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Studies on pollen deposition pattern in relation to modern vegetation of flood prone region in Assam, India

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ABSTRACT

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This paper presents a palynological dataset on Pashumara Wetland and Ranga Reserve Forest to differentiate flooded and non–flooded area in relation to existing vegetation in Assam. Study reveals that the palynoassemblage in Pashumara Wetland is an admixture of arboreal local and extra–local taxa and not fully matches with present vegetation. The various pollen distributions were observed in continuation to study sites and confirmed that pollen deposition pattern in wetland depends on parent plant growth, flood activity and surrounding vegetation. Presence of broken pollen is indicative of long distance transportation under a fluvial environment. The palynoassemblage of Ranga Reserve Forest located in non–flooded area to display modern pollen and vegetation relationship and identification of local arboreal taxa in the region. The main forest elements include *Syzigium*, *Lagerstroemia* and *Emblica* in the palynoassemblage are suggestive of presence of tropical deciduous forest under warm and humid climate. Pollen clumps in the palynoassemblage signifies their local origin and entomophily. This generated palynodata could be precisely utilized to distinguish flooded and non–flooded area and to interpret palaeovegetation and past climate changes in relation to palaeoflood episodes by the analysis of wetland core from the region and to correlate other tropical flood prone region of the globe.

Key–words—Assam, Flood prone area, Modern pollen deposition, Palaeoecological reconstruction, Palaeoflood episodes, Pollen clumps.

भारत में असम के बाढ़ प्रवृत्त अंचल की आधुनिक वनस्पति के संबंध में पराग निक्षेपण प्ररूप पर अध्ययन

साधन कुमार बसुमतारी

सारांश

असम में व्याप्त वनस्पति के संबंध में बाढ़ग्रस्त और गैर–बाढ़ग्रस्त क्षेत्र में अंतर करने हेतु यह शोध–पत्र पशुमाड़ा आर्द्रभूमि तथा रंगा आरक्षित वन के आंकड़ा समुच्चय प्रस्तुत करता है। अध्ययन से पता चलता है कि पशुमाड़ा आर्द्रभूमि में परागाणु समुच्चय स्थानीय वृक्षीय व अतिरिक्त स्थानीय वर्गक का अधिमिश्रण है तथा विद्यमान वनस्पति से पूर्णतः मेल नहीं खाता। स्थलों के अध्ययन की निरंतरता में विविध पराग वितरण प्रेक्षित किए गए तथा पुष्टि हुई है कि आर्द्रभूमि में पराग निक्षेपण प्ररूप मूल पादप वृद्धि, बाढ़ गतिविधि और आस–पास की वनस्पति पर निर्भर करता है। छिन्न–भिन्न पराग की विद्यमानता नदीय पर्यावरण में लंबी दूरी परिवहन का द्योतक है। गैर–बाढ़ ग्रस्त क्षेत्र में स्थित रंगा आरक्षित वन का परागाणु समुच्चय अंचल में आधुनिक पराग एवं वनस्पति संबंधता तथा स्थानीय वृक्षीय वर्गक का अभिनिर्धारण प्रदर्शित करता है। परागाणु समुच्चय में *सायज़ीजियम, लेगरस्ट्रोमिया* एवं *एम्बलिका* सहित मुख्य वन तत्व कोष्ण और आर्द्र जलवायु के अंतर्गत उष्णकटिबंधीय पतझड़ी वन की मौजूदगी के सूचक हैं। परागाणु समुच्चय में पराग गुच्छे अपने स्थानीय उद्गम एवं कीट–पराग द्योतित करते हैं। बाढ़ग्रस्त एवं गैर–बाढ़ग्रस्त क्षेत्र में अंतर करने तथा पुरा बाढ़ घटनाओं के संबंध में पुरावनस्पति व गत जलवायु परिवर्तनों की व्याख्या अंचल से प्राप्त पृथ्वी के आर्द्रभूमि क्रोड के विश्लेषण तथा अन्य उष्णकटिबंधीय बाढ़ग्रस्त अंचल से संबंध जोड़ने को संक्षिप्त रूप से प्रयुक्त किया जा सकता है।

सूचक शब्द—असम, बाढ़ प्रवृत्त क्षेत्र, आधुनिक पराग निक्षेपण, पुरापारिस्थितिकीय पुनर्संरचना, पुराबाढ़ घटनाएं, पराग गुच्छ।

