Kamrup reserve forest, lower Brahmaputra flood plain of Assam and largely composed of grasses, Cyperaceae (sedges) with other terrestrial and marshy herbs and ferns interspersed with scattered tropical mixed deciduous arboreals. Grasses including both non–cereal (wild grass) and cereal (crop plant) along with Brassicaceae, *Plantago erosa*, *Jussiaea suffruticosa*, *Ludwigia adscedens*, *Polygonum serrulatum*, *P. plebeium*, Ranunculaceae, *Polygala chinensis*, *Costus speciosus*, *Colocasia esculenta*, *Rumex acetosella* and *Impatiens balsamina* luxuriantly grow as the major plant taxa at the swampy area. Aquatic vegetation in the swamp consists of both Angiosperms and a few Pteridophytes namely *Nymphoides indica*, *Potamogeton pectinatus*, *Nymphaea nouchali*, *N. alba*, *Typha latifolia*, *Trapa bispinosa*, *Lemna minor*, *Eichhornia crassipes*, *Utricularia flexuosa*, *U. exoieta*, *Spirodela polyrhiza*, *Wolffia arrhiza*, *Nelumbo nucifera*, *Myriophyllum indicum*, *Ceratopteris thalictroides*, *Marsilea minuta*, *Pistia stratiotes*, *Salvinia oblongifolia* and *Azolla pinnata* respectively. *Cyathea gigantea*, *Adiantum phillippense*, *Polypodium heracleum*, *Selaginella biformis*, *S. ciliaris*, *Angiopteris evecta*, *Dryopteris filix–mas*, *Pteris stenophylla*, *P. vittata*, *P. quadriaurita*, *Diplazium esculentum* and *Blechnum orientale* are the common Pteridophytic taxa occurring along the periphery of the swamp.

Major tree taxa such as *Terminalia bellirica*, *Dillenia pentagyna*, *Artocarpus integrifolia*, *Syzygium cumini*, *Lannea coromandelica*, *Salmalia malabaricum*, *Alstonia scholaris*, *Emblica officinalis*, *Semecarpus anacardium*, *Acacia catechu*, *Albizia lebbeck* and a few species of Arecaceae are scarcely distributed. Shrubby plants such as *Melastoma malabathricum*, *Ziziphus mauritiana*, *Desmodium laxiflorum*, *Holarrhena pubescens*, *Grewia hirsuta*, *Strobilanthes scaber*, *Justicia adhatoda*, *Evolvulus nummularius* and *Jasminum sambac* form bushy stands around the swamp at places. Some characteristic grasses of the riparian areas are *Saccharum, Anthisteria, Erianthus, Arundo* and *Phragmites* covering vast tracts along with Amaranthaceae, *Chenopodium album*, *Majus japonicus*, *Justicia simplex*, *Crotolaria juncea* and *Sida rhombifolia*. Unique combination of bamboos, viz. *Dendrocalamus hamiltonii*, *D. gigantea*, *Bambusa bambos*, *B. balcooa*, *B. nutans*, *B. pallida* and *Melocanna bambusoides* are also scatteredly growing at places around the swamp.

SOIL AND CLIMATE

The soil of the study area is characterized by recent deposition of alluvium, moderately deep to very deep with grey to mottled grey colour. It is mostly composed of sandy to silty loams and slightly acidic in nature. On the riverbanks, it is less acidic and sometimes neutral or slightly alkaline. The soil lack in profile development and is deficient in phosphoric

