



# VEGETATION AND CLIMATE CHANGE AROUND ROPAN CHHAPRA TAL IN DEORIA DISTRICT, THE CENTRAL GANGA PLAIN DURING THE LAST 1350 YEARS

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## ABSTRACT

Pollen proxy records from 1.2m deep sediment profile from Ropan Chhapra Tal, Deoria district in Uttar Pradesh have revealed that between 1350 and 600 yr BP, open grassland vegetation comprising largely grasses and heathland taxa viz., Asteraceae, Chenopodiaceae/Amaranthaceae, etc. with sprinkle of trees viz., *Holoptelea*, *Symplocos*, *Acacia*, etc. occurred in the region adjoining to the lake under a dry climate with moderate monsoon rainfall. The presence of aquatic plants implies the existence of lake. A brief spell of pluvial environment occurred between 600 and 425 yr BP as depicted by presence of sand layer at 65-50cm depth. The retrieval of Cerealia and other culture pollen taxa deciphers the agricultural activities in the region. From 425 yr BP onwards the expansion of grasses and coeval sharp reduction in trees denote the onset of relatively drier climate, probably in response to reduction in the monsoon rainfall. The agricultural practice continued with almost same pace as earlier.

**Keywords:** Late Holocene, Palaeovegetation, Palaeoclimate, Ropan Chhapra Tal, Central Ganga Plain

## INTRODUCTION

The Ganga Plain, an alluvial flat terrain, has a number of potential sedimentary deposits and extant lakes for Quaternary palaeoclimatic studies. The geological information generated so far have divulged that the large number of existing lakes in the Ganga Plain were formed during the early Holocene as a consequence of channel abandonment owing to change in base level and tectonic activity (Agarwal, 1992; Srivastava, *et al.* 2003; Singh, 1996, 2005). Nevertheless this region has, not received enough attention to understand the palaeovegetational succession and corresponding climatic oscillations witnessed in the past, except for some disjunctive information available from the Central Ganga Plain based on pollen evidence (Gupta, 1978; Chauhan *et al.*, 1990; Chauhan *et al.*, 2005, 2009; Chauhan *et al.*, 2004; Chauhan and Chatterjee, 2008) and multiproxy records (Sharma *et al.* 2004; Singh, 2005; Saxena *et al.*, 2006). The present communication brings out some interesting inferences concerning the temporal vegetation shifts attributed to short-term climatic variability, the pace of agricultural practice and the impact of anthropogenic activities in the region during the last millennium or so through the pollen analytical investigation of 1.2m deep trench profile from Ropan Chhapra Tal in Deoria District.

Ropan Chhapra Tal is situated about 42 km southeast of Deoria city between 26°3' N and 83°58' E in the vicinity of Ropan Chhapra Village near Lar (Fig.1). This ephemeral lake, measuring approximately 500m in outline, is horse-shoe-shaped. The lake has a gentle dip of about 5-10 degree in 270 degree. It is located west of Chhoti Gandak river. The geomorphological feature of the lake gives the indication of its formation by meander cut off and abandoned channel of Chhoti Gandak river. The lake remains dried for most part of the year, gets filled with water only during monsoon season and assumes a wider expanse. Intensive cultivation is going on in the adjoining region, because it gets filled with water only during excessive rain in monsoon season.

## CLIMATE

The Central Ganga Plain is characterized by a humid subtropical climate, which is largely influenced by southwest monsoon (Chauhan *et al.*, 1990). This region experiences three distinct seasons i.e. winter, summer and rainy seasons. The cold season (November to February) is characterized by mean minimum and maximum temperature of 6°C and 21°C respectively. However, the temperature descends to 1°C during the extreme cold month of January and consequently the weather turns foggy. The summer season (March to June) with the average mean minimum temperatures of 27°C and maximum temperature of 32.5°C is marked by the prevalent hot winds, which are commonly known as 'loo'. The temperature rises up to 45°C or even higher during the extreme hot months of May and June. Rainy season commenced from mid-June and continues till mid-September and it is characterized by heavy rains with an average annual record of 1300mm. The weather becomes humid and sultry during this period.

