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PROXY RECORDS OF LATE HOLOCENE VEGETATION AND CLIMATE CHANGES FROM BASAHA JHEEL, CENTRAL GANGA PLAIN

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ABSTRACT

Pollen analysis of a 2.6 m deep trench profile from Basaha Jheel (district Unnao, Uttar Pradesh), situated in the central Ganga plain, reveals that from about 3300 yrs BP open vegetation occupied the region. Vegetation comprising grasses, sedges, Chenopodiaceae/ Amaranthaceae (Cheno/Am), etc., together with scanty trees of *Bauhinia*, *Holoptelea* and Sapotaceae occurred under semi-humid climatic conditions. The recovery of pollen from aquatic taxa, viz., *Nymphoides*, *Lemna*, *Myriophyllum* and *Potamogeton* demonstrates the existence of a lake at the site. Cerealia and other culture pollen taxa indicate anthropogenic activity in the region. Between 3200 and 2800 yrs BP, open vegetation continued to occupy the region, though the invasion of some trees such as *Acacia*, *Dalbergia*, *Grewia* and Anacardiaceae occurred and much increased values of *Bauhinia* are recorded. This change suggests a phase of increased humidity in the region attributed to monsoon rainfall. Further increase in frequencies of aquatic taxa demonstrates that the lake expanded in size as a consequence of increased rainfall. Agricultural activities continued with more or less the same pace as before. Subsequently, the climate became less humid with a decrease in rainfall between 2800 and 2200 yrs BP, as shown by the decline in arboreal pollen, particularly *Bauhinia*, followed by Sapotaceae, contemporary rise in grasses, other herbs and a decline in aquatic taxa. During this period, the expansion of agriculture is indicated by an increase in the value of Cerealia and other culture pollen taxa. Between 2200 and 1800 yrs BP, arboreals further dwindled and the lake turned into a swamp as suggested by an increase in marshy elements chiefly sedges and *Polygonum* with a prominent decline in monsoonal precipitation. Arboreal vegetation almost vanished soon after *ca.*1800 yrs BP, except for stray Sapotaceae elements associated with the simultaneous expansion of grasses along with other heath land taxa, portraying a further decline in precipitation. This top phase is also characterized by poor representation of aquatic elements and a sharp rise in marshy taxa. This is probably indicative of siltation of the lake into a marshy lowland lacking a prominent water body. A marked decline in culture pollen taxa during this change corroborates well the drier climatic conditions in the form of reduced rainfall. Aridity most likely resulted in increased soil alkalinity/salinity over the whole region, hampering growth of trees and hastening the decline in agricultural practice.

Key words: Late Holocene, Palaeovegetation, Palaeoclimate, Basaha Jheel, Central Ganga Plain.

INTRODUCTION

The Ganga Plain, a neglected area for Quaternary pollen analytical studies, has not received due attention for deciphering of palaeovegetation succession and contemporary climatic oscillations, except for some disjunctive information from the central Ganga plain (Gupta, 1978; Chauhan, Khandelwal, Bera and Gupta, 1990; Sharma, Chauhan, Sharma, Sharma and Singh, 2001; Sharma, Joachchimski, Sharma, Tobschall, Singh, Chauhan and Morgenroth, 2004). Nevertheless, information so far available reveals that a large number of existing lakes in the southern Ganga plain formed during the early Holocene as a result of channel abandonment due to change in base level and tectonic activity (Agarwal, Rizvi, Singh, Kumar and Chandra, 1992; Singh, 1996; Singh, 2001, 2002; Srivastava, Singh, Sharma, Shukla and Singhvi, 2003). The present communication brings out some interesting information on the vegetation succession in time and space attributed to climatic fluctuations and the impact of anthropogenic activities as a result of agricultural practices commencing in the region. The study covers the last few millennia as deduced through pollen analysis of a trench profile from Basaha Jheel (lake) – an ancient lake basin situated about 60 km southwest of Lucknow. The site is in the vicinity of two villages - Itkuti and Jamanwa (fig.1) between 80° 15' Long. & 26° 30' Lat., originating as an abandoned channel.