INTRODUCTION

ASSAM is the highest annual flood affected state in India. The District of North Lakhimpur located in the northeast part of Assam lies between the 26°48' and 27°53' N and 93°42' and 94°20' E and it is very rich of forest flora and fauna due to presence of large number of rivers, streams and wetlands (Fig. 1). Most of the rivers, namely Subansiri, Ranga and Dikrong originate from the Eastern Himalaya and running through the district to join mighty Brahmaputra River. During summer due to heavy rainfall large part of the state are flooded and directly affected the local peoples of the region. The Brahmaputra River is one of the largest tropical rivers in the world and the second largest river in terms of sediment load (1128 tones/km^2/yr) after the Yellow River of China (1403 tones/km^2/yr) (Goswami, 1985). Therefore, the region may be one of the best sites to study the palaeoecological reconstruction in relation to palaeoflood episodes and palaeomonsoon using pollen proxy. The study of modern pollen deposition in relation to existing vegetation is considered as one of the best ways for palaeoecological reconstruction (Bent & Wright, 1963; Janssen, 1967; Wright, 1967; Overpeck *et al*., 1985, Prentice, 1985; Bunting *et al*., 2004; Xu *et al*., 2005; Gosling *et al*., 2009). Some palynologists have carried out investigation between the surface and lake sediments samples to display the modern pollen and vegetation relationship (Davies *et al*., 1971; Luly, 1997; Birks & Seppa, 2004; Wilmshurst & McGlone, 2005; Zhao *et al*., 2009). Some preliminary palynological works have been carried out on surface samples from the different parts of the northeast India (Gupta & Sharma, 1985; Bera, 2000; Basumatary & Bera, 2007; Dixit & Bera, 2012; Bera *et al*., 2012, 2014; Basumatary *et al*., 2013, 2014). However, till today, no such information is available to differentiate the flooded and non–flooded areas based on the pollen proxy. Therefore, the main aim of this study is threefold (1) To understand the modern pollen depositional pattern in Pashumara Wetland (a flood prone wetland) and Ranga Reserve Forest (a non–flooded forest) in relation to existing vegetation. (2) To identify the local and extra–local arboreal pollen taxa in the region in relation to growing

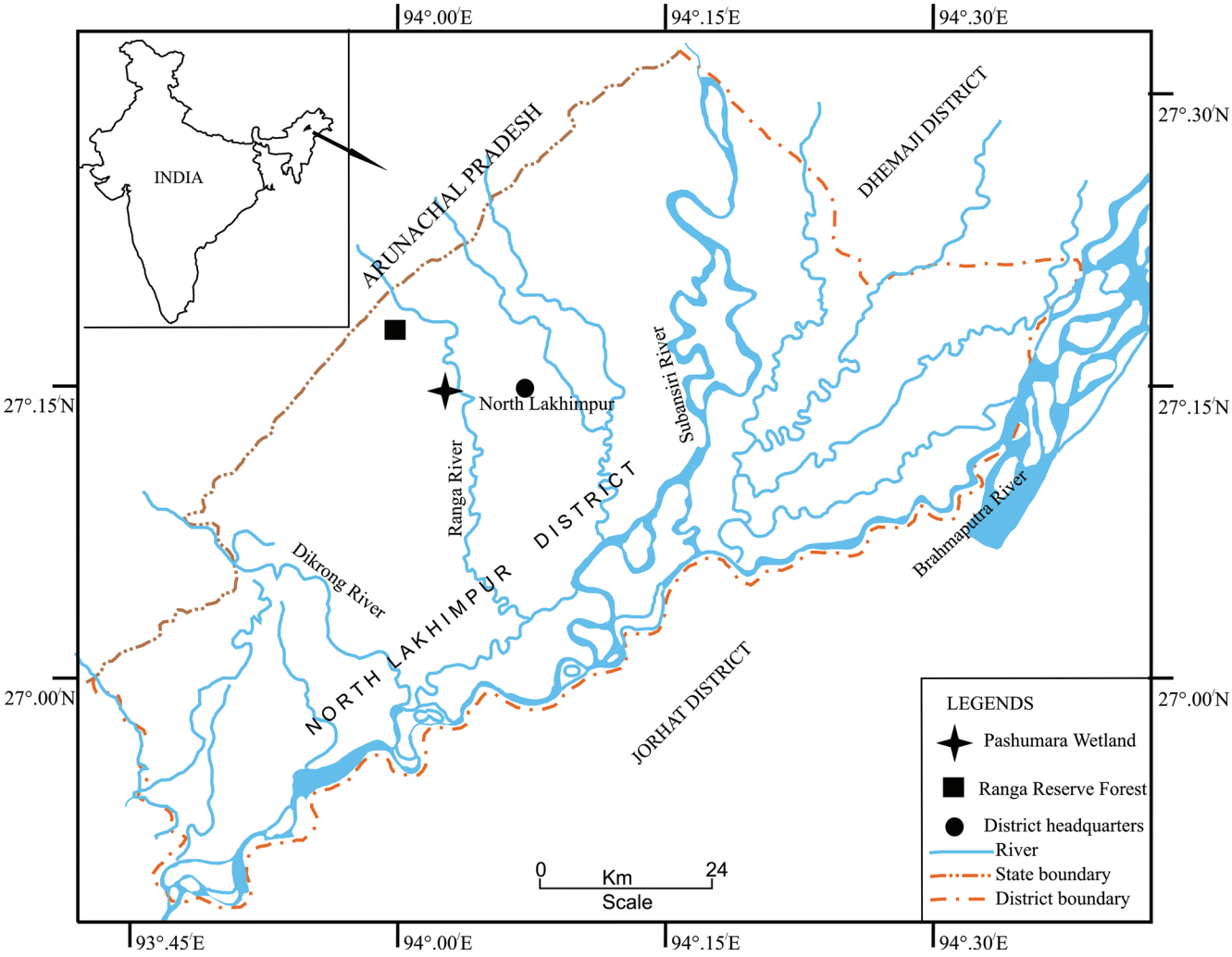


Fig. 1—Location map and showing of the study area.

vegetation within the Ranga Reserve Forest and openland closed to Pashumara Wetland. (3) To differentiate the flooded and non–flooded pollen assemblage.