## VEGETATION

Deoria District has an open mixed dry deciduous type of vegetation (Champion and Seth, 1968). The natural vegetation, although scanty, consists of shrubs, grasses with sparsely distributed trees. The landscape has dominance of scrub forests, occurring in groves interspersed with open area. However, *Acacia nilotica*, *Holoptelea integrifolia*, *Diospyros melanoxylon*, *Emblia officinalis*, *Butea monosperma*, *Mimosa* sp., *Albizia lebbek*, etc. together with the thickets of *Flacourtia indica*, *Ziziphus mauritiana*, *Carissa spinarum*, *Adhatoda vasica*, *Nyctanthes abor-tritis*, etc. occur in scattered pockets. A few stands of *Holoptelea integrifolia*, *Syzygium cumini*, *Dalbergia sissoo*, *Bombax malabaricum* and *Acacia catechu* are also found in certain areas. The ground vegetation, in general, is dominated by grasses together with *Ageratum conyzoides*, *Artemisia* sp., *Chenopodium album*, *Achyranthes aspera*, *Euphorbia hirta*, *E. thymifolia*, *Oxalis acetosella*, *O.*

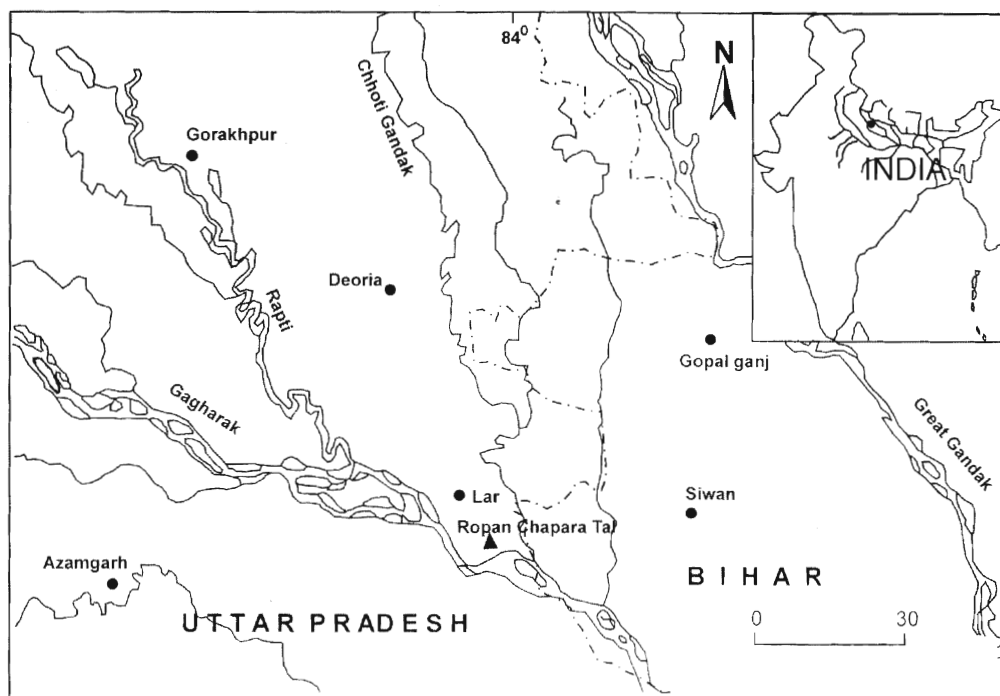


Fig. 1. Map showing the investigation site - Ropan Chhapra Tal in Deoria District (Uttar Pradesh).

*corymbosa*, *Mazus japonicus*, etc. as other major terrestrial herbs. The marshy vegetation along the lake margins and stream banks includes *Cyperus rotundus*, *Scirpus auriculatus*, *Eriocaulon quinqueangulare*, *Rotala rotundifolia*, *Polygonum plebeium*, *P. serrulatum*, *Polygala chinensis*, etc. *Potamogeton javanicus*, *Lemna polyrrhiza*, *Nymphoides cristatum* and freshwater algae - *Spirogyra* sp. and *Botryococcus* sp. inhabit frequently the lotic and lentic water bodies.

## MATERIAL AND METHODS

A 1.2m deep trench was dug in the middle part of the dried lake and in all 22 samples were collected from this profile with the sampling interval of 5cm each between the depths of 0-120cm and at 10 cm interval between the depths of 100 to 120cm for palynological investigation. In addition, 4 bulk samples were also taken at larger intervals for radiocarbon dating.