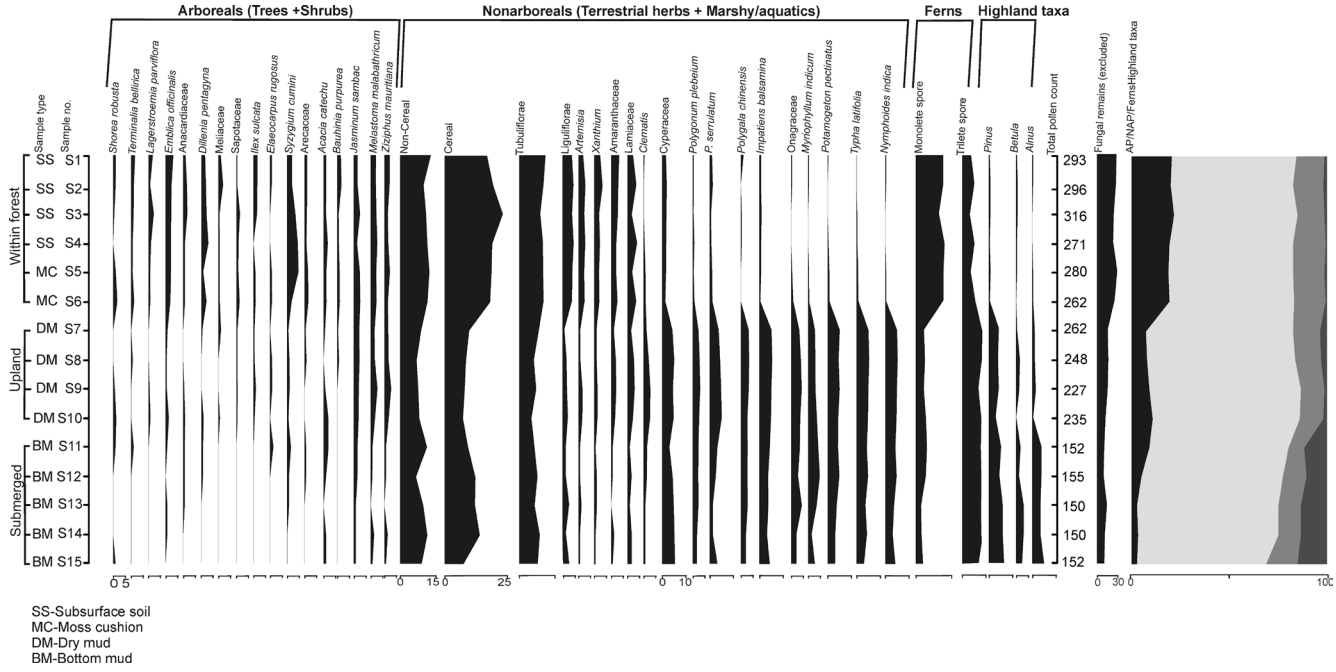

Fig. 2—Pollen spectra around Bhogdoi swamp, lower Brahmaputra flood plain of Assam.

acid, nitrogen and humus (Karunakaran, 1974). The climate in the District is subtropical with semi–dry summers and cold winters. Rain makes its first appearance in the month of April with occasional and irregular light showers and at times becoming heavy downpour followed by cyclonic storm. The irregular rainfall continues up to the end of May, due to the influence of northeastern winds. Annual rainfall ranges between 1500 to 2600 mm. About 80% rainfall comes from Southwest Monsoon. The maximum temperature attains 38°C during July and August and the minimum temperature dips down to 7°C in the month of January. Floods occur generally in the low lying areas of the district during May to August every year. Late floods during the later part of September and October also occur. The occurrence of floods in the district is due to the river Brahmaputra and its tributaries.

MATERIAL AND METHODS

In the present study samples from both surface and sedimentary profile were collected. A set of samples including Subsurface Soil (SS), Moss Cushion (MC), Dry Mud (DM) and Bottom Mud (BM) were procured along north to south from within forest, across open land comprising upland and submerged area of Bhogdoi swamp. Total 15 samples numbering S 1 to S 15 were collected. The surface samples S 1 to S 6 were collected from within forest, S 7 to S 10 from upland area and S 11 to S 15 from submerged part of the swamp respectively at a distance of about 500 m each to study modern/pollen vegetation relationship in and around the study site.

Total 18 samples from a 1.8 m deep sedimentary profile were collected for pollen analysis of which three samples were chosen for radiocarbon dating. The C–14 dating was carried out at the radiocarbon lab of Birbal Sahni Institute of Palaeobotany, Lucknow. The sediment was manually cleaned, sieved and carbonate free sediment was combusted in the continuous flow of oxygen and resulting carbon dioxide was collected and converted to acetylene and then benzene using standard catalyst and procedures. The counting was done in a Liquid Scintillation Counter (Quantulus 1220). Based on the three C–14 dates, i.e. 3,795 ± 170 yrs BP at 180 cm, 2,530 ± 90 yrs BP at 110 cm and 680 ± 90 at 40 cm, the sedimentation rate is determined to 0.05 cm/year at 0–40 cm, 0.04 cm/year at 40–110 and 110–180 cm. Sediments were chemically processed using standard acetolysis method for palynological studies and 150–380 pollen and spores per sample were counted (Erdtman, 1954). Grasses (Poaceae) in the text are categorized into non–cereal (wild grass) with pollen < 60 µm and cereal (crop plant) with pollen > 60 µm. Pollen spectra and diagram was made using Microsoft Excel Worksheet which was modified in CoralDraw–12 software programme (Figs 2 & 3). Plant elements in the pollen spectra and diagram have been categorized into arboreals (trees and shrubs), nonarboreals (terrestrial herbs and marshy/aquatics), ferns and highland taxa. Fungal remains were excluded from pollen sum to interpret pollen spectra and diagram. Photodocumentation of

