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Late Holocene vegetation and climate change in Loktak Lake region, Manipur, based on pollen and chemical evidence

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ABSTRACT

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The pollen and elemental analyses from a 73 cm deep sediment profile from Loktak Lake region, Manipur have provided insight into the changing vegetation and climatic scenario in the region during the Late Holocene. The investigation has revealed that between 1650 and 600 yr B.P., open vegetation comprising largely grasses and heathland taxa Asteraceae, Chenopodiaceae/Amaranthaceae, etc. with sprinkle of trees viz., *Holoptelea*, *Symplocos*, *Acacia*, etc. occurred in the region adjoining to the lake. The good profusion of ferns, fungal and algal remains as well as presence of aquatics implies that a humid climate prevailed in the region. The low C/N ratio also corroborates such climatic condition. The retrieval of Cerealia and other cultural pollen taxa denotes some sort of agricultural practice in the vicinity of the lake. From 600 yr B.P. to Present the expansion of open vegetation and a contemporary reduction of trees infer the inception of a less humid climate probably owing to reduction in monsoon precipitation. This is also evidenced by a sharp decline in ferns, fungal and aquatic elements. However, the agricultural practice continued with same pace, as before since the culture pollen taxa do not show any distinct alteration.

Key-words—Late Holocene, Loktak Lake, Pollen, Palaeoclimate, Sediments.

पराग एवं रासायनिक प्रमाण पर आधारित मणिपुर के लोकटक झील क्षेत्र में होलोसीन-अंत काल के वनस्पति एवं जलवायु परिवर्तन

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सारांश

मणिपुर के लोकटक झील क्षेत्र से प्राप्त एक 73 सेमी गहरी अवसाद परिच्छेदिका से प्राप्त पराग व रासायनिक अभिलेखों ने होलोसीन के अंतिम दौर में क्षेत्र में बदलते वानस्पतिक और जलवायवी परिदृश्य पर अंतर्दृष्टि प्रदान की है। अन्वेषण से खुलासा हुआ है कि 1650 वर्ष पूर्व एवं 600 वर्ष पूर्व के बीच झील के समीप के क्षेत्र में वृक्षों के छितराव अर्थात् *होलोप्टेली, सिंपलोकॉस, एकासिया* इत्यादि सहित खुली वनस्पति मुख्य रूप से घास एवं हीथलैंड टैक्सा ऐस्टेरासी, कीनोपोडिएसी/अमरेंथेसी इत्यादि पाई गईं। पर्णांग, कवक एवं शैवाल अवशेष के आधिक्य के साथ-साथ जलीयों की विद्यमानता संकेत देती है कि क्षेत्र में आर्द्र जलवायु थी। निम्न कार्बन/नाईट्रोजन अनुपात भी ऐसी जलवायु स्थिति को संपुष्ट करता है। सेरेलिया एवं अन्य 'कल्चर' परागाणु टैक्सा की

प्राप्ति झील के सान्निध्य में कृषि को इंगित करती है। 600 वर्ष पूर्व से वर्तमान तक खुले वनस्पति के प्रसार एवं वृक्षों की समकालीन कमी संभवतः मानसून वर्षण में कमी जनित कम आर्द्र/शुष्क जलवायु के आरंभ को अनुमानित करती है। यह पर्णांग, कवक एवं जलीय तत्वों में तेजी से अवनति द्वारा भी सुस्पष्ट है। फिर भी, कृषि पूर्व की भाँति जारी रही क्योंकि 'कल्चर' परागाणुओं में कोई विशिष्ट परिवर्तन नहीं दिखता।

संकेत-शब्द—होलोसीन, लोकटक झील, पराग, पुराजलवायु, अवसाद।

INTRODUCTION

Northeastern region of India, which abounds with diversified tropical forests, has hitherto not received adequate attention concerning the floristic antiquity and the climatic changes this region has experienced during the Quaternary Period, despite the presence of a large number of potential lakes/swamps for palaeoclimatic investigation. Some reports are available for the Quaternary of Digboi (Gupta, 1971; Bhattacharya & Chanda, 1982) and Tinsukia (Bhattacharya *et al*., 1986), upper Assam and Tripura (Goswami, 1981), but the Manipur region has remained almost untouched from the Quaternary palaeoclimatic viewpoint except for a brief report from Loktak Lake (Roy & Chanda, 1987), based on pollen evidence. In the present communication an attempt has been made to reconstruct the short-term climatic variability and contemporary vegetation as well as the impact of anthropogenic activities in the region through the pollen and chemical analyses of a small sediment profile from the Loktak Lake. The palaeoclimate study becomes significant in view of its potential as base on which to build climate change models (Nautiyal & Chauhan, 2003).