CLIMATE AND SOIL

The climate of the study area is controlled by the southwest and northeast monsoons. In, general, the region experiences a warm and a very humid climate. Average maximum summer temperature is 31°C, however, it shoots up to 38°C during the hot months of May and June. The average maximum winter temperature recoded is 19°C. The temperature descends to 4°C during the cold months of December and January. The annual rainfall in the study region ranges from 2050 to 3252 mm. The relative humidity is generally very high, ranging from 77–95%. The soil of the wetland is alluvial fine loamy in nature formed from recent river deposits and the forest soil is fine loam sandy in nature and rich in organic matter.

STUDY SITE AND VEGETATION

The Pashumara Wetland (lat. 27°12' N and long. 94°02' E) and Ranga Reserve Forest (lat. 27°18' N and long. 93°58' E) are located in the North Lakhimpur District of Assam adjacent to the Papumpare District of Arunachal Pradesh (Fig. 1). The Ranga river is running near the wetland which originates from the Eastern Himalaya. During rainy season due to heavy rainfall, the Ranga river and other tributaries carry the massive water load and inundate the wetland and its vicinity. Generally during summer the wetland becomes wider due to heavy rainfall and during winter it gets smaller owing to low rainfall and dryness. However, the Ranga Reserve Forest (RRF) lies 10 kilometer distance towards the west of Pashumara Wetland which adjacent to the foothills of Arunachal Pradesh.

The vegetation of wetland is rich in diversity due to conservation by the local people. The central portion of the wetland is dominated by the *Nymphaea nouchali*, *Nymphoides*, *Trapa bispinosa*, *Lemna minor*, *Potamogeton pectinatus*, *Myriophyllum indicum* and *Eichhornia crassipes*. The margin of the wetland is dominated by *Polygonum orientale*, *Cyperus platystylis*, *Scirpus articulatus*, *Sagittaria segitifolia*, *Jussiaea repens*, *Costus speciosus* and *Ipomoea aquatica*. The migratory birds and fishes are also very rich in and around the wetland (Fig. 2 A). However, the wetland is surrounded by the crop field and very closed to the flowing Ranga river which repeatedly buried by the flood water in every year. The openland area adjacent to the wetland is composed of the sparsely growing deciduous trees such as *Terminalia bellirica*, *Salmalia malabarica*, *Syzygium cumini*, *Dillenia indica*, *Lagerstroemia parviflora*, *Albizia lebbeck* and *Emblica officinalis*. The shrubby elements are dominated by *Melastoma malabathricum*, *Clerodendron viscosum*, *Vitex negundo* and *Justicia adhatoda*. The ground vegetation is comprises mainly *Cynodon dactylon*, *Justicia simplex*, *Leucus aspera* and *Euphorbia hirta* along with scatter presence of fern allies, like *Dryopteris sylvestris*, *Adiantum philippense* and *Lycopodium cernuum*. The Ranga Reserve Forest is generally tropical deciduous type and is composed of *Terminalia billirica*, *Salmalia malabarica*, *Semecarpus anacardium*, *Sterculia villosa*, *Dillenia indica*, *Lagerstroemia speciosa*, *Careya arborea* and *Syzygium cumini*. The forest floor is rich in humus and often covered by grasses, associated with other herbs like *Euphorbia hirta*, *Curcuma aromitica*, *Evolvulus alsinoides*, *Boerhavia diffusa* and *Justicia simplex*. The emergent ferns largely of *Dryopteris chrysocoma*, *Lycopodium cernuum*, *Blechnum orientale*, *Gleichenia linearis*, *Lygodium japonicum*, *Pyrrosia lanceolata* and *Drynaria propinqua* are luxuriantly growing in the forest. Wood rooting fungi like *Agaricus campestris*, *Polyporus alveolaris* and *Polystictus versicolor* are conspicuously seen on fallen tree trunks and branches at places.