MATERIALS AND METHODS

The deposits of Basaha lake (near Sonik) are about 3 m in thickness. In a complete profile, the lake deposits overlie a sand layer, deposited when a channel was active. The sand layer is followed by about 60

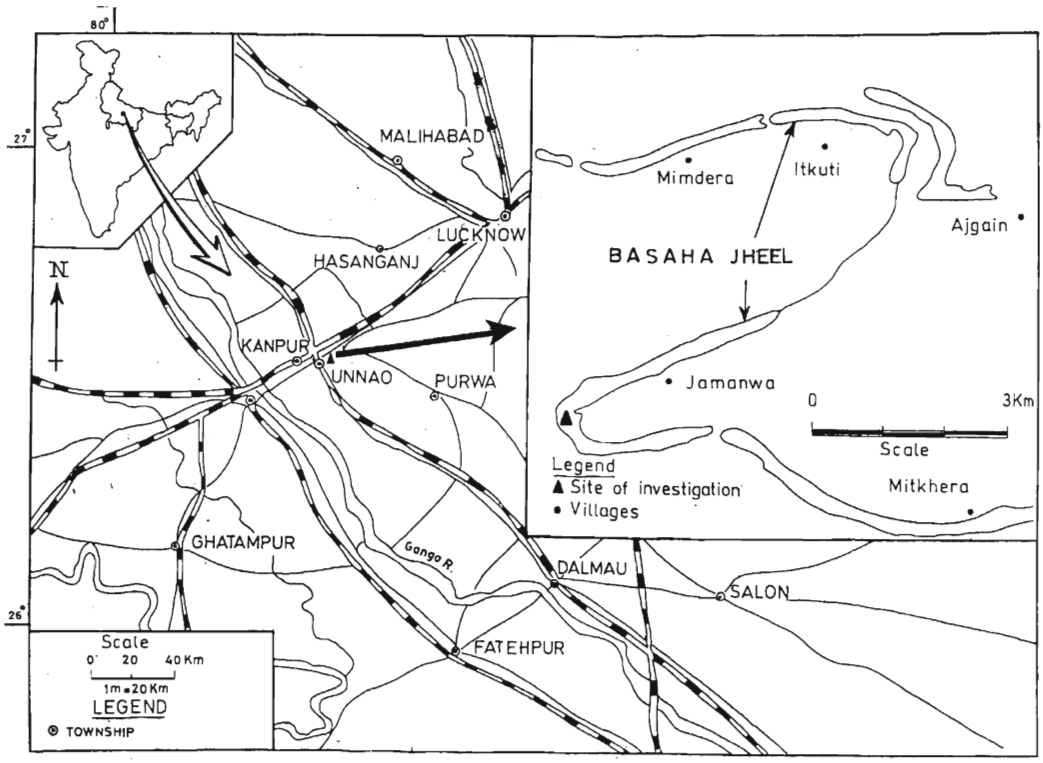

Fig.1. Location map showing the site of investigation.

cm thick shell layer (marl), followed by about 2 m thick muddy sediments. The basal part of the shell layer is dated about 8300 yrs, while top of the shell layer is dated about 2800 yrs (Agarwal *et al.,* 1992; Rajagopalan, 1992). Thus, the river channel changed to a lake aroudn 8500 yrs. BP.

In the present study, a 2.6 m thick trench profile was dug out from this ancient lake basin for pollen analytical investigation. The trench could not be dug upto sand layer as it was flooded by water. Thus, only the younger part of the lake deposits are investigated. In total, 23 pollen samples were collected from the trench at different intervals, taking into consideration changing lithological composition. In addition, 4 samples were also taken prominent lithologies, at appropriate intervals for ^{14}C dating. The sediment deposit of the profile exhibited three lithologies, viz., sub-soil, black loamy soil and marl from the top downwards (fig.2).