Loktak Lake is a tear-drop-shaped natural freshwater lake in Manipur, with irregular boundary line and is situated at about 93°46' to 93°55' E and 24°25' to 24°42' N (Fig. 1). This is the biggest freshwater lake in that region with an area of about 47 sq km during dry and about 247 sq km during rainy season. Its depth varies from 0.5 to 4.58 m with the average being 2.7 m (Manihar, 1999). The lake is situated in the basin about 52 km south of Imphal. This may be considered a sub-basin of the basin of the Manipur river, which flows along the basin-slope to south. The lake stands at an altitude of about 767 m above sea level. It is flanked by lineaments on both sides. It is recognized as a wetland of international importance under Ramsar Convention of 1990. The lake has close to 700 huts on the floating islands called phumdis and they are inhabited by 4000 people and also sangai, the brow antlered deer. We have used the lake-shore-trench-samples as archive of the past climate of that area, carrying out pollen and elemental (carbon, nitrogen and others) analyses. The idea was to reconstruct the past vegetation and climate of the region as reflected in the pollen assemblage, carbon, and nitrogen concentrations.

At present, the valley experiences a sub-tropical to temperate climate with an annual rainfall of 1392 mm in the lake area and 150 rainy days on average. The water-inflow from rains and Manipur river system contributes one half with the streams from the western catchments making the other half. Relative Humidity is usually in the range of 51 to 81%. The highest is in August and the lowest (40%) in March. The average wind velocity is 2 to 5 km per hour. The temperature can vary from a minimum of 0°C during winter to the maximum of 36°C during summer. However, the climate is sub-alpine at higher altitude (Manihar, 1999; Trisal & Manihar, 2000).

MATERIAL AND METHOD

Seven samples were picked up from 73 cm deep trench dug out at the southern-eastern shore of Loktak Lake from 2-8 cm, 13-17 cm, 20-24 cm, 28-33 cm, 43-47 cm, 57-63 cm and 70-73 cm depths, for pollen, chemical analyses and dating. The topsoil is sandy and then there is dominantly reddish clay up to 57 cm depth. There is a dark band between 57 cm and 63 cm depth, while the deepest sample (70-73 cm) is yellowish clay.

The samples not being very rich in carbon, out of the 4 samples tried, only one sample yielded sufficient

carbon to enable dating by C-14 method on benzene prepared from the samples and using a Liquid Scintillation Counter at BSIP. The calibrated C-14 age of 498 (+23, -175) years B.P. for 20-24 cm deep sample, when linearly extrapolated to a depth of 73 cm, makes the deepest sample about 1650 year old.

The pollen of trees, herbs, and shrubs along with fungal remains and fungi were separated from the sediments by maceration and identified and counted following standard techniques and methods (Erdtman, 1943; Chauhan, 2000). The pollen sums range from 150 to 200 depending upon pollen potential of the samples. The pollen of aquatic plants and spores of ferns and fungi have been excluded from the pollen sums owing to their origin from local sources. The percentages of the recovered pollen taxa have been calculated in