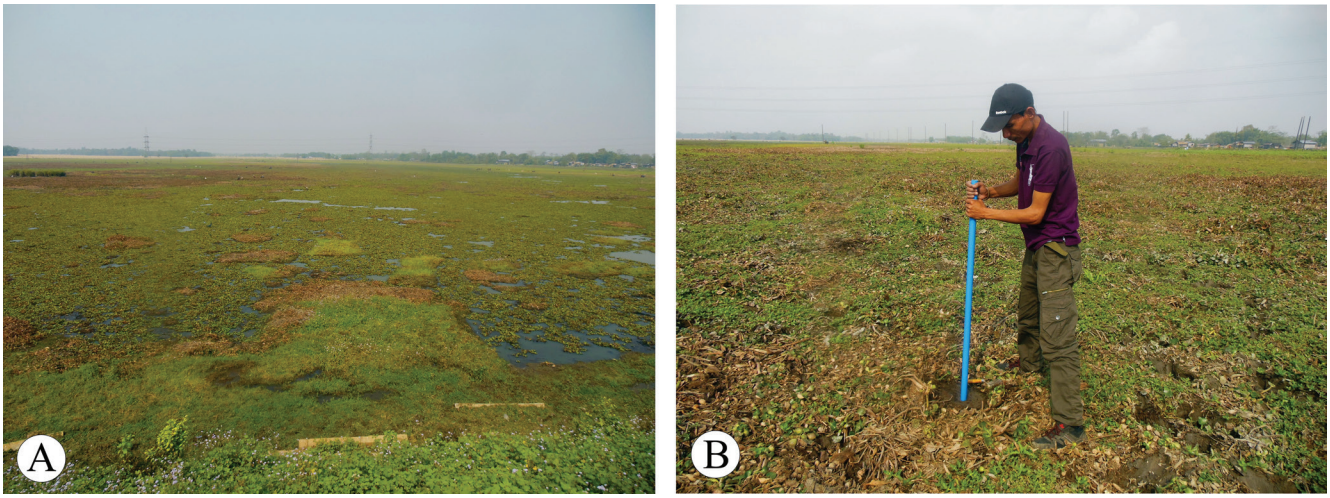


Fig. 2—A. View of a Pashumara Wetland, B. A field photo of sample collection by PVC pipe from the Wetland.

MATERIAL AND METHODS

Field work

The total number of 30 soil samples were procured selected in a linear transect at approximately 50 meter intervals from the central part towards the openland of the wetland. The 80 mm diameter PVC water pipe was push into the wetland bed and the upper 0.5 cm of sediment was procured for palynological investigation (Fig. 2 B). Out of 30 soil samples, systematically 6 (P1–P6) were collected from the openland adjacent to the Pashumara Wetland, 6 (P7–P12) from cropland, 6 (P13–P18) from the margin of the Wetland, 6 (P19–P24) from in between central part and margin, and 6 (P25–P30) from the central part of the Pashumara Wetland. A total of 10 (R1–R10) surface samples (soil and moss cushions) were also procured at approximately 100 meter intervals from inside of the Ranga Reserve Forest.

Laboratory work

The palynological samples (soil and moss cushions) were successively treated with 10% aqueous Potassium Hydroxide (KOH) solution to deflocculate the pollen and spores from sediments followed by 40% Hydrofluoric Acid (HF) to dissolve silica content. Thereafter, the conventional procedure of acetolysis (Erdtman 1953) was followed using acetolysis mixture (9: 1 anhydrous acetic acid and concentrated sulfuric acid). Finally the samples were prepared in 50% glycerol solution with a drop of phenol to protect the pollen and spore from microbial degradation. A total pollen sum of 250 to 300 was counted in each sample to make pollen spectra. The recovered taxa were categorized as arboreal local taxa (deciduous), arboreal extra–local taxa (evergreen and highland), nonarboreals, ferns and fungal remains. The distinction between arboreal local and extra–local taxa has been made based on the growing major tree taxa within forest and openland close of the Pashumara Wetland. For identification of fossil palynomorphs, I consulted the reference slides of Birbal Sahni Institute of Palaeosciences herbarium of India as well as published descriptions and photographs (Chauhan & Bera, 1990; Nayar, 1990; Bera *et al*., 2009). Observation of the palynomorphs was done using the Olympus BX–61 microscope under 40X magnification. Pollen frequencies were calculated from the total sum of palynomorphs including ferns and fungal remains.

RESULTS

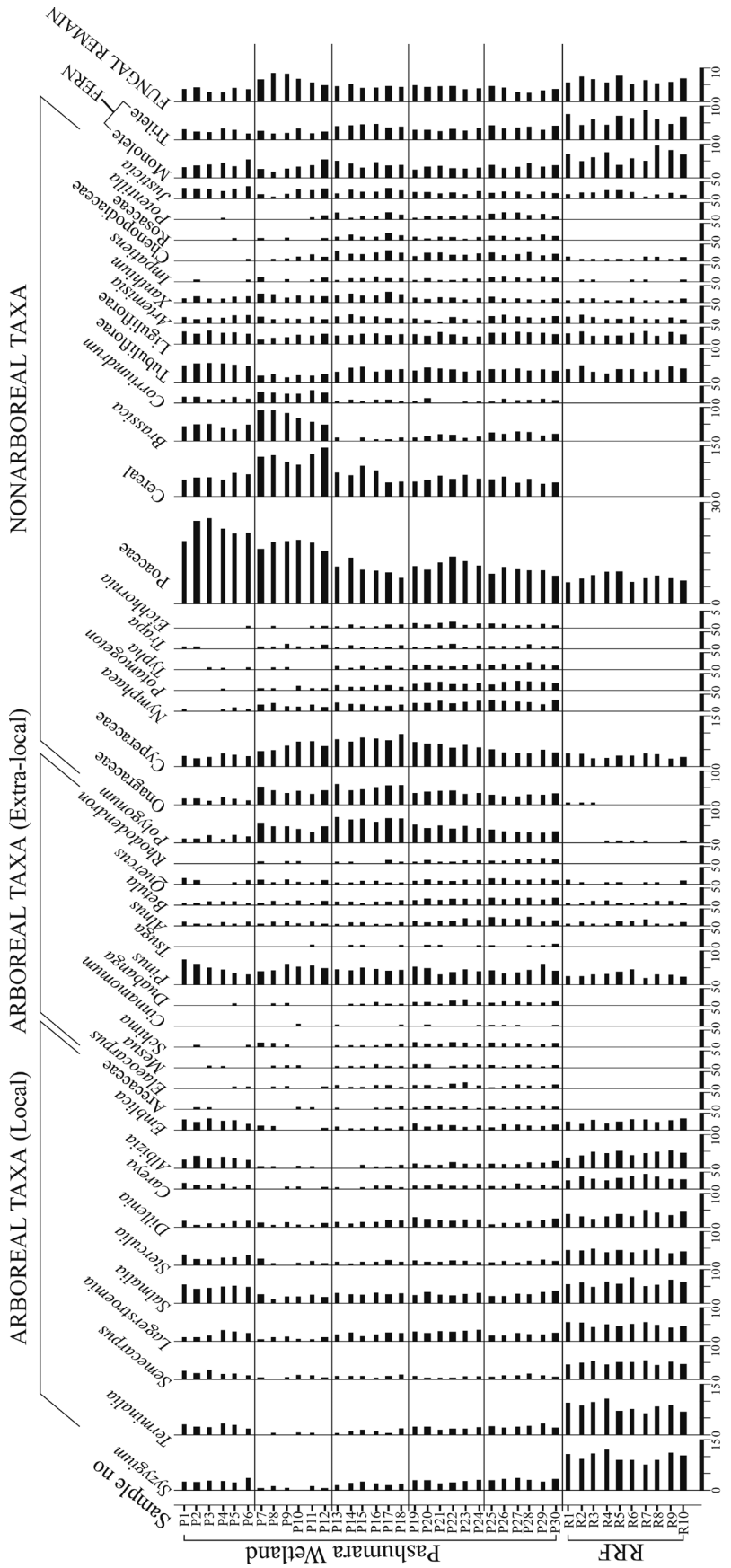
The pollen spectra of Pashumara Wetland and Ranga Reserve Forest are described separately below (Fig. 3).

