Palaeoenvironmental changes in the Ganga Plain deduced from proxy records in lake fill sequences

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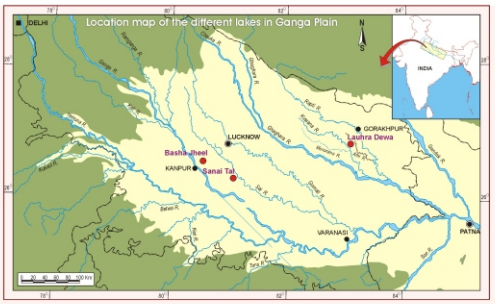
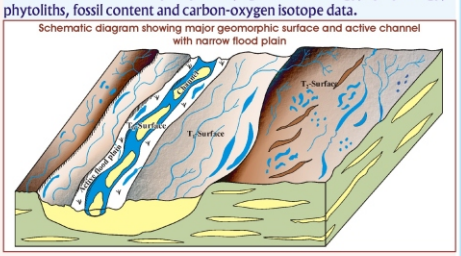
Introduction

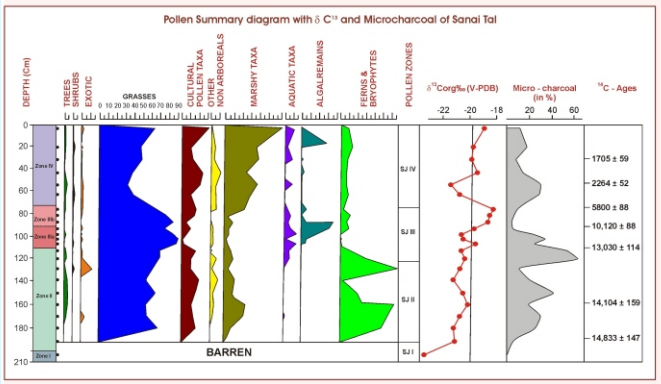
Late Quaternary is a time of repeated climate change effecting the monsoon rainfall and fluvial processes. These changes led to the development of highly diversified geomorphic features. The large-scale features are linked to major climate change and tectonics in the Late Quaternary, while small scale features are related to minor fluctuations. Large-scale migration of man about 3-4 Ka back into the Ganga Plain also had pronounced effect on the landscape development.

The Ganga Plain has diversified network of drainage system, with large number of lake and ponds. Most of these lakes are formed as a consequence of channel abandonment and channel disruption, and records the complete depositional history of Late Pleistocene- Holocene as proxy tools to deduce the palaeoenvironment.



Several lakes (Sanai Tal, Lahuradewa lake, Basha Jheel) of the area have been studied for multiproxy data, general lithology, palynology, phytoliths, fossil content and carbon-oxygen isotope data.





Results of Multi-Proxy data of different Lakes

Zone 1 Palynologically barren (stray occurrences of grass pollens), low $\delta^{13}C$ values

Zone 2 Comparatively lighter values of $\delta^{13}C$, high abundance of Poaceae (60-70%), Cyperaceae (10-25%) Cheno/Am (10-15%) and Urticaceae (5-10%), with Cerealia indicates anthropogenic activity; poor occurrence of exotic and arboreal pollen, ferns prominent.

Zone 3a Maximum development of aquatic and terrestrial vegetation, high $\delta^{13}C$ values; increase in Poaceae (61-95%), decrease in Cyperaceae, Cheno/Am, Caryophyllaceae and Urticaceae.Appearance of *Typha, Poatmogeton, Botryococcus* (3-35%) in high frequencies suggest high precipitation and expansion of lake. Significant decline in overall vegetation cover about estimated time range of 11,500-10,500 indicates short spell of dry climate.

Zone 3b 80-90% marl, high prevalence of warmth loving marshy taxa, decline in sedges and ferns indicate humid climate, expansion of lake.

Zone 4 Lighter $\delta^{13}C$ values, increase in marshy taxa, overall decline in Poaceae, with improvement in Cerealia and other cultured pollen taxa indicates the agricultural activities with fluctuation from humid to dry climate. Upper part indicates the increase in grasses and aquatic taxa, heavier $\delta^{13}C$ values.

Zone 1 Heavier δC^{13} values, prevalence of Botryococcus, Cyperaceae, poor arboreal pollen, microcharcoal, low frequency of phytoliths, (sedges and wild rice present in stray) indicate the lake as marshy low land.

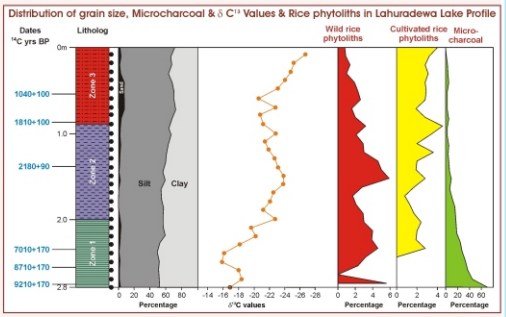
Presence of some cultivated pollen, *Rumex*, Chen/Am Caryophyllaceae, slight increase in abundance of diatoms, phytoliths indicate expansion of lake.

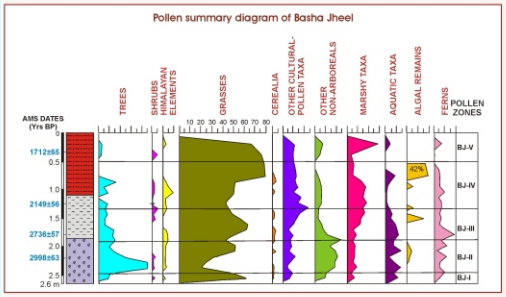
First appearance of cultivated rice phytoliths, *Cerealia*, with other cultured pollen taxa, pollens of *Madhuca indica*, *Aegle*, *Acacia*, *Terminalia:* microcharcoal, paddy field diatoms indicate good precipitation, expansion of lake and some sort of agricultural practices, also evidenced by the occurrence of rice husk (~ 8000 yrs BP) from archaeological sites.