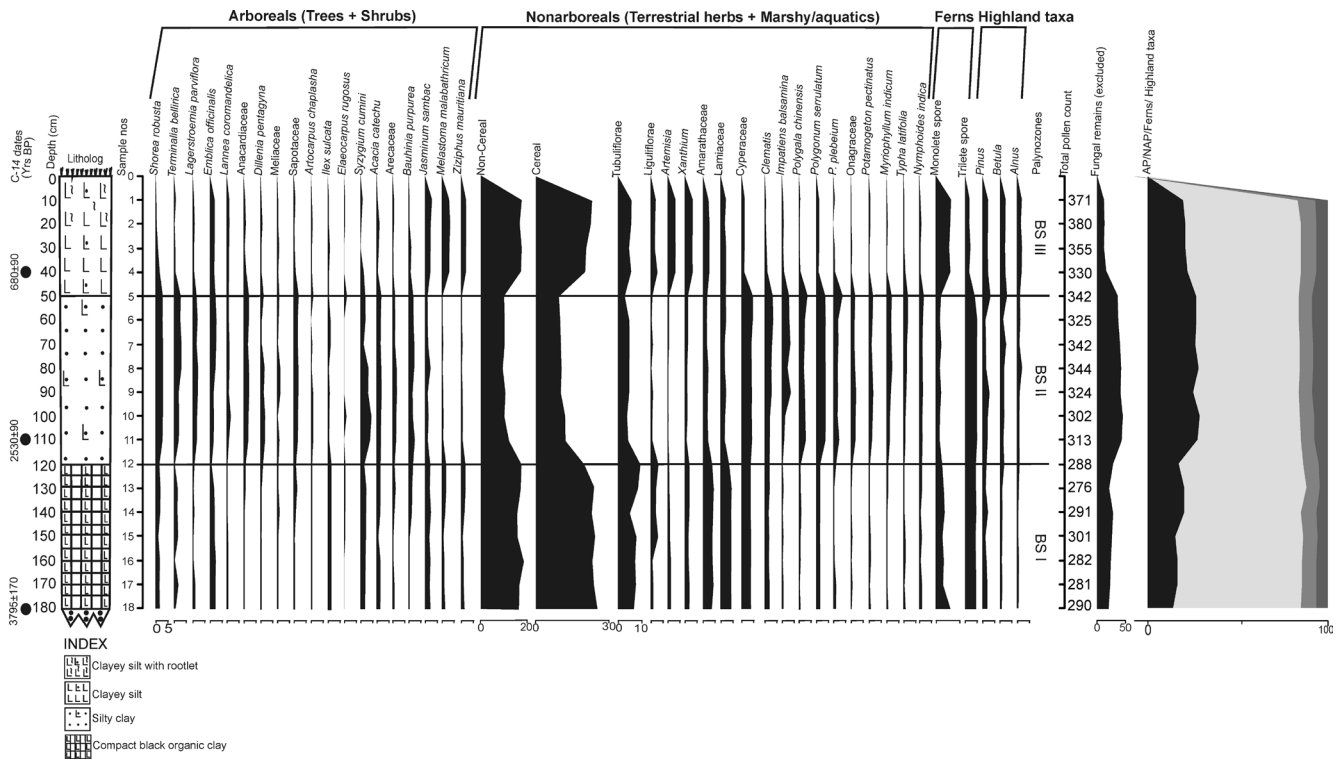

Fig. 3—Pollen diagram from Bhogdoi swamp, lower Brahmaputra flood plain of Assam.

palynomorphs were done using Olympus BX 61 Microscope with DP–25 camera (Pl. 1). The sediment composition of the core exhibits the presence of clay, silt and organic matter in variable fractions.