Openland (P1–P6)—The palynoassemblage of the openland showed that the nonarboreals (56.6%) are dominant over arboreal taxa (33.3%). The ferns and fungal remains are exhibited at the value of 6.6% and 3.5% respectively. Among arboreals the local taxa such as *Salmalia*, *Lagerstroemia*, *Sterculia*, *Emblica* and *Albizia* are dominant at the value of 24.9% whereas the extra–local taxa, *Pinus*, *Betula* and *Quercus* are recorded at the value of 8.3%. Among nonarboreals the Poaceae is dominant and the other associates such as Tubuliflorae, Liguliflorae and *Justicia* are also consistently present in the palynoassemblage. However, the marshy taxa such as Cyperaceae, Polygonaceae and Onagraceae are recorded at the value of 6.4%. Aquatic taxa namely *Potamogeton*, *Nymphoides* and *Eichhornia* also exhibit at the value of 1.2% in the palynoassemblage.

Cropland soil sample ((P7–P12)—The pollen analysis of cropland soil sample shows the dominance of nonarboreals (69.8%) over arboreal taxa (17.9%). However, the ferns and fungal remains with exhibit at the value of 5.6% and 6.7% respectively. Among arboreals the extra–local taxa namely *Pinus*, *Betula*, *Alnus* and *Quercus* are recorded at the value of 10.0% and the local taxa such as *Salmalia*, *Emblica* and *Lagerstroemia* are met with at the value of 7.9%. Among nonarboreals the Poaceae along with other associates such as *Brassica*, *Coriandrum*, *Xanthium*, *Justicia* and Tubuliflorae are also consistently recovered in the palynoassemblage. However, the marshy taxa namely Cyperaceae, Polygonaceae and Onagraceae are encountered at the value 14.7%. Aquatic taxa such as *Nymphoides*, *Potamogeton* and *Eichhornia* are represented at the value of 3.7% in the palynoassemblage.

Swamp margin soil sample (P13–P18)—The pollen analysis shows that the nonarboreals (63.2%) are dominant over arboreal taxa (24.1%). Ferns and fungal remains depicts at the values of 18.2% and 4.5% respectively in the palynoassemblage. Among arboreals the local taxa such as *Salmalia*, *Lagerstroemia*, *Syzygium* and *Emblica* at the value of 13.5% followed by the extra–local taxa namely *Elaeocarpus*, *Mesua*, *Pinus* and *Rhododendron* occur at the value of 10.7%. Among nonarboreals the Poaceae is dominant and the other associates such as Liguliflorae, *Justicia* and *Xanthium* are also consistently present in the palynoassemblage. However, the marshy taxa, viz. Cyperaceae, Ranunculaceae, Onagraceae and *Polygonum* and aquatic elements such as *Trapa* and *Nymphoides* are represented with the values of 20.4% and 5.4% respectively.