The depth-wise lithological details of the trench profile are as follows:

Depth	Lithology
0-1.08m	Sub-soil
1.08-1.81m	Black loamy soil
1.81-2.60m	Marl

Sediments were devoid of seeds, charcoals and leaves; therefore, bulk carbon was used for AMS dating at larger intervals. The dating was carried out at AMS Laboratory, Institute of Physics, University of Erlangen-Nuremberg, Germany. Radiocarbon dates (AMS) from four samples for different horizons from the investigated profile are as follow:

Depth	Laboratory Reference Nos.	AMS ^{14}C dates (yrs BP)
0.24m	HOLMONBASAHA 07/01-6	1712 ± 65
1.15m	HOLMONBASAHA 07/01-4	2149 ± 56
1.79m	HOLMONBASAHA 07/01-3	2736 ± 57
2.15m	HOLMONBASAHA 07/01-2	2995 ± 63

The above-mentioned AMS dates have been

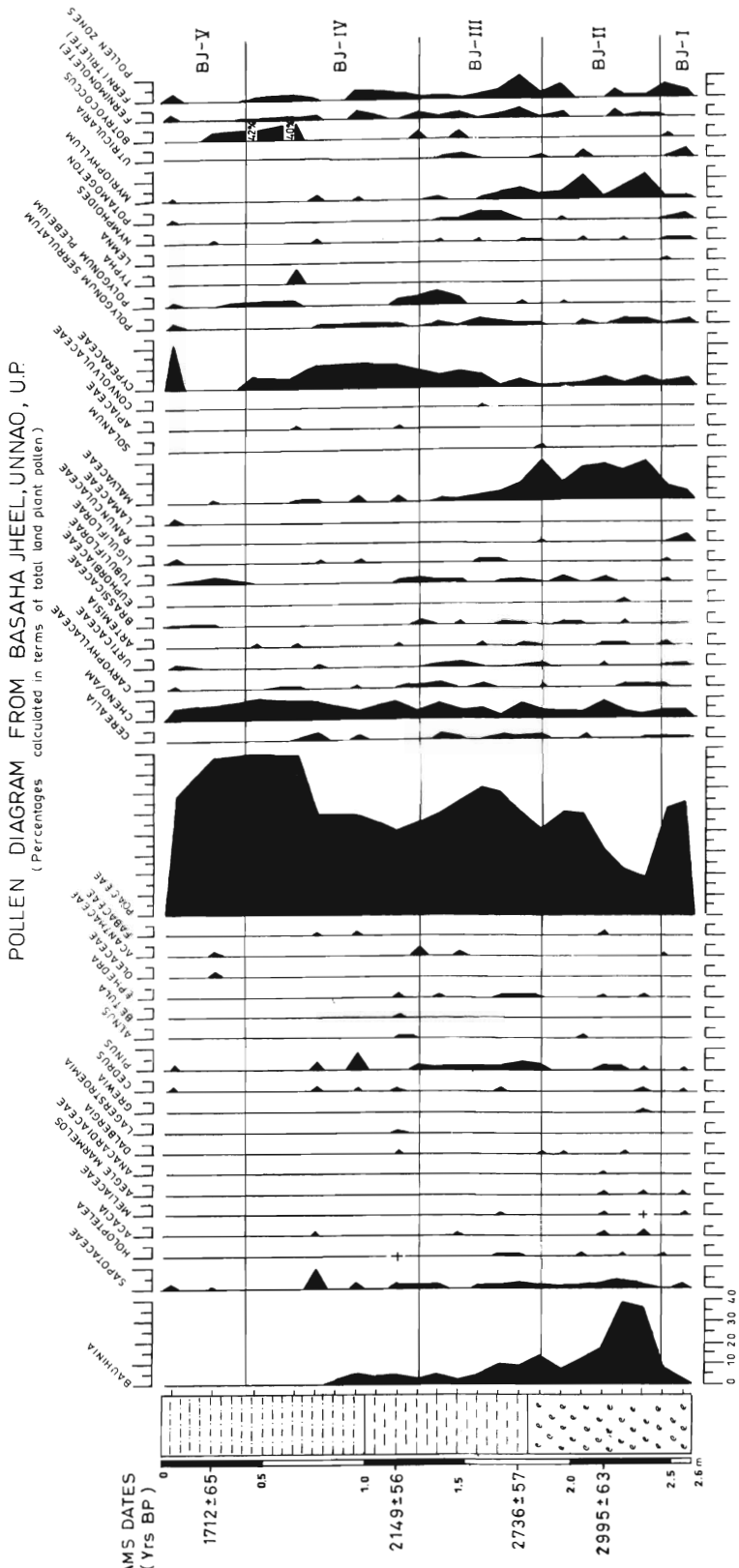

Fig.2. Pollen diagram from Basaha Jheel, Unnao District (U.P.).

taken into consideration for the calibration of sedimentation rates for different horizons of the profile. Three sedimentation rates calibrated at the depths of 2.15-1.79 m, 1.85-1.25m and 1.15-0.24m of the profile are 1cm/7.2 yrs, 1cm/9.1 yrs and 1cm/5.8 yrs respectively. They have been used to extrapolate four more dates i.e. 3300 yrs BP at 2.6m depth, 3200 yrs BP at 2.45m depth, 2800 yrs BP at 1.85m depth and 1800 yrs BP at 0.40m depth for the precise understanding of vegetation shifts, lake level fluctuations and contemporary climatic changes in the Ganga Plain in a definite time-frame.