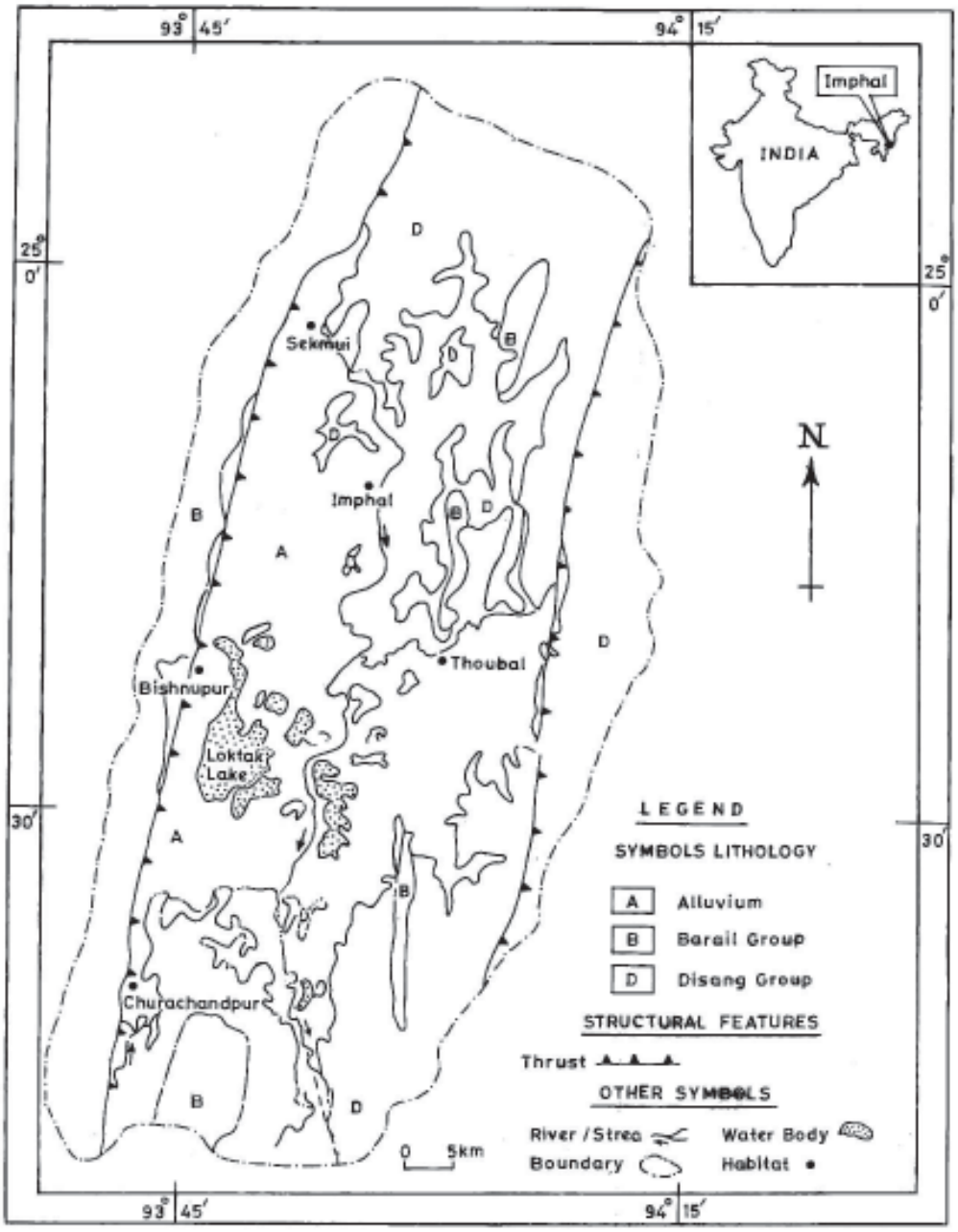

Fig. 1—Map showing Loktak Lake in Imphal Valley, Manipur.