Between central and margin soil sample (P19–P24)—The pollen assemblage of soil samples collected in between of the central and margin of wetland reveals that the nonarboreals (57.1%) are dominant over arboreal taxa (32.7%). However, the ferns and fungal remains are recovered at the values of 5.9% and 4.3% respectively. Among arboreals the local taxa such as *Terminalia*, *Salmalia*, *Lagerstroemia* and *Semecarpus* demonstrate at the value of 18.2% followed by the extra–local taxa namely *Mesua*, *Pinus*, *Quercus* and *Rhododendron* are recovered at the value of 14.5%. Among nonarboreals the Poaceae along with other associates such as Tubuliflorae, *Xanthium*, *Justicia*, *Impatiens* and Chenopodiaceae are also



P1-P6: Openland; P7-P12: Cropland; P13-P18: Margin; P19-P24: Between central and margin; P25-P30: Central;
R1-R10: RRF (Ranga Reserve Forest)

Fig. 3—Comparative pollen spectra from the different sites of Pashumara Wetland and Ranga Reserve Forest.

consistently depicted in the palynoassemblage. The marshy elements such as Cyperaceae and *Polygonum* and aquatic elements, viz. *Potamogeton*, *Nymphoides* and *Eichhornia* are represented at the values of 14.7% and 8.2% respectively in the palynoassemblage.

Central wetland soil sample (P25–P30)—The soil sample analysed from the central part of wetland demonstrate that the nonarboreals (54.8%) are dominant over arboreal taxa (34.5%). The ferns and fungal remains demonstrate the values of 7.2% and 3.5% respectively. Among arboreals the local taxa namely *Salmalia*, *Lagerstroemia*, *Careya*, *Dillenia* and *Syzygium* are encountered at the value of 18.4% followed by the extra–local taxa, *Schima*, *Elaeocarpus*, Arecaceae, *Pinus*, *Tsuga* and *Rhododendron* at the value of 16.6%. Among nonarboreals the Poaceae is dominant and the other associates such as Tubuliflorae, *Potentilla*, *Justicia*, Rosaceae and *Impatiens* are also continuously present in the palynoassemblage. However, the marshy taxa such as *Polygonum* and aquatic elements, viz. *Nymphoides*, *Potamogeton* and *Nymphaea* are represented with the values of 8.7% and 10.4% respectively in the palynoassemblage.

Ranga Reserve Forest (R1–R10)—The pollen analysis of forest surface samples (soil and moss cushion) showed that the arboreal taxa (57.6%) are dominant over nonarboreals (23.4%). The ferns and fungal remains portray the values of 12.7% and 6.3% respectively. Among arboreals the local taxa, namely *Salmalia*, *Terminalia*, *Syzygium*, *Semecarpus*, *Dillenia*, *Lagerstroemia* and *Albizia* are marked by the value of 52.3% and the extra–local taxa include *Pinus*, *Betula* and *Alnus* with the value of 5.3%. Among nonarboreals the Poaceae, Tubuliflorae, Liguliflorae and *Justicia* are consistently present in the palynoassemblage. However, the marshy taxa, Cyperaceae and *Polygonum* are represented with the value of 3.6% in the palynoassemblage.

DISCUSSION

Pollen distribution pattern in Pashumara Wetland

The palynoassemblage recovered from the central bottom soil samples of Pashumara Wetland with reveals that the diversity and frequency of the pollen and spores are relatively higher in comparison to the other studied sites (in between central and margin, margin, cropland and openland). Among arboreals the admixture of local and extra–local taxa, *Terminalia*, *Dillenia*, *Salmalia*, *Tsuga*, Arecaceae, *Elaeocarpus* and *Rhododendron* was marked and suggests that the main source of these pollen in the wetland sediments is the immediate vicinity from of study site as well as long distance transport from higher Himalaya through Ranga river during flood. Besides, among nonarboreals namely *Impatiens*, Rosaceae and *Potentilla* are also strongly indicative of the massive flood activity in and around the study area because these taxa are luxuriantly growing in higher Himalaya. However, the abundance of *Pinus*, *Betula* and *Alnus* with comparatively higher than the other extra–local taxa in the palynoassemblage may be due to the influence of strong wind activity and anemophilous (wind pollinated) nature of these taxa. The surface lake sediments accumulated pollen and spores cover a greater source area than surface soils and moss cushion (Wilmshurst & McGlone, 2005). However, the over representation of aquatic taxa namely *Nymphaea*, *Lemna*, *Nymphoides* and *Potamogeton* in the soil samples of central part in comparison to the other sites and the reason could be the proximity of the parent plants grow, deepness, and proper settlement in the wetland basin. However, pollen sedimentation is strongly influenced by pollen yield, blooming season, transport, and the distance between pollen sources and the lakeshore (Xiao *et al*., 2011). In between the margin and central part of the wetland the frequency and diversity of the pollen taxa were comparatively lower than the central site and the reason may be not suitable for proper sedimentation having a steep gradient of the transition zone. In the lake margin samples, the frequency of arboreals and aquatic taxa were comparatively lower than the central samples. The recovery of marshy taxa chiefly Cyperaceae, *Polygonum* and Onagraceae was marked in high values in comparison to the other sites. This could be due to proximity of the parent plant growing in the wetland. The pollen accumulation in the lake sediments depends on the size of lake basin, dispersal and depositional characteristic (Prentice, 1987; Sugita, 1993; Borstrom *et al*., 2008). In the cropland, the abundance of cereal pollen along with *Brassica* and Apiaceae in the palynoassemblage reflects the intensive crop cultivation by the local people. Similarly, the recovery of Poaceae (non cereal) along with other associates including *Justicia*, Tubuliflorae, *Xanthium* and Chenopodiaceae in the palynoassemblage is indicative of the seasonal dryness in the region. The consistence of marshy elements, Cyperaceae and Onagraceae along with aquatic taxa, namely *Eichhornia* and *Typha* were consistently represented in trace value in the palynoassemblage strongly implies the wider lake condition as well as river water overflow during flooding. The regular representation of local arboreal taxa such as *Salmalia*, *Dillenia* and *Albizia* in the palynoassemblage is marked and the reason probably due to inwash rain water from the nearby openland where all these taxa grow scantily. However, the recovery of arboreals extra–local taxa namely Arecaceae, *Mesua* and *Duabanga* along with *Cyathea* (tree fern) in the palynoassemblage is also strongly suggestive of the pollen deposition during overflow of flood water. Similarly, the strong flood activity was confirmed as evidenced by the presence of Arecaceae, *Schima*, *Rhododendron* and *Tsuga* chiefly in the palynoassemblage because these taxa grow luxuriantly in the upper eastern Himalayan region. The retrieval of fungal remains especially *Helminthosporium* and *Alternaria* suggests the open nature of vegetation as they are the common pathogens of herbaceous plants, particularly on grasses. The openland is characterized