Samples were treated with 10% aqueous KOH solution and 40% HF in order to liberate the pollen/spores and to dissolve the silica content respectively. Then conventional acetolysis (Erdtman, 1943) was followed using the acetolysing mixture (9:1, acetic anhydride and concentrated sulphuric acid). Finally, the samples were mounted in 50% glycerine solution for microscopic examination.

POLLEN ANALYSIS

Almost all samples were productive in their pollen and spores content. The pollen sum ranges from 155 to 200 depending upon the yield of the samples. This excludes the pollen of aquatics, spores of ferns and algal remains on account of their origin from local sources. The low pollen sum of the samples could be possibly attributed to the scanty vegetation cover in the Ganga Plain, predominance of entomophilly in most of the tropical plants, organic poor loam and marl sediments and differential pollen preservation. The frequency percentages of the recovered pollen taxa have been calculated in terms of total land plant pollen. However, the frequency percentages of the pollen of aquatics, spores of ferns and algal remains have been calculated independently from the pollen sum. The plant taxa have been grouped as trees, shrubs, herbs, aquatics, ferns and algal remains, plotted in the same order in the pollen diagram (Fig.2). Also a summary pollen diagram (Fig. 3) depicting the major plant groups has been prepared to project the changing vegetation in the region at a glance. Based on fluctuations seen in the frequencies of prominent arboreal and non-arboreal taxa, five distinct pollen zones, viz., BJ-I, BJ-II, BJ-III, BJ-IV and BJ-V are recognized. The pollen zones are described as follows:

Pollen Zone BJ-I (2.6-2.45m): Poaceae-Bauhinia-Sapotaceae-Ranunculaceae-Malvaceae Utricularia-Ferns assemblage