DESCRIPTION OF POLLEN SPECTRA

To establish modern/pollen vegetation relationship in and around the study sites, surface samples were analyzed for differential pollen dispersal and sedimentation. Detailed values of pollen data recovered from variable substrates within forest to open land area (upland and submerged) are described below:

Pollen spectra (within forest)

Sample nos.–S 1–4 (SS) and S 5–6 (MC)—Palynological studies of subsurface soil and moss cushion show that an average value of nonarboreal taxa (64.85%) is dominant over arboreal taxa (20.03%), ferns (13.97%) and highland taxa (1.15%). Among nonarboreals, grasses dominate with cereals (20.17%) and non–cereals (13.35%) with a combined value of 33.52% followed by other terrestrial herbs like Tubuliflorae (9.33%), Liguliflorae (4.02%), *Xanthium* (2.79%), Amaranthaceae (2.72%), Lamiaceae (2.63%) and *Artemisia* (2.62%) in moderately high values. Marshy taxa include Cyperaceae (1.45%) followed by *Clematis*, *Polygonum serrulatum*, *P. plebeium*, *Polygala chinensis*, Onagraceae and *Impatiens balsamina* in trace values. *Myriophyllum indicum*, *Potamogeton pectinatus*, *Typha latifolia* and *Nymphoides indica* are represented sporadically as aquatic taxa in the assemblage. Among ferns, monolete (10.00%) and trilete spores (3.97%) are encountered in high to moderate values respectively.

Among arboreals, tree species are represented by moderate values of *Syzygium cumini* (2.56%) and *Emblica officinalis* (2.32%) followed by *Dillenia pentagyna* (1.69%), *Lagerstroemia parviflora* (1.31%), Anacardiaceae (1.14%) and Arecaceae (1.11%) at lower values. However, *Shorea robusta* associated with *Terminalia bellirica*, Meliaceae, Sapotaceae and *Acacia catechu* are recorded in sporadic values. Semi evergreen taxa are represented by *Ilex sulcata* and *Elaeocarpus rugosus* in sporadic values. Prominent shrubby taxa are represented by *Melastoma malabathricum* (2.22%), *Jasminum sambac* (1.99%) and *Ziziphus mauritiana* (1.85%) in moderate values, whereas, *Bauhinia purpurea* (1.22%) occurs in low value. Highland taxa are represented by *Pinus*, *Betula* and *Alnus* in sporadic values. Fungal remains are represented as most of the grass pathogen including *Xylaria*, *Alternaria*, *Diplodia*, *Glomus, Cookeina*, *Curvularia* and Microthyriaceous fruiting body.

Pollen spectra (upland area)

Sample nos.–S 7–10 (DM)—Palynological studies of dry mud samples show that an average value of nonarboreal taxa (74.88%) is dominant over arboreal taxa (9.00%), ferns (10.70%) and highland taxa (5.42%). Among nonarboreals, grasses include both cereals (8.80%) and non–Cereals (9.14%) with a combined value of 17.94%. Other prominent terrestrial herbs include a high value of Tubuliflorae (6.14%) together with low values of Amaranthaceae and Lamiaceae (1.77% each), Liguliflorae (1.57%), *Xanthium* (1.45%) and *Artemisia* (1.26%) in lower values. Marshy taxa including *Impatiens balsamina* (5.35%), *Polygonum serrulatum* (4.55%), Cyperaceae (4.12%), Onagraceae (3.51%), *Polygonum plebeium* (3.10%) and *Polygala chinensis* (2.98%) are observed in moderately high values. Aquatic taxa comprise *Typha latifolia* and *Nymphoides indica* (5.35% each), *Potamogeton pectinatus* (5.04%) and *Myriophyllum indicum* (2.44%) in higher values. Among ferns, monolete (3.00%) and trilete spores (7.70%) are encountered in moderate to higher values respectively.

Among arboreals, tree species are sporadic and are represented by *Syzygium cumini, Emblica officinalis*, *Dillenia pentagyna*, *Lagerstroemia parviflora*, Anacardiaceae, *Shorea robusta*, *Terminalia bellirica*, Meliaceae, Sapotaceae, Arecaceae and *Acacia catechu* along with scarce presence of semi evergreen tree taxa like *Ilex sulcata* and *Elaeocarpus rugosus*. Among prominent shrubs, *Melastoma malabathricum*, *Bauhinia purpurea*, *Jasminum sambac* and *Ziziphus mauritiana* are encountered with almost same values of 1.87%, 1.85% and 1.82% respectively. Highland taxa are represented by *Pinus* (3.42%) with *Betula* and *Alnus* in lower values of 1.00% each. Fungal remains are represented in fairly good values.