by the dominance of nonarboreals over arboreals. Among nonarboreals the Poaceae is dominant and the other associates such as Tubuliflorae, Liguliflorae, *Xanthium* and *Justicia* are also consistently represented in the palynoassemblage. The consistent presence of arboreals such as *Terminalia*, *Syzygium* and *Lagerstroemia* in the palynoassemblage from Pashumara Wetland corresponds with their frequent occurrence in the local forest vegetation. The abundance of fern spores, especially *Dryopteris*, *Polypodium* and *Pteris* is significant and elucidates their origin from the local sources as all these taxa grow profusely under warm and humid climatic condition in and around the region.

Modern pollen deposition in Ranga Reserve Forest

The forest area is characterized by the over representation of the local arboreal taxa. The presence of local arboreal taxa chiefly *Terminalia*, *Syzygium*, *Dillenia*, *Semecarpus* and *Lagerstroemia* in the palynoassemblage is indicative of the presence of dense tropical deciduous forest under warm and humid condition in the region. However, the trace values of arboreal extra–local taxa, *Pinus*, *Betula* and *Alnus* in the palynoassemblage is suggestive of strong wind activity in and around the study area due to anemophilous nature. The flood control area has been identified as evidenced by the presence of remarkable local arboreal pollen taxa and absence of extra–local taxa especially *Rhododendron* and *Tsuga* pollen in the recovered palynoassemblage. The abundance of local arboreal taxa along with *Dendropthoe* and *Impatiens* is observed depicting the undisturbed forest and high rainfall receiving belt because these taxa are sensitive to forest disturbance and high rainfall. Among nonarboreals such as Poaceae, Tubuliflorae, Liguliflorae and *Justicia* are consistently represented in the palynoassemblage and are indicative of the rich ground forest vegetation. The very frequent presence of pollen clumpings in the forest surface samples clearly reflects for their local in origin. The pollen clumping is characteristic feature of entemophily plants which disperses in shorter distance than the solitary pollen grains (Faegri & van der Pijl, 1966; Martin *et al*., 2009). The presence of ferns such as *Lycopodium*, *Dryopteris* and *Pyrrosia* (epiphytic fern) in the palynoassemblage was