This pollen zone with an extrapolated date of

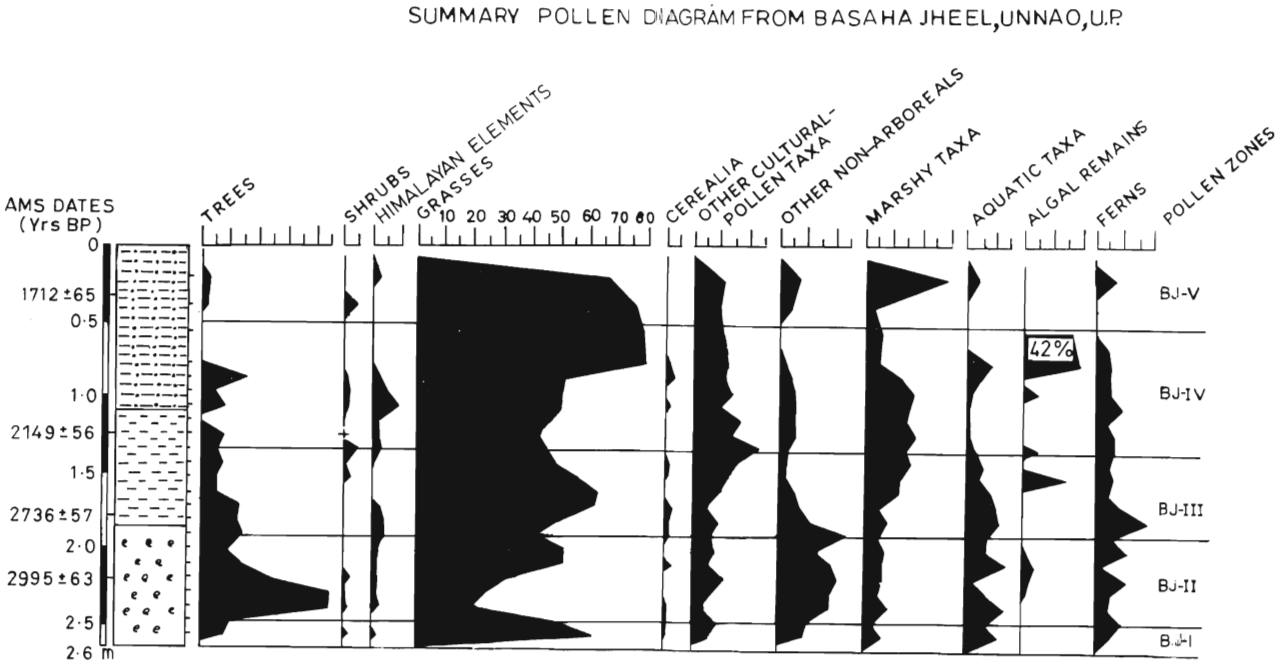

Fig.3. Summary pollen diagram from Basaha Jheel, Unnao District (U.P.) showing major plant groups.

ca. 3300 yrs BP is characterized by high frequencies of Poaceae (55%), followed by Malvaceae, Ranunculaceae, Cheno/Am (5% each), Cyperaceae (4%) and Cerealia (2%). Among the arboreal taxa, *Bauhinia* (3-8%) has an increasing trend, whereas, Sapotaceae (3%) is recorded consistently. *Aegle marmelos*, *Holoptelea*, Meliaceae (2% each) and shrubby element of Acanthaceae (1%) are in only one sample. Aquatic vegetation is represented by moderate values for *Utricularia* (5%), *Nymphoides*, *Potamogeton* (3% each), *Lemna* and *Myriophyllum* (2% each), whereas, the fresh-water alga, *Botryococcus* (1%) is met with in only one sample. Ferns are recorded in good frequencies. Long distance transported pollen of two Himalayan taxa - *Pinus* and *Cedrus* are recovered sporadically.

Pollen Zone BJ-II (2.45-1.85m): Bauhinia-Sapotaceae-Poaceae-Malvaceae-Chenopodiaceae/ Amaranthaceae- Myriophyllum assemblage

This pollen zone ^{14}C dated to 2995±63 yrs BP (2.15m depth) and covering a time span of 3200 to 2800 yrs BP is marked by an over all increase in the number and frequency of tree taxa. *Bauhinia* attains its maximum value of 40% in the lower half of the zone. Sapotaceae (2.5%) is also consistently represented in improved values together with *Holoptelea* (2%). *Acacia* (3%), *Dalbergia* (1%), Anacardiaceae and *Grewia* together with shrubby elements, viz., *Ephedra* and Fabaceae appear sporadically in low values. Some tree taxa, viz., Meliaceae and *Aegle marmelos* maintain more or less the same frequencies as in Pollen Zone BJ-I. Among the non-arboreals, Poaceae (20-50%) exhibits a sharp decline at the beginning but increases in the upper part of this zone. Similarly, Malvaceae (20%) occurs in increasing frequency. Other non-arboreals, viz., Cheno/Am (4-8%), Tubuliflorae (2-5%), Cerealia (2-3%), *Artemisia,* Brassicaceae and Caryophyllaceae (2% each) are also the major constituents of the ground vegetation. Among the aquatics, *Myriophyllum* (2-13%) attains its maximum values, whereas, *Potamogeton* and *Nymphoides* (2% each) have reduced values. The marshy vegetation is predominantly represented by Cyperaceae (5%) and *Polygonum serrulatum* (2-5% each), though in moderate values. *Polygonum plebeium* (1%) appears sporadically in extremely low frequencies. Monolete fern spores (2-5%) show increased values, whereas, trilete fern spores (2-6%) decline considerably.