Pollen spectra (submerged area)

Sample nos.–S 11–15 (BM)—Palynological studies of bottom mud samples show that an average value of nonarboreal taxa (68.00%) is dominant over arboreal taxa (6.61%), ferns (12.72%) and highland taxa (12.67%). Among nonarboreals, grasses include cereals (11.60%) and non–cereals (11.22%) with a combined value of 22.82%. Prominent terrestrial herbs comprise high value of Tubuliflorae (6.85%) along with low values of Liguliflorae (1.85%) and Lamiaceae (1.05%). However, Amaranthaceae, *Xanthium* and *Artemisia* are sporadic. Marshy taxa such as Cyperaceae (4.88%), *Impatiens balsamina* (4.08%) and Onagraceae (2.77%) are encountered in moderately higher values. *Polygonum serrulatum*, *P. plebeium* and *Polygala chinensis* (2.37% each) are observed in moderate values. Aquatic taxa are represented by *Typha latifolia* and *Nymphoides indica* (4.34% each), *Potamogeton pectinatus* (4.08%) and *Myriophyllum indicum* (3.15%) in high values. Among ferns, monolete (3.36%) and trilete spores (9.36%) are also recorded in moderate to higher values respectively.

Among arboreals, tree species such as *Syzygium cumini*, *Emblica officinalis*, *Dillenia pentagyna*, *Lagerstroemia parviflora*, Anacardiaceae, *Shorea robusta*, Meliaceae, Sapotaceae and *Acacia catechu* are sporadically represented along with

scarce presence of semi evergreen tree taxa like *Ilex sulcata* and *Elaeocarpus rugosus*. Among prominent shrubs, *Melastoma malabathricum*, *Bauhinia purpurea*, *Jasminum sambac* and *Ziziphus mauritiana* are sporadically represented. Highland taxa are represented by *Pinus* (5.55%), *Alnus* (4.61%) and *Betula* (2.51%) in moderately higher values. Fungal remains are fairly represented in the assemblage.

DESCRIPTION OF POLLEN DIAGRAM

To understand the vegetation and climate succession, three pollen zones have been recognised in the pollen diagram (Fig. 3). Each pollen zone is prefixed by BS after the name of the Bhogdoi swamp from where the soil profile has been analysed (Faegri & Iverson, 1989). These pollen zones are described below separately:

Pollen zone BS I (180–120 cm; 3,795–2,530 years BP): Grasses–Tubuliflorae–Amaranthaceae–Syzygium–Emblica–Cyperaceae–Ferns–Highland taxa assemblage—The compact black organic clay phase is characterized by the dominance of nonarboreals at the average value of 70.92% over arboreals (16.15%), ferns (7.56%) and highland taxa (5.37%). Among nonarboreals, grasses both cereals (23.81%) and non–cereals (17.69%) with a combined value of 41.50% are dominant over other terrestrial herbs like Tubuliflorae (7.67%), Lamiaceae (3.92%), Amaranthaceae (3.88%) in moderately high values along with low values of Liguliflorae (1.88%), *Xanthium* (1.65%) and *Artemisia* (1.10%). Marshy taxa like Cyperaceae, *Clematis* and *Polygonum serrulatum* are observed at the tune of 3.24%, 1.99% and 1.15% respectively. *Polygonum plebeium, Polygala,* Onagraceae and *Impatiens balsamina* are sporadic. Aquatic taxa, viz. *Nymphoides indica, Potamogeton pectinatus, Myriophyllum indicum* and *Typha latifolia* are encountered sporadically in the assemblage. Ferns are encountered as monolete (2.59%) and trilete spores (4.97%) in moderately good values.

Among the major tree taxa, *Syzygium cumini* (1.89%) along with other tree taxa like *Emblica officinalis* (1.59%), *Shorea robusta* (1.40%), *Acacia catechu* (1.20%) and *Terminalia bellirica* (1.09%) are encountered in lower values. Other deciduous arboreals like Meliaceae, Anacardiaceae, *Lagerstroemia parviflora*, *Lannea coromandelica*, *Dillenia pentagyna* and Arecaceae are found scattered. Semievergreen tree taxa like *Ilex sulcata* (1.35%) is found in low value along with sporadic *Artocarpus chaplasha* and *Elaeocarpus rugosus*. Prominent shrubs like *Jasminum sambac* dominate with the moderate frequency of 2.24% followed by *Melastoma malabathricum* (1.30%) and *Ziziphus mauritiana* (1.28%) in lower values, while *Bauhinia purpurea* is sporadic. Highland taxa like *Pinus, Betula* and *Alnus* are encountered with a steady frequency of 5.37%. Fungal remains are represented by Microthyriaceae, *Nigrospora*, *Alternaria*, *Cookeina*, *Diplodia* and *Xylaria* in moderate values.