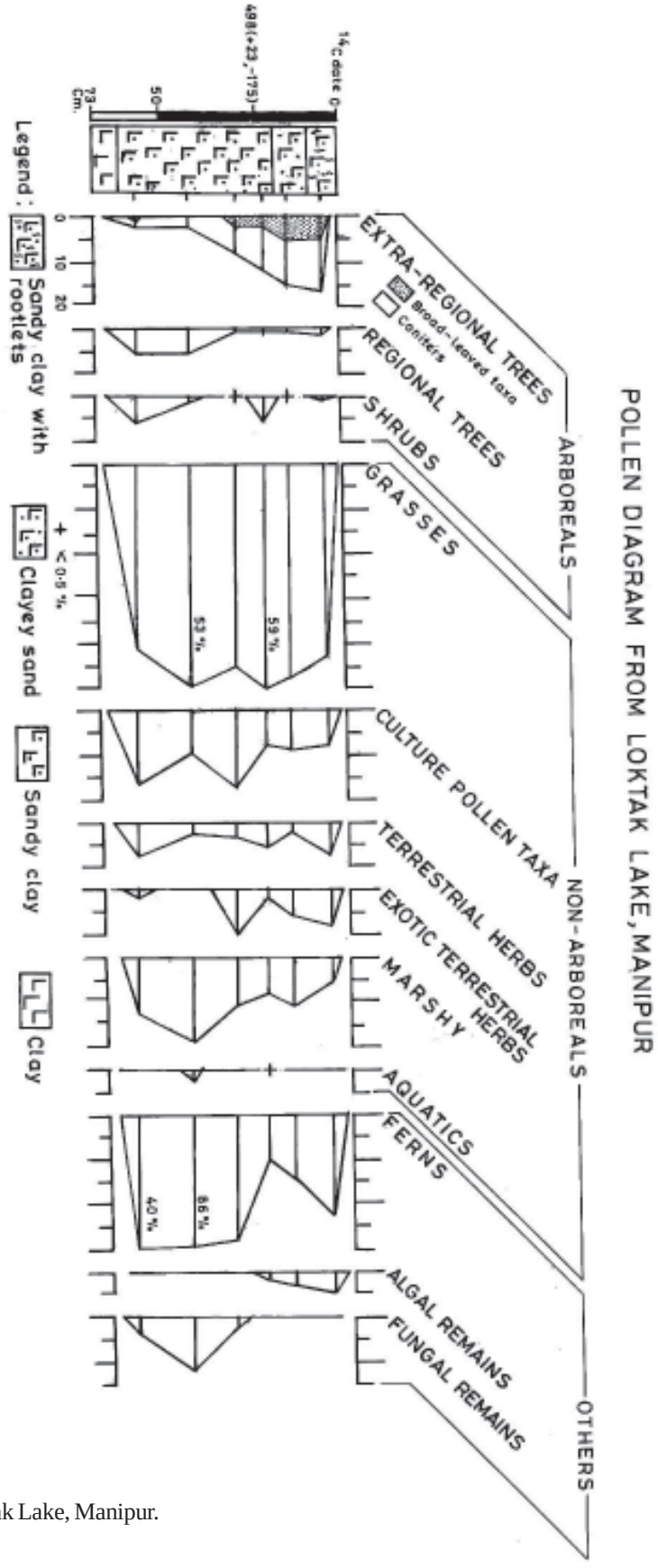

Fig. 2—Pollen Diagram Loktak Lake, Manipur.

Arboreals	Non-arboreals	Others
Extra-regional trees *Pinus*, *Alnus*, *Betula*, *Corylus*, *Carpinus*, *Quercus* **Regional trees** *Acacia*, *Lagerstroemia*, Sapotaceae, *Symplocos*, *Holoptelea*, Meliaceae **Shrubs** *Grewia*, *Aspidopterys*, Oleaceae, Fabaceae, Rutaceae	**Terrestrial herbs** Poaceae, *Alternanthera*, Caryophyllaceae, Tubuliflorae, Liguliflorae, Ranunculaceae, Convolvulaceae, Lamiaceae, Malvaceae, *Geranium* **Culture pollen taxa** Cerealia, Cheno/Am, *Artemisia*, Caryophyllaceae, *Rumex*, Brassicaceae **Exotic taxa** *Lantana*, *Xanthium* **Marshy taxa** Cyperaceae, *Polygonum plebeium*, *Polygonum* sp., *Solanum* **Aquatic taxa** *Lemna*, *Myriophyllum*	**Ferns** Ferns producing monolete spores, Ferns producing trilete spores **Algal remains** Zygospores of *Spirogyra* and *Zygnema* **Fungal spores** Microthyriaceae, *Tetraploa*, *Alternaria*

Fig. 3—Major pollen taxa recovered in the sediment profile from Loktak Lake.

terms of terrestrial only. The plant taxa grouped as trees, shrubs, herbs, ferns, algal remains and fungal spores have been shown in the pollen diagram in the same manner (Fig. 2). Six out of seven samples collected were analyzed for pollen grains and spores. The results of pollen analysis indicate that the climate in the region has changed during past 1650 years or so. The Fig. 3 incorporates the taxa recognized in the profile, in detail.

The elemental percentage (standardless) was determined using EDAX attached to Leo 430 SEM at BSIP (Fig. 4). The carbon and nitrogen measurements were made using HCNO-S analyser at Regional Sophisticated Instrumentation Centre, Lucknow.