Long distance transported pollen of *Pinus* shows an increasing trend, whereas, its associate *Cedrus* remains sporadic in the zone. *Alnus* appears sporadically for the first time in this zone.

Pollen zone BJ-III (1.85m - 1.25m): Poaceae-Chenopodiaceae/Amaranthaceae– Malvaceae - Bauhinia-Myriophyllum assemblage

This pollen zone, with a radiocarbon date of 2736±57 yrs BP (1.79m) and encompassing a temporal range of 2800 to 2200 yrs BP, demonstrates a sharp decline in *Bauhinia* (5-9%) and Sapotaceae (3%) associated with the disappearance of many arboreals. *Holoptelea, Acacia* and Meliaceae (2% each) also become more sporadic with reduced values. Among the non-arboreals, Poaceae (60%), Cheno/Am (3-8%), Caryophyllaceae, Urticaceae (3% each), *Artemisia* (1-2.5%) and Cerealia (3%) show an increasing trend but Malvaceae (20-3%) declines considerably. Other terrestrial taxa such as Brassicaceae and Liguliflorae (2% each) increase, whereas, Tubuliflorae (2%) decreases compared with the preceding zone. The aquatics, *Myriophyllum* (7-3%) and *Nymphoides* (2%) decline in this zone and *Potamogeton* (5%) and *Utricularia* (4%) increase. The marshy taxa, viz., Cyperaceae (2.5-10%), *Polygonum plebeium* (2-6%) and *P. serrulatum* (2-4%) increase with the onset of this zone. Fern spores (monolete 5-7% and trilete 2-10%) also show fluctuating, frequencies increasing at the beginning of this zone but declining thereafter.

Pollen Zone BJ-IV (1.25-0.40m):Poaceae-Cyperaceae-Bauhinia-Chenopodiaceae/ Amaranthaceae—Ferns assemblage

This pollen zone ^{14}C dated to 2149±56 yrs BP (1.15m) and covering a time period of 2200 to1800 yrs BP reveals a further decline in *Bauhinia* (3-5%), whereas, Sapotaceae, *Holoptelea*, *Dalbergia*, etc. are other arboreal taxa which are represented by their reduced frequencies. *Lagerstroemia* (2%) occurs for the first time in one sample. Shrubby elements, viz., Acanthaceae, *Ephedra* and Fabaceae are

sporadically represented. Among the non-arboreals, Poaceae (up to 78%) has a declining trend in the lower half but increases thereafter. Cheno/Am (5-10%) and Cerealia (4%) also exhibit an increase in their frequencies in this zone, whereas Urticaceae and Caryophyllaceae (2% each) are rarely present in contrast to previous zone. Malvaceae declines considerably and becomes sporadic. Tubuliflorae and *Artemisia* maintain the more or less same values as in the preceding zone. Aquatics become rare and are represented only by extremely low values of *Nymphoides* and *Myriophyllum*. However, *Botryococcus,* a fresh-water alga, attains maximum values of 42% in the upper half of this zone. Marshy vegetation is characterized by enhanced values for Cyperaceae (5-13%). *Polygonum plebeium* (2-5%) and *P. serrulatum* (3%) are also marked by their good representation, despite reduced frequencies as compared to Pollen Zone BJ-III. *Typha* (7%) occurs for the first time in this zone. Fern spores maintain their consistent representation in moderate values. Improved values of long distance transported pollen of *Pinus* are encountered throughout in this zone, whereas, *Cedrus*, *Alnus* and *Betula* are rarely represented.