The sediments of the trench profile exhibit three distinct lithologies of varying thickness. The bottom-most zone (120-65cm) is the thickest and composed of clayey silt. Overlying this is a band of sand (65-50cm). The uppermost zone is constituted of silty clay (50-0cm). Beyond the depth 120cm further digging of trench could not feasible owing to oozing of subterranean water.

Out of four bulk samples, only two have yielded absolute dates and these are  $1100 \pm 110$  yrs BP (BS-2649) at 80-120cm depth and  $100 \pm 90$  yrs BP (BS-266) at 0-30 depth from top and bottom lithounits of the sediment profile respectively. The dating of the samples was carried out at Geochronology Laboratory, Birbal Sahni Institute of Palaeobotany, Lucknow.

While processing the sample for C-14, the rootlets have been completely eliminated by fine sieving of sample dispersed in large quantity of distilled water. The clayey mud was then centrifuged. Carbonates of the samples were eliminated by treating them with HCl at 90°C for one hour. Standard laboratory procedure of C-14 dating was carried out for the age determination

(Rajagopalan *et al.*, 1978). Based on the above mentioned C-14 dates i.e.  $1100 \pm 110$  yr BP at 80-120 cm depth and  $100 \pm 90$  yr BP at 0-30cm depth, the sedimentation rate calculated for the present sediment profile is approximately 11.76 years/cm. This sedimentation rate has allowed us to date the beginning of the lithocolumn to 1350 yr. Furthermore, two more dates i.e. 600 yr BP at 65 cm depth and 425 yr BP at 50 cm depth have also been calculated for this sedimentary profile in order to delineate the temporal vegetation shifts and corresponding climate changes in the region.

The standard procedure of acetolysis (Erdtman, 1943) through the use of 10% aqueous KOH solution, 40% HF and acetolysing mixture (9:1 ratio of acetic anhydride and concentrated sulphuric acid) was employed to extract the pollen/spores from the profile samples. The pollen sums vary from 150-350, depending upon the pollen productivity of the samples. However, the samples from the sandy zone were palynologically barren. The pollen grains of higher aquatic plants, fern spores and algal remains have not been included in the pollen sums. The percentage frequencies of the recovered palynomorphs have been calculated in terms of total terrestrial plant pollen. The plant taxa in the sediments have been grouped as tree, shrubs, herbs, ferns and drifted and are put in the same order in the pollen diagram.

## DESCRIPTION OF POLLEN DIAGRAM

For the precise understanding of the sequential alterations in the vegetation patterns and the corresponding climatic events, the pollen diagram has been divided into two distinct pollen zones, on the basis of fluctuations in the values of some prominent arboreal (trees & shrubs) and non-arboreal taxa (Fig. 2). These pollen zones (RCT-1 and RCT-2), numbering from bottom to top, are prefixed with the initials 'RCT' after the name of the site investigated-Ropan Chhapra Tal. In between them a barren zone devoid of adequate pollen is also identified.