POLLEN AND CHEMICAL ANALYSES OF SEDIMENT PROFILE

Pollen composition of sediment profile—The pollen assemblage derived through the investigation of the sediment profile from Loktak Lake, Manipur has shown distinct changes in the representation of the plant taxa retrieved in the sediment in the lower as well as upper halves of the pollen sequence (Fig. 2). The lower half between 73 cm and 40 cm depths is characterized by the dominance of non-arboreals and low frequencies of arboreals (trees & shrubs). Poaceae (grasses 30-53%) followed by Chenopodiaceae/Amaranthaceae (Cheno/Am 5-8%) and Tubuliflorae (2-5%) are the major constituents of ground flora. Others such as Convolvulaceae, Lamiaceae and Malvaceae (1% each) are scantily present. Cerealia and other culture pollen taxa viz., Brassicaceae (2%), *Artemisia*, *Rumex* and Caryophyllaceae (1% each) are recorded sporadically. The marshy elements, Cyperaceae (sedges 7-12%) and *Polygonum* sp. (2-5%) are recovered in moderate values, whereas *P. plebeium* and *Solanum* (<1% each) are rare. *Lemna* (2%) and *Myriophyllum* (1%) represent the aquatic vegetation. Trees are met with meagerly and are represented in low frequencies by Sapotaceae (2%), *Holoptelea*, *Symplocos* and *Acacia* (1.5% each). Rutaceae (2%), *Aspidopterys* (1.5%), *Grewia* and Fabaceae (1% each) with low values, constitute the shrubby vegetation. The record of pollen of temperate elements viz., *Pinus* (1-3%), *Alnus* and *Corylus* (1% each) denotes their transportation from the higher elevations. Among the fungal remains,

Sample depth (cm)	Carbon (weight %)	Nitrogen (weight %)	Carbon/ Nitrogen
2-8	0.58	0.059	6.5
13-17	3.13	0.33	9.4
70-73	2.43	0.29	8.3

Fig. 4—Carbon and Nitrogen abundances and their ratio in sedimentary samples from Loktak

Microthyriaceae (1-10%) is much better represented in contrast to *Tetraploa* (1-3%), fungal spores (1-2%) and *Alternaria* (1%). Fern spores (monolete 10-15% & trilete 10-14%) are recovered very frequently. Algal remains (2-5%) are met with in a declining trend.

The upper half (40-0 cm) of the pollen sequence also reveals the dominance of non-arboreals, however, Poaceae (grasses 43-59%) and Tubuliflorae (3-8%) have increased frequencies than in the preceding half. The exotic elements, *Lantana* (1-6%) and *Xanthium* (3-5%) appear for the first time in good frequencies. Cerealia does not show any noticeable change, whereas Caryophyllaceae (1-3%), *Rumex* (1-2%) and *Artemisia* (2%) exhibit slight improvement than in the preceding half. *Alternanthera* (1-2%) is new addition to the herbaceous complex. Marshy elements Cyperaceae (sedges 5-7%), *Polygonum* sp. (5-1%) and *P. plebeium* (< 0.5%) are marked by their declining trend. Trees become more-scanty and are represented by *Lagerstroemia, Acacia*, Meliaceae and Sapotaceae (1% each) only along with shrubby elements such as *Grewia* and Fabaceae (1% each). Interestingly, *Pinus* (5-12%) and *Alnus* (1-4%) are characterized by their much high frequencies than seen in the preceding half. *Quercus* (1-3%) turns up first time with moderate values together with *Betula* (2%) and *Carpinus* (0.5%). Fern spores (monolete 10-15% & trilete 4-14%), in general, have reduced values compared to the earlier half. *Typha*, the only aquatic element, is sporadically present.

Chemical composition of sediment profile—The higher abundance of aquatic vegetation in earlier stage is also supported by relatively lower C/N values (6.5) in the deepest sample compared to the upper samples (8.3 and 9.4 for 2-8 cm and 13-17 cm deep samples). The much lower (0.58 wt %) carbon content of deepest sample is in agreement with its being barren from the angle of pollen. Low values for C/N ratios in all samples indicate the domination of local vegetation of aquatic nature all through. It may be mentioned that these are ratios for total carbon (Fig. 4). The organic carbon values would be still lower. However, simple hydrochloric acid treatment indicated absence of carbonate.

The elemental percentage (standardless) using EDAX attached to Leo 430 SEM, of grains in 3 samples taken from depths of 2-8 cm (sample 1), 13-17 cm (sample 2) and 70-73 cm (sample 7) are not absolute due to in-built normalization procedure. However, they serve as comparative variations. They expectedly showed domination of oxygen (O), silicon (Si), nitrogen (N), aluminium (Al), carbon (C) and some iron (Fe) in decreasing order. Potassium (K) and phosphorus (P) present in equal amounts (both close to one percent) with slightly lower magnesium. The variations in all 3 samples are small for all the above elements with the exception of iron, which is nearly double in the 13-17 cm deep sample as compared to that in top (2-8 cm) and bottom (70-73 cm) samples. Barring chromium (Cr), the other main metals viz., magnesium (Mg), copper (Cu), cobalt (Co) and manganese (Mn) are also present in the higher amounts in sample 2 (13-17 cm depth) compared to the top and bottom samples. Chromium (Cr) percentage in the samples 1 (2-8 cm depth), 2 (13-17 cm depth) and 7 (70-73 cm depth) are 0.06, 0.05 and 0.04 percent respectively but in view of the very low peak- to-background ratio for Cr and Mn, not much faith can be had in them. The iron to phosphorus ratio, generally constant in sediments (Mackereth, 1966) is also much higher (over 3 times) in the sample 2 but almost equal (3.21 and 3.13) in the samples 1 (2-3 cm depth) and 7