Pollen zone BS II (120–50 cm; 2,530–680 years BP): Grasses–Cyperaceae–Shorea–Lagerstroemia–Polygonum–Impatiens–Myriophyllum–Ferns–Highland taxa assemblage—The silty clay phase is characterized by the predominance of nonarboreals at the average value of 65.03% over arboreals (21.42%), ferns (6.97%) and highland taxa (6.58%). The major nonarboreals are represented by grasses including both cereals (11.20%) and non–cereals (10.93%) with a combined value of 22.13%. Other terrestrial herbs like Tubuliflorae (3.42%), Lamiaceae (2.44%), Amaranthaceae (2.27%) are found in moderate values whereas, *Xanthium* (1.00%) is observed in lower value. Other major herbaceous taxa such as *Artemisia* and Liguliflorae are sporadic. Marshy taxa like Cyperaceae (4.21%), *Polygonum serrulatum* (3.39%), *Clematis* (3.00%), *Impatiens* (2.71%), *Polygala chinensis* (2.62%), *Polygonum plebeium* (2.10%) and Onagraceae (1.79%) are observed in highly improved value than preceding phase. Among aquatics, *Myriophyllum indicum* predominates with moderate value of 2.24% along with *Potamogeton pectinatus*

PLATE 1

Palynoassemblage recovered from sediments of Bhogdoi swamp, Assam.

1. *Syzygium cumini*
2. *Lagerstroemia parviflora*
3. *Shorea robusta*
4. *Dillenia pentagyna*
5. *Mimusops elengi*
6. *Terminalia bellirica*
7. *Elaeocarpus rugosus*
8. *Ilex sulcata*
9. *Artocarpus chaplasha*
10. *Acacia catechu*
11. *A. oxyphylla*
12. *Pinus khasiana*
13. *Betula* sp.
14. *Alnus* sp.
15. *Melastoma malabathricum*
16. Oleaceae
17. Non–cereal (Poaceae)
18. Cereal (Poaceae)
19. Tubuliflorae
20. *Sonchus asper*
21. *Artemisia parviflora*
22. *Alternanthera sessilis*
23. *Chenopodium album*
24. Cyperaceae
25. Ranunculaceae
26. *Woodwardia* sp.
27. *Cyathea* sp.
28. Ascospore of *Cookeina* sp.
29. *Xylaria* sp.
30. *Glomus* sp.
31. Microthyriaceous fruiting body.

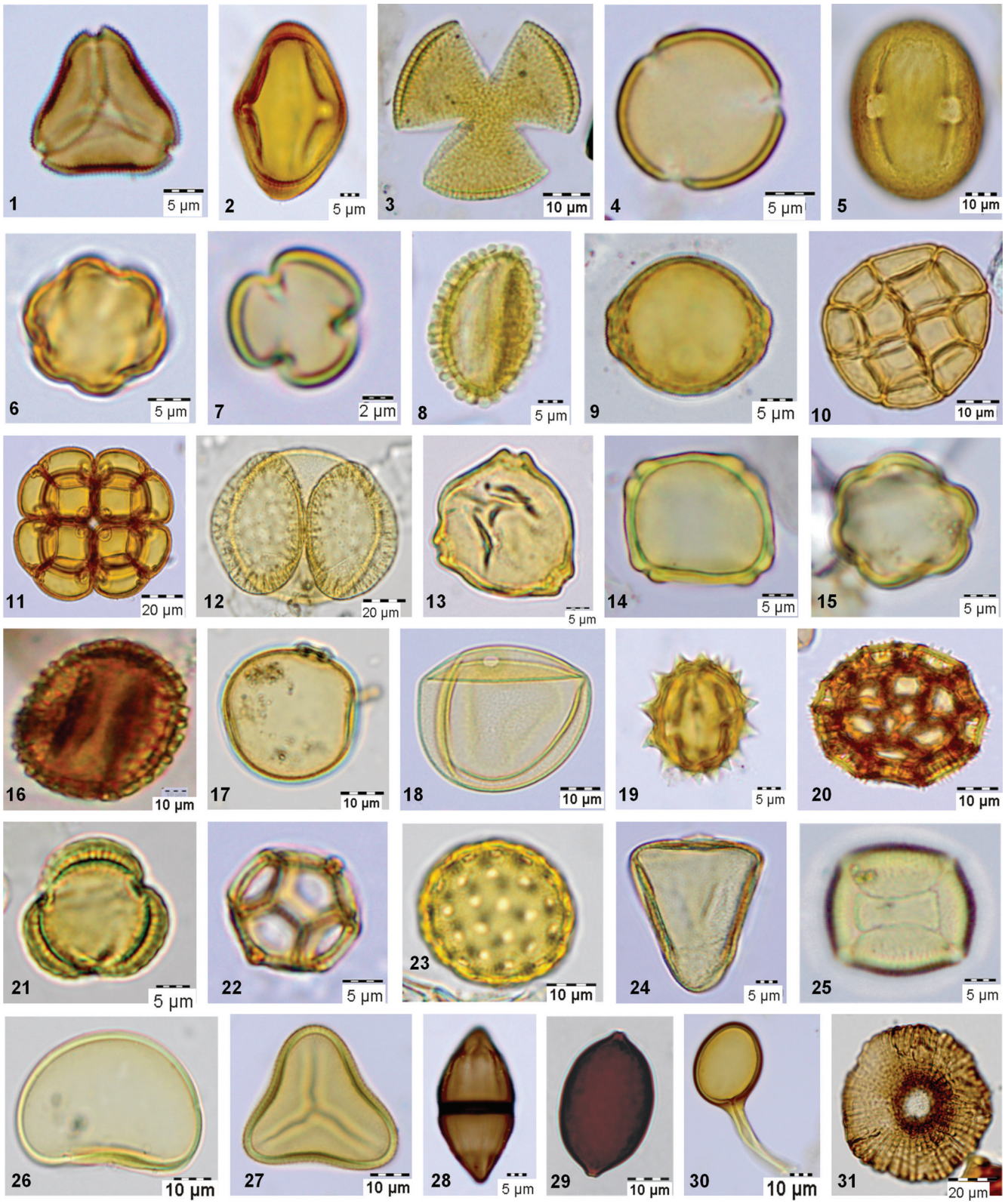
1
5 µm
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PLATE 1