Zone 2 Consistent occurrence of cultivated phytoliths, paddy field diatoms, occurrence of *Trapa* with other cultured taxa indicate anthropogenic activity. Slight increase in chloridoid phytoliths, lighter δC^{13} values suggest climate deterioration.

High rainfall and expansion of lake inferred from prevalence of deciduous trees pollen, abundance of Poaceae, aquatic taxa, increasing tendency of cultivated rice phytoliths, panicoid phytoliths, and diatoms.

Zone 3a Influence of human activity is prominent as evidenced by increased sedimentation (due to siltation), prevalence of Malvaceae, Asteraceae, Cheno/Am, *Emblica*, *Madhuca* etc., abundance of cultivated rice phytoliths, consistent occurrence of microcharcoal throughout the profile suggestive of warm and humid climate.





BJ - I (~ 3300-3200 Yrs BP) dominated by Poaceae (55%) and tree elements (*Bauhinia*, *Aegle* etc.). Cerealia and cultural pollen taxa (Cheno/Am) are present. Moderate aquatic vegetation (Nymphoides, Potamogeton, Utricularia); suggesting prominent lake water body.

BJ - II (3200-2800 yrs BP) Dominance of grasses, significanct increase in trees (Bauhinia, Malvaceae,) due to anthropogenic influence. Prevalence of aquatic taxa (*Myriophyllum* dominates) indicate enhanced rainfall and expansion of lake.

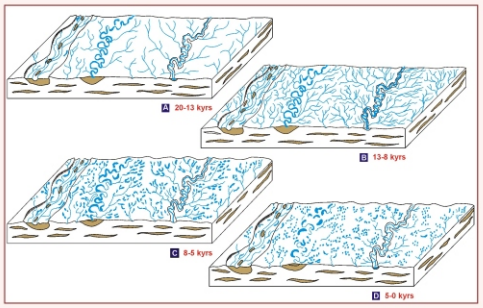
BJ - III (2800-2200 yrs BP) Increase in the Poaceae, Cerealia, and other cultured taxa (Ch/Am, Caryophyllaceae, Urticaceae); simultaneous decrease in tree taxa and aquatics indicate reduction in rainfall and lake water body.

BJ - IV (2200-1800 yrs BP) Tree taxa dwindled, increase in marshy taxa; significant decline in aquatics (*Potamogeton* disappears), *Botryococcus* attains maximum value indicating prominent decline in precipitation and lake.

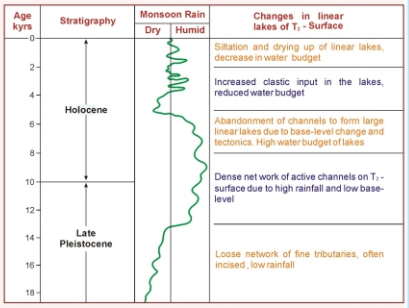
BJ - V (1800 yrs BP-Present) Arboreal vegetation almost vanished, significant expansion of grasses and sedges; decrease in aquatic taxa and Botryococcus, absence of Cerealia and other culture pollen taxa indicates reduction in rainfall, and lake dimension; discontinuation of agricultural practices in the region.

Palaeoclimate Reconstruction

- Based on the study of lake fill sequences, major inferences for last 20 ka are as follows:
- 20 to 13 Ka BP-Formation of new drainages and incision of finer tributaries, low rainfall and low drainage density.
- 13 to 8 Ka BP- Increased rainfall due to intense monsoon system, formation and extension of dense network of tributaries. Reactivation of abandoned channels and meander-cutoff lakes or marshy areas.
- 8 to 6 Ka BP- Formation of large linear lakes as a result of channel abandonment and channel disruption, High precipitation.
- 6 to 4 Ka BP- Reduction in the area, accompanied by increased supply of terrigenous clastic sediments in the lakes.
- 4 to 2 Ka BP- Further siltation and reduction in the dimensions of lakes, low rainfall and prevailing agricultural practices.
- 2 to 0 Ka BP Fragmentation of large lakes into small ponds, continued siltation and reduction in the dimension of lakes, strong anthropogenic influence on the rate of the siltation of lakes.



Geomorphic evolution of the Ganga Plain during the last 20 kyrs



Climate change due to monsoon rain fall variation in Ganga Plain during latest Pleistocene - Holocene and change on the Upland Interfluve Surface and their lakes

Conclusion

Palynological studies of lake deposit profiles for the last 15 kyrs BP suggest that the region was open grassland with few forest thickets. It can be inferred that Indo-Gangetic plains with a large variety of fluvial landforms, availability of water in rivers and lakes, good vegetation and plenty of fauna must had attracted humans for inhabitation. It seems highly probable that humans living in Ganga Plain already adapted simple agricultural techniques during Last Glacial Maxima (LGM) between 20-13 kyrs BP. With improvement of monsoon rainfall, more intense agricultural activity probably started around 13 kyrs BP; and Early Holocene (10-8 kyrs BP) witnessed spread of well developed agricultural practices, especially the cultivation of rice. Some type of agricultural activity and evidence of slash and burn cultivation are present since 15 kyrs BP in the form of Cerella and cultural pollens and micro-charcoal. The agriculture in the Ganga Plain emerged out of a complex background of climatic variation, shifting phytogeographic (vegetaion) zones, monsoon pattern change, and river system evolution.