(70-73 depth). The possibility exists that the phosphorus may be a result of biotic precipitation rather than chemical. But this does not seem to be supported by correlation between phosphorus and organic carbon.

DISCUSSION

The pollen and chemical based proxies emerged out through the investigation of sediment profile from Loktak Lake has brought out some interesting inferences on the changing vegetation scenario and climate in the region during last 1650 years. The pollen evidence has envisaged that around 1650 to 600 yr B.P., open vegetation dominated by grasses together with other prominent herbaceous associates of Chenopodiaceae/Amaranthaceae and Tubuliflorae occurred in the vicinity of the lake. A few trees comprising *Holoptelea, Symplocos, Acacia* and thickets of *Grewia, Aspidopterys,* Fabaceae, etc. were sparsely distributed upon the open vegetation. The preponderance of ferns and frequent occurrence of epiphyllous fungi- Microthyriaceae in particular, together with *Tetraploa* and fungal spores are suggestive for the prevalence of humid climate in the region during the course of sediment accumulation. This is also substantiated by low C/N ratio, which is indicative of abundant aquatic vegetation. The prolonged existence of the lake is depicted by the occurrence of aquatic taxa, *Myriophyllum*, *Lemna* and algal remains. The lake was most probably bordered with a wide swampy margin as evidenced from the high frequencies of marshy elements of sedges and *Polygonum* sp. The area adjoining to the lake was under some sort of cereal-based agricultural practice and anthropogenic activities as inferred from the record of pollen of Cerealia and ruderal plants viz., *Artemisia*, *Rumex*, Brassicaceae, Caryophyllaceae, Chenopodiaceae/Amaranthaceae, etc. respectively. The retrieval of pollen of subtropical and temperate elements viz., *Pinus, Alnus* and *Corylus* suggests their transportation from the higher elevations, where they occurred abundantly.

During the subsequent phase encompassing the time span from 600 yr B.P. to Present the open vegetation continued to occupy the region with more profusion of grasses and Asteraceae than before. However, arboreals became much sparse as evidenced by extremely sporadic presence of trees of *Lagerstroemia, Acacia*, members of Sapotaceae and Meliaceae along with thickets of Oleaceae and Fabaceae. Such a change in the floristic composition reveals that the climate turned less humid by this time. This is also well corroborated by the reduction in ferns and total absence of fungal remains right from the beginning of this phase. The diminishing trend of aquatic vegetation and further relatively higher carbon/nitrogen ratio than during the preceding phase symbolize the reduction of lake dimension due to onset of a less humid climate, attributable to decreased monsoon precipitation. The much improvement of *Pinus* followed by *Alnus* and *Quercus* most likely implies the lowering of the subtropical/temperate belt in response to prevailing harsh climate. The agricultural practices continued with more or less same intensity as Cerealia and other culture pollen do not exhibit any significant change. However, the improvement in most of the culture/ruderal plants viz., *Rumex*, Caryophyllaceae, Brassicaceae and *Artemisia* as well as debut of *Alternanthera* in appreciable frequencies suggest the acceleration of human activities in the vicinity of the lake. This is also testified by the high iron/phosphorus ratio in this upper part of pollen sequence. Amazingly, the abrupt invasion of noxious exotic weeds such as *Lantana* and *Xanthium* in substantial frequencies might have occurred as a consequence of the increasing anthropogenic activities/biotic pressure in the form of illicit exploitation of natural vegetation as well as over grazing in the region with the beginning of this phase. Presently, these two weeds occur gregariously in most of the degraded area, particularly around habitations.

The low carbon- to- nitrogen ratios also support the domination of aquatic vegetation all through but with a decreasing trend from the past to present. The lower carbon in the deepest sample studied is also an indication of low biological production in the past.

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