(1.52%), *Nymphoides indica* (1.09%) and *Typha latifolia* (1.08%) in lower values. Among ferns, both monolete (1.97%) and trilete spores (5.00%) are represented in moderate values.

Among the major tree taxa, *Syzygium cumini* (2.56%), *Shorea robusta* (2.50%), *Terminalia bellirica* (2.38%) and *Emblica officinalis* (2.12%) are found in moderate values along with low values of *Lagerstroemia parviflora* (1.85%), Anacardiaceae (1.75%), *Acacia catechu* (1.66%), Sapotaceae (1.35%), Arecaceae (1.18%), *Dillenia pentagyna* (1.14%) and *Lannea coromandelica* (1.00%). However, Meliaceae occur in traces. Semievergreen tree taxa like *Ilex sulcata*, *Artocarpus chaplasha* and *Elaeocarpus rugosus* are observed in lesser values than preceding phase. Shrubby taxa like *Bauhinia purpurea* (1.57%) and *Jasminum sambac* (1.31%) are found in lower values along with sporadic *Melastoma malabathricum* and *Ziziphus mauritiana*. Highland taxa like *Pinus, Betula* and *Alnus* are encountered consistently with higher frequency of 6.58%. Fungal remains are encountered in high values.

Pollen zone BS III (50–0 cm; 680 years BP onward): Grasses–Tubuliflorae–Xanthium–Emblica–Lannea–Melastoma–Ferns–Highland taxa assemblage—The clayey silt with rootlet phase is characterized by the predominance of nonarboreals at the average value of 66.14% over arboreals (15.68%), ferns (8.27%) and highland taxa (9.91%). Among nonarboreals, grasses both cereals (22.17%) and non–cereals (18.60%) with a combined value of 40.77% are dominated over other terrestrial herbs like Tubuliflorae (5.11%), *Xanthium* (3.67%), *Artemisia* (3.34%), Amaranthaceae (2.63%) and Liguliflorae (2.28%) in moderately high values along with low value of Lamiaceae (1.57%). Marshy taxa are represented by Cyperaceae (1.22%) and *Polygonum serrulatum* (1.01%) in lower values. However, *Polygala chinensis, Polygonum plebeium*, Onagraceae and *Impatiens balsamina* are sporadic. Aquatic taxa like *Potamogeton pectinatus, Nymphoides indica, Myriophyllum indicum* and *Typha latifolia* are also sporadically represented. Among ferns, monolete (6.60%) and trilete spores (1.67%) are recovered in high to low value respectively.