Pollen Zone BJ-V (0.40-0.0m): Poaceae-Chenopodiaceae/Amaranthaceae-Cyperaceae assemblage

This pollen zone with a radiocarbon date of 1712±65 yrs BP (0.24 m) is characterized by the overall absence of most of the arboreal taxa in comparison to earlier pollen zones, except for the sporadic occurrence of Sapotaceae. The shrubby vegetation also becomes rare; Oleaceae and Acanthaceae are represented in only one sample.

Among the non-arboreals, Poaceae attains a maximum frequency of 78% in this zone. Cheno/Am also occurs in good values. Other non-arboreal taxa remain static in the lower half, but exhibit an increasing trend in the upper part together with *Polygonum plebeium* and *P. serrulatum*. However, Cyperaceae (up to 25%) registers much higher values in the upper part only. *Nymphoides*, *Potamogeton* and *Myriophyllum* occur in extremely low numbers in this zone. *Botryococcus* (9%) declines sharply in the lower half and disappears towards the end of this zone. Fern spores (monolete and trilete) dwindle sharply.

Long distance transported pollen taxa also decline considerably being represented by stray *Pinus* and *Cedrus* pollen.

DISCUSSION AND CONCLUSIONS

Little information is available about palaeovegetation dynamics and corresponding climatic events from pollen analytical investigation of sedimentary profiles from different areas of the Ganga plain. Gupta (1978) has inferred four climatic phases and incipient agricultural practice, as well as its subsequent trends, based on the pollen records retrieved from early to late Holocene meander lake sediments from Pratapgarh. Similarly, pollen proxy records generated from Sanai Tal, Rae Bareli district (Sharma *et al.*, 2001; Sharma *et al.*, 2004) have provided information regarding changing vegetation scenarios, lake level fluctuations and pace of agricultural practice in the region prior to the Holocene. Efforts have also been made to decipher the short term climatic variability and anthropogenic impact in the region through pollen analysis of a small core from Kathauta Tal, a lake located close to the Gomti River (Chauhan *et al.*, 1990).

The proxy data generated from the pollen analysis of the 2.6m deep sedimentary profile, from the dug out trench in Basaha lake has located five well-defined phases of vegetation succession and corresponding climatic fluctuations associated with lake level changes and agricultural practice in the region since the late Holocene.

From 3300 yrs BP, open scrubby vegetation comprised mainly grasses, associated with elements of Ranunculaceae, Malvaceae, Chenopodiaceae/Amaranthaceae, etc. together with scattered arboreals such as *Bauhinia*, Sapotaceae, *Aegle marmelos*, *Holoptelea* and Meliaceae, which occupied the region under semi-humid climatic conditions. The recovery of Cerealia together with other cultural pollen taxa such as Chenopodiaceae/Amaranthaceae, *Artemisia* and Urticaceae suggests that this area was under the impact of anthropogenic activities. The record of aquatic taxa such as *Lemna*, *Nymphoides*, *Myriophyllum* and *Potamogeton*, together with the

fresh-water alga, *Botryococcus,* denotes the prolonged existence of a lake.

Between 3200 and 2800 yrs BP, open scrubby vegetation dominated by grasses and other non-arboreals continued to thrive in the region, with a simultaneous overall improvement in arboreals. Excessively high frequencies of *Bauhinia* demonstrate that this tree might have been growing abundantly in the area, most likely in localized pockets in close proximity to the lake. This tree might have flourished on account of its utility for local inhabitants, chiefly as fodder and vegetables (flower buds and pods). In addition, increased frequencies of Sapotaceae (cf. *Madhuca indica*); *Aegle marmelos* and Meliaceae together with the invasion of *Acacia*, *Dalbergia*, *Grewia* and Anacardiaceae for the first time in the region suggest the onset of a phase of increasing humidity or enhancement of precipitation. Increase in aquatic taxa, particularly *Myriophyllum*, demonstrates that the lake expanded in size as a consequence of enhanced rainfall. Agricultural activities continued at more or less the same pace, since cultural pollen taxa do not portray any major change.