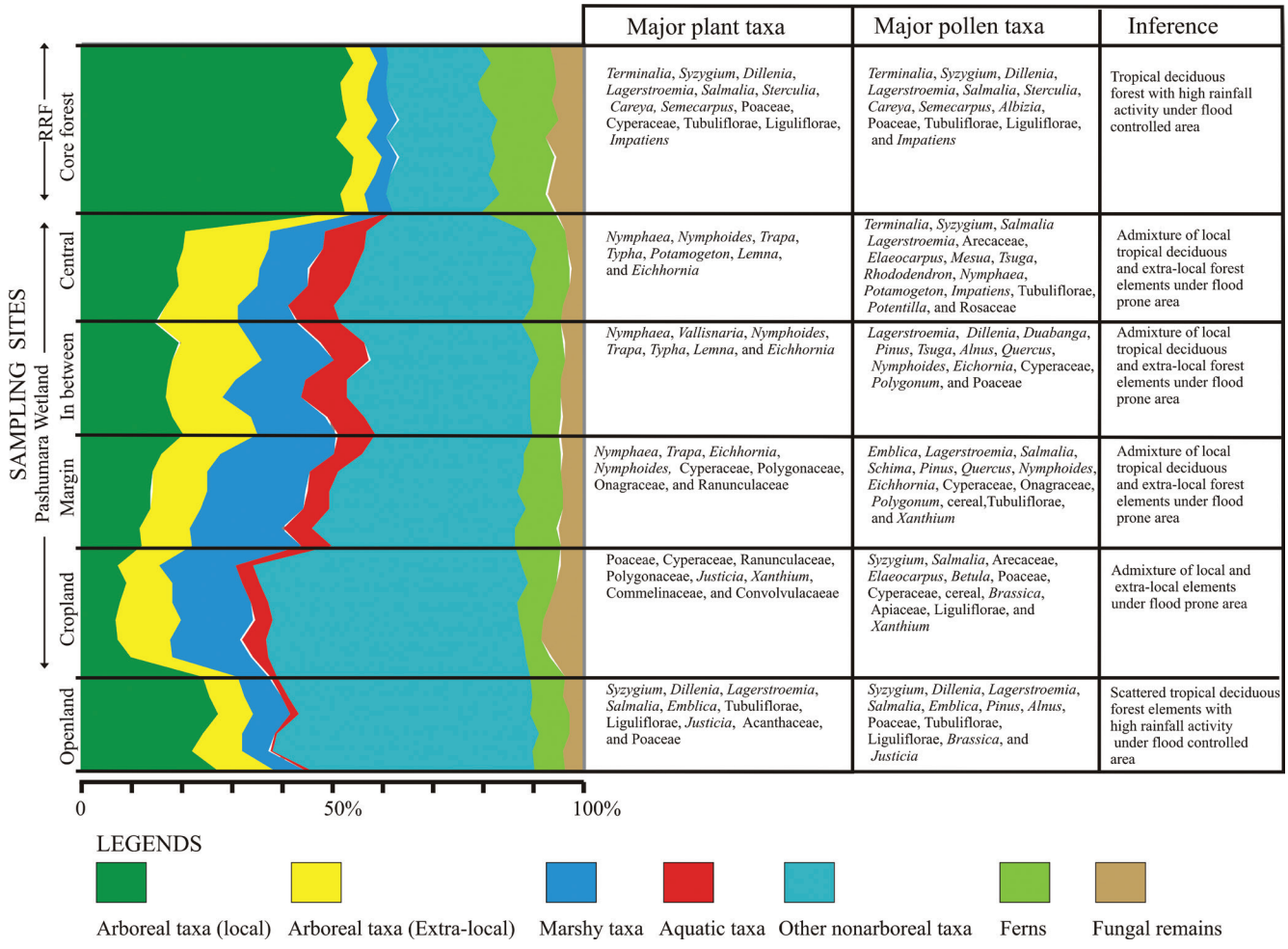


Fig. 4—The composite diagram in relation to the present vegetation and major pollen taxa and the inference in the Pashumara Wetland and Ranga Reserve Forest.

strongly indicative of the warm and humid condition in response to the high rainfall in the region. The record of fungal remains namely *Tetraploa*, Microthyriaceae, *Glomus* and *Cookeina* in the palynoassemblage implies the microbial decomposition during sedimentation.

The generated palynodata from the different sites of Pashumara Wetland is characterized by an experienced of frequent floods in the region as evidence by the admixture of the arboreal local and extra–local taxa in the palynoassemblage. The high values of *Rhododendron*, *Mesua* and Arecaceae along with *Cyathea* (tree fern) reflect numerous inputs during the flood water overflow of the Ranga river and also suggestive of the long distance water pollen transport. The frequent encounter of broken pollen and spore in the palynoassemblage denotes their long distance water transport in the region under high energy dispositional environment. The presence of *Duabanga* (a major tree of riparian forest) pollen signifies the proximity of riparian forest in and around the investigation site in eastern Himalaya. Similarly, the recovery of Arecaceae pollen in the palynoassemblage was significant and strongly suggestive of the palm forest in the Arunachal Pradesh which actually presents at least 200 kilometer distance from the study area. It is also observed that the river and streamlets originate from the eastern Himalaya and passes through the different vegetation types such as grassland, conifers, broad leaved and evergreen, and the rain water facilitates the surface pollen on the ground towards the northeastern India during flood time. The generated palynodata of the Ranga Reserve Forest display a good relationship between modern pollen and present vegetation. The abundance of local arboreal taxa and trace or absence of extra–local arboreal taxa especially *Rhododendron*, *Tsuga* and Arecaceae in the palynoassemblage is strongly suggestive of the non–flooded area in the region. The pollen composition diagram along with present vegetation corresponding to the major pollen taxa is given in the Fig. 4.

There are some differences between pollen percentages and diversity in the wetland and the forest surface samples: (i) The pollen diversity in wetland samples is comparatively higher than the forest surface samples, (ii) The frequency of local arboreal taxa is higher in the forest samples, (iii) Among arboreal, the extra–local taxa especially, *Elaeocarpus*, Arecaceae, *Tsuga* and *Rhododendron* are not present in the forest samples, and (iv) The pollen clumps were very common in the forest samples (v) The broken pollen and spores are very common in the wetland samples (vi) The fungal remains along with degraded palynomorphs are comparatively higher in the wetland samples.

CONCLUSIONS

The generated palynodata distinctly distinguish that the Pashumara Wetland is a flood prone area and the Ranga Reserve Forest comes under flood control area. Modern pollen assemblages from surface wetland sediments reflect the admixture of the local and extra–local taxa, and forest surface samples mainly display the local vegetation. It is also deduced that the pollen depositional pattern of Pashumara Wetland in different sites (central, margin, cropland and openland) depends on the proximity of the parent plant grow, flood and human activity. However, it is very important to note that the palynoassemblage from the forested and openland of nearby wetland should be considered for confirmation the local arboreal taxa, otherwise it would be mislead during interpretation of the wetland sedimentary soil profile in a region. Lastly, this study will be very helpful in interpreting the palaeovegetation and past climate changes in relation to monsoonal variability and palaeoflood episodes in such flood prone area of Assam and to correlate other tropical flood prone areas of the globe.

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