Among the major tree taxa, *Emblica officinalis* (2.23%) is found moderately along with low value of *Lannea coromandelica* (1.45%). Other associated tree taxa like *Syzygium cumini, Terminalia bellirica*, *Shorea robusta*, *Acacia catechu, Lagerstroemia parviflora,* Anacardiaceae, Arecaceae, *Dillenia pentagyna*, Sapotaceae and Meliaceae are encountered in trace values. Semi evergreen tree taxa like *Artocarpus chaplasha*, *Ilex sulcata* and *Elaeocarpus rugosus* also occur in trace values. The prominent shrubby taxa are represented by *Melastoma malabathricum* (2.50%), *Jasminum sambac* (2.17%) and *Ziziphus mauritiana* (2.00%) in moderate values along with sporadic *Bauhinia purpurea*. Highland taxa like *Pinus, Betula* and *Alnus* are encountered consistently in higher values (9.91%). Fungal remains are encountered in relatively low values.

DISCUSSION AND CONCLUSIONS

1. Evaluation of pollen and spores recovered from surface samples has reflected the existence of factual forest composition of arboreals in the woody confines of the study area but their frequency dwindles in the samples away from the forest. The special feature indicates under–representation of *Shorea robusta* as a dominant ingredient of the forest which could be attributed to poor preservation of its pollen in sediments despite its high pollen productivity (Bera, 1990). However, the erratic representation of other arboreals could be attributed to low pollen productivity owing to prevalence of entomophilly (e.g. *Salmalia* and *Dillenia* sp.). Pollen rain in open land area show relative reduction in arboreals in contrast to the woods. However, grasses and other heathland taxa attain higher frequency than those of forest. Ferns are represented constantly in and in the outskirts of the forest.

Open land samples reveal noticeable increase in nonarboreals as compared to arboreals which is directly proportional to the distance from forest outskirt/edges. Frequency of both ferns and fungal remains has not been given so much of importance because of its local origin despite their presence causing humid climate. However, impact of highland taxa signify the long distance pollen transport by upthermic wind and/or water courses from upper reaches.

2. The pollen records from Bhogdoi sedimentary sequence have demonstrated three phases of development of tropical mixed deciduous forest under coetaneous climatic changes in lower Brahmaputra flood plain of Assam since Late Holocene. During 3,795–2,530 years BP, this region was in a state of enrichment of tropical mixed deciduous forest as evidenced by fair value of deciduous element including *Shorea robusta*, *Dillenia pentagyna*, *Syzygium cumini* and *Acacia catechu* along with moderate marshy/aquatic elements, viz. Cyperaceae, *Polygonum*, *Polygala*, Onagraceae, *Impatiens*, *Clematis*, *Potamogeton*, *Nymphoides* and *Myriophyllum*, attributable to onset of Southwest monsoon under warm and humid climatic regime. Occurrence of fungal elements like Microthyriaceous fruiting body, *Glomus* and *Nigrospora* in fair amount support the climatic interpretation during this phase.

During 2,530–680 years BP, final settlement of tropical mixed deciduous forest has been witnessed by the invasion of Sal and its close associates like *Lannea coromandelica*, *Lagerstroemia parviflora*, *Salmalia malabaricum*, Sapotaceae and Anacardiaceae. Relative increment in fungal elements especially *Pleospora*, Microthyriaceous fruiting body, *Nigrospora*, *Cookeina*, *Alternaria*, *Diplodia* and *Xylaria* in the assemblage is attributable to increased Southwest Monsoon under increased warm and humid climatic regime corresponding to the Medieval Warm Period (Anderson *et al*., 2002). With the inception of a relatively drier climate owing to reduction in monsoon precipitation, around 680 years BP onwards, the gradual reduction in typical mixed deciduous elements was

noticed. This period of harsh climate partly falls within the temporal range of LIA too, which is recorded at global level between AD 1450 and 1850 (Lamb, 1977; Bradley, 1985; Grove, 1988).

This relative dryness observed through palynoassemblages recovered may also be attributed to clearance of forest through anthropogenic activities appearing as Jhuming, Lumbering and Pasturing in lower Brahmaputra reserve forest area which presently poses a serious threat for biodiversity conservation. Increase in cereal pollen with other ruderal element like Tubuliflorae, *Xanthium*, Lamiaceae, Amaranthaceae, Acanthaceae and *Artemisia* hints persistent pastoral activity. It is important to note that the coincidence of the advent of monsoon rainfall becomes a crucial and decisive factor for the regeneration and proliferation of main constituent of tropical mixed deciduous in the Indian subcontinent, especially in northeastern flood plains.

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