Pinus, *Cedrus*, *Alnus* and *Ephedra* pollen are transported by long-distance dispersal by winds from nearby Himalaya where these taxa grow abundantly.

The climatic conditions became less humid in response to a reduction in precipitation between 2800 and 2200 yrs BP as evidenced by the decline in arboreals, especially *Bauhinia*, followed by Sapotaceae and disappearance of other tree taxa, associated with a contemporary rise in grasses and other herbaceous taxa, viz., Tubuliflorae, Brassicaceae, Chenopodiaceae/Amaranthaceae, Urticaceae and *Artemisia.* This change is also signalled by a sharp decreasing trend of most aquatic taxa, more particularly *Myriophyllum* and *Nymphoides*, except for *Potamogeton*, which shows improvement during this phase. The gradual improvement in marshy elements, viz., sedges (Cyperaceae), *Polygonum serrulatum* and *P. plebeium* envisages the development of swampy condition along the lake margin. However, expansion of agricultural practice is suggested by increased frequencies of Cerealia and other cultural pollen taxa such as Chenopodiaceae/Amaranthaceae, Caryophyllaceae, Brassicaceae, *Artemisia* and Urticaceae. This could probably have occurred with the availability of more terrestrial land around the investigation site for reclamation as a consequence of reduction in lake dimension.

Later on, between 2200 and 1800 yrs BP, the tree taxa dwindled further as evidenced by the reduction in their pollen frequencies, together with shrubby elements, except for the stray pollen of *Lagerstroemia*, which invaded the region for the first time during this phase. Also, the lake started turning into swamp, as reflected by an increase in the pollen of marshy elements, chiefly sedges and *Polygonum* spp., associated with a corresponding further decline in most aquatic taxa especially *Myriophyllum* and *Nymphoides* as well as total disappearance of *Potamogeton*. The much high frequency of *Botryococcus* only during this phase denotes its restricted occurrence in reduced lake and adjoining waterlogged areas. However, *Typha* flourished and inhabited the swampy margin of the lake in this phase for the first time. The overall vegetation mosaic signifies a prominent decline in monsoonal precipitation. Further, no marked change in the anthropogenic activities has been witnessed in the region as manifested by the more or less similar representation in the culture pollen taxa as seen in the preceding phase.

During the last phase, commencing from 1800 yrs BP, the arboreal vegetation almost vanished, barring the stray presence of Sapotaceae (*cf. Madhuca indica*). Simultaneously, grasses expanded or flourished along with other heath land taxa such as Asteraceae, Lamiaceae, etc., portraying a further reduction in rainfall. This drier phase is also characterized by a poor representation of aquatic taxa, indicative of progressive siltation of the lake leading ultimately to marshy lowland without a perennial water body. This is further substantiated by a sharp decline in *Botryococcus*, a fresh-water alga, as well as a much increase in sedges (Cyperaceae), though in the latter half of this phase such a change in vegetation is attributed to a response to adverse climatic conditions as a result of reduction in precipitation. Total absence of Cerealia pollen and a contemporary marked decline in other cultural pollen taxa such as

Chenopodiaceae/Amaranthaceae and Caryophyllaceae imply the existence of dry climate and saline soil in the region and adjoining areas, hostile to the growth of arboreal elements and to discontinuation of agricultural practice in the region.

On the marign of Basaha lake, a single culture archaeological site is present. Preliminary study of the pottery suggests that habitation at this site existed during time span of about 30000 to 2200 yrs BP. Abandonment of the site around 2200 yrs BP is probably related to reduced monsoon rainfall and increased alkalinity of the soils near the site. At present, the area adjoining to Basaha lake has large tracts of alkaline soil, with little plant cover except grasses. It seems reasonable to asume that alkainity of soil in the Basaha lake region increased significantly around 2200 yrs BP, and became very prominent at about 1800 yrs BP.

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