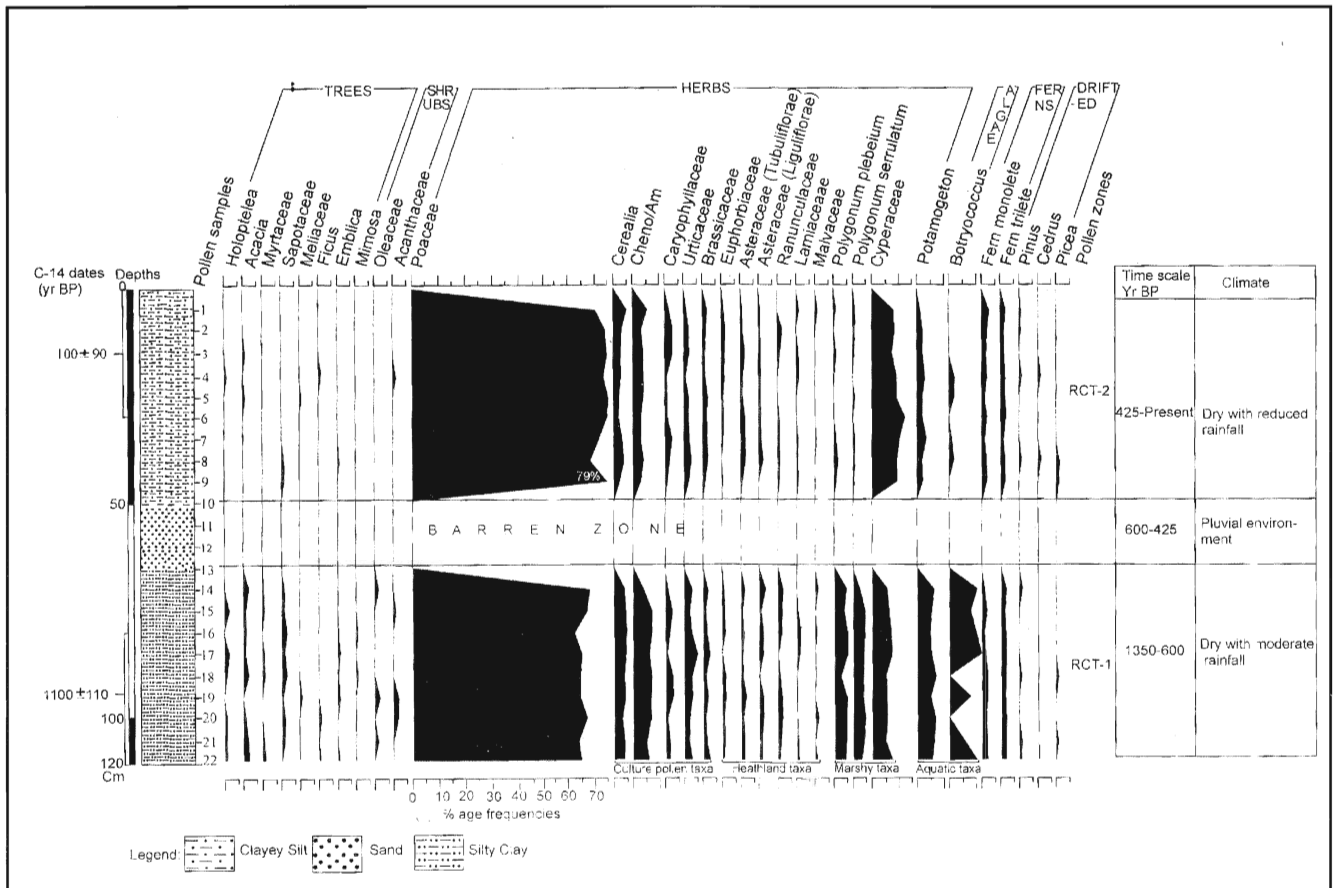


Fig. 2. Pollen diagram from Ropan Chhpra Tal, Deoria District (Uttar Pradesh).

Table 1: Palaeovegetational and palaeoclimatic inferences from Ropan Chhpra Tal pollen sequence.

Period (yr BP)	Vegetation composition and other salient features	Climate	Pollen zones
425 to Present	<ul style="list-style-type: none"> <li>Decline in most of the trees, particularly <i>Holoptelea</i>, <i>Acacia</i>, Myrtaceae, Sapotaceae, Meliaceae, <i>Ficus</i> and <i>Emblica</i> signifies more-sparse open vegetation.</li> <li>Agricultural practice continued with same intensity as before.</li> <li>Lake shrunk and assumed present ephemeral status as inferred by the decline and ultimate disappearance of <i>Botryococcus</i> and other aquatic plants.</li> </ul>	Relatively more dry (reduced monsoon rainfall)	RCT-2
600 to 425	<ul style="list-style-type: none"> <li>No palaeovegetational inferences could be drawn due to paucity of pollen in the sediments.</li> <li>Presence of sand denotes the intense pluvial activity.</li> </ul>	Pluvial environment	Barren Zone
1350 to 600	<ul style="list-style-type: none"> <li>Open vegetation constituted of grasses and Chenopodiaceae/Amaranthaceae with scanty groves of trees viz., <i>Holoptelea</i>, <i>Acacia</i>, Myrtaceae, Sapotaceae, Meliaceae, <i>Ficus</i> and <i>Mimosa</i> occupied the area.</li> <li>Presence of pollen of <i>Cerealia</i> and other cultural taxa denotes cereal-based agriculture practice and human activities in the region.</li> <li>Record of few aquatic plants, <i>Potamogeton</i> and freshwater alga-<i>Botryococcus</i> suggests the existence of a small and shallow lake.</li> </ul>	Dry (with moderate monsoon precipitation)	RCT-1

**Pollen Zone RCT-1 (120-65cm): Poaceae-Chenopodiaceae/Amaranthaceae-Cerealia-Urticaceae-Brassicaceae-Sapotaceae-Acacia-Holoptelea-Cyperaceae-Polygonum-Potamogeton assemblage**

This pollen zone with solitary radiocarbon date of  $1100 \pm 90$  yr BP and covering a time span of 1350 to 600 yr BP reveals the dominance of non-arbores and relatively low frequencies of arbores. Among the non-arboreal elements, Poaceae (58-63%) is recorded in high values, whereas Cerealia (3.5-4.5%), Chenopodiaceae/Amaranthaceae (3.5-6.5%), Urticaceae (2-5%), Caryophyllaceae, Brassicaceae (1-2.5% each), Liguliflorae (1-3%), Tubuliflorae (1-2%) and Ranunculaceae (0.5-2.5%), Euphorbiaceae, Malvaceae and Lamiaceae (0.5-1.5% each) are also the prominent elements of ground flora.

The marshy taxa, Cyperaceae (5-7%), *Polygonum plebeium* (4-0.5%) and *Polygonum serrulatum* (3-5%) are recorded in good frequencies. *Potamogeton* (4-6%), the only higher aquatic plant, is recorded in moderate values. Freshwater alga- *Botryococcus* (6-12%) is frequent.

The arbores are met with sporadically and are marked by moderate to low frequencies of Sapotaceae (1-2%), *Holoptelea*, *Acacia*, Myrtaceae (0.5-1.5% each), *Ficus*, *Mimosa*, Meliaceae and *Emblia* (0.5% each). Fern spores (monoete & trilete 2% each) are consistently present. The drifted elements, *Pinus* and *Cedrus* (1% each) are met with sporadically.

**Barren Zone (65-50cm):** This zone with time bracket of 600-425 yr BP and characterized by the presence of sand is altogether palynologically barren, except for the stray occurrence of grass pollen.

**Pollen Zone RCT-2 (50-0cm): Poaceae-Cyperaceae-Chenopodiaceae/Amaranthaceae-Cerealia-Caryophyllaceae assemblage**

This pollen zone again with lone radiocarbon date of  $100 \pm 90$  yr BP (0-30cm) and encompassing the time interval from 425 yr BP to Present is characterized by the sharp reduction in the number and frequencies of arboreal taxa in comparison to Pollen Zone RCT-1 and they are represented sporadically by *Acacia*, Myrtaceae, Meliaceae and *Ficus* (1% each), *Holoptelea*, Sapotaceae, *Emblia* (0.5% each). Acanthaceae (0.5%) with extremely low frequency is the sole representative of shrubby vegetation.

Among the non-arboreal pollen (NAP), Poaceae (67-79%) attains a maximum frequency in this zone. Chenopodiaceae/Amaranthaceae (2.5-6%), Cerealia (2-5%), Caryophyllaceae (0.5-2.5%), Urticaceae and Brassicaceae (0.5-1.5% each) are encountered consistently, though in lower frequencies than the preceding pollen zone. The heathland taxa such as Tubuliflorae (1-3%) and Liguliflorae (1-2%) are met with statically, whereas Ranunculaceae (1-25%), Lamiaceae and Malvaceae (1% each) are recorded intermittently. The marshy taxon, Cyperaceae (7-12%) exhibits higher frequency in contrast to Pollen Zone RCT-1, whereas *Polygonum plebeium* and *Polygonum serrulatum* decline considerably. *Potamogeton* (4-1%), a sole representative of aquatic vegetation, demonstrates a decreasing trend. Fern spores (monoete and trilete 1-2% each) have slightly reduced values compared to the previous zone. The drifted pollen grains of *Pinus*, *Cedrus* and *Picea* (1% each) have also been recorded scantily in this zone as before.

## DISCUSSION AND CONCLUSIONS

The pollen assemblage data generated through an investigation of 1.2m deep sediment profile from Ropan Chhapra Tal, Deoria District, Uttar Pradesh has helped deduce some interesting inferences concerning the short-term climatic change and contemporaneous vegetation scenarios in this region of the Central Ganga Plan since the last 1350 years (Fig. 2). The study has revealed that during 1350 to 600 yr BP i.e. 650 AD to 1350 AD (Pollen Zone RCT-1), open grasslands vegetation existed in the vicinity of the lake, which was largely constituted of grasses together with members of Chenopodiaceae/Amaranthaceae, Euphorbiaceae, Malvaceae, Lamiaceae and Asteraceae. A few trees such as *Holoptelea*, *Acacia*, Myrtaceae, Sapotaceae, Meliaceae, *Ficus* and *Mimosa* occurred either sparsely distributed or in small groves upon the open grasslands. However, the vegetation diversity was relatively much better than that seen today in this part of the Ganga Plain. Hence, from the large vegetation scenario it is evident that a dry climate with moderate monsoon rainfall prevailed in the region during this period. Retrieval of Cerealia pollen associated with other culture pollen taxa viz., Chenopodiaceae/Amaranthaceae, Caryophyllaceae, Urticaceae, etc., unravels that the region was under agricultural practice and some other anthropogenic activity during this phase. The frequent record of aquatics element, *Potamogeton* together with abundance of freshwater alga-*Botryococcus* suggests that the lake was shallow, but it was certainly wider in expanse than today (Table 1). The climatic inferences deduced from the present investigation have also been substantiated by the pollen record from northeastern Madhya Pradesh (Chauhan, 2005), where the tropical deciduous sal forests flourished under warm and less moist climate around 1600 to 850 yr B.P. An equivalent climatic condition also prevailed during last 1800 yr BP in the Central Ganga Plain (Chauhan *et al.*, 2004) as indicated by the presence of open grassland vegetation. The sporadic record of pollen of high altitude plants like *Pinus* (chirpine), *Picea* (spruce) and *Cedrus* (deodar) indicates their transportation by winds or water from nearby subtropical and temperate belts of the Himalayan region, where these plants occurred abundantly in pure formations.

For the brief time lapse of 600 to 425 yr BP, i.e. 1350 AD to 1525 AD (Barren Zone), no inferences could be drawn concerning vegetation scenario in the region due to lack of adequate pollen, barring a few pollen of grasses. However, the presence of sandy layer at 65-50cm depth in the lithocolumn implies that the sediments might have been deposited in a pluvial environment.

During the phase covering the time bracket from 425 yr BP i.e. 1525 AD to Present (Pollen Zone RCT-2), the open vegetation dominated by grasses continued to grow in the region, however, the arbores (trees and shrubs) diminished severely as well demonstrated by the stray presence of *Holoptelea*, *Acacia*, Myrtaceae, Sapotaceae, Meliaceae, *Ficus* and *Emblia* compared to the preceding phase (Pollen Zone RCT-1). This is also well corroborated by the simultaneous much expansion grasses along with other heathland taxa such as Asteraceae, Lamiaceae, etc. This change in the vegetation composition occurred in response to reduction in monsoon rainfall and consequently a relatively drier climate with reduced monsoon rainfall prevailed in the region, which did not favour

the tree taxa to thrive and regenerate. The lake turned ephemeral and shallow and assumed a smaller dimension owing to harsh climatic conditions. This is well evidenced from the severe depletion in aquatic element, *Potamogeton* and freshwater alga-*Botryococcus*. The much improvement in sedges (Cyperaceae) is indicative of progressive siltation of the lake, leading ultimately its transformation into marshy lowland without perpetual water body. Contrary to this *Polygonum serrulatum* and *P. plebeium* declined sharply by this time as they required much water-logged condition. The climatic implications derived for this time bracket are in agreement with the pollen results from some lakes such as Basaha Jheel (Chauhan *et al.*, 2004) and Kathauta Tal (Chauhan *et al.*, 1990) from the Ganga Plain. Instead of prevailing adverse climatic condition, the agricultural practice continued in the region with almost same intensity as before, probably to cope with the increasing human population in the region during recent past. This is well-indicated by a similar representation cerealia and other cultural pollen taxa as witnessed in the prior phase.

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