
Vegetation and climate during Late Holocene in Garhwal Himalaya

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Pollen analysis of a 5 metre deep profile from Chharaka Tal (Sat Tal) in Garhwal Himalaya has brought out that during 2800-1900 BP mixed conifer-broad leaved temperate forests comprising chiefly *Pinus*, *Cedrus*, *Betula*, *Quercus* associated with *Abies*, *Alnus*, *Salix* and *Carpinus* grew in the region under cool and moist conditions. Later on, during 1900-1200 BP the temperate forests continued but with reduced frequencies of *Pinus*, *Betula*, *Quercus*, *Carpinus*, *Alnus*; sedges, however, improved. This change in vegetation composition reflects deterioration of the climate. The increase in frequencies of sedges indicates transformation of the lake into a swamp. Subsequent to this period, the expansion of *Pinus*, *Cedrus* and *Abies* together with non-arboreal elements, viz., sedges, grasses, *Artemisia*, Ranunculaceae, etc. indicates further deterioration of climate.

Key-words—Vegetation, Palaeoenvironment, Garhwal Himalaya, Late Holocene, India.

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सारांश

गढ़वाल हिमालय में अनंतिम होलोसीन के समय वनस्पति और जलवायु

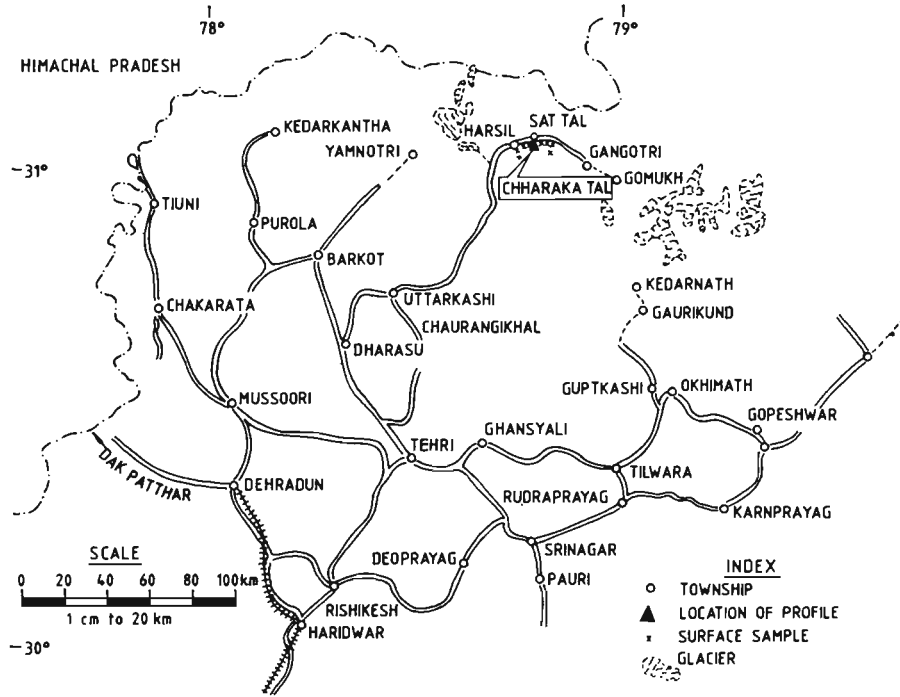
मोहन सिंह चौहान, छाया शर्मा एवं गोविन्दराजा राजगोपालन

गढ़वाल हिमालय में छरका ताल (सत ताल) की एक पाँच मीटर गहरी परिच्छेदिका के परागकण विश्लेषण से यह पाया गया है कि 2800-1900 वर्ष पूर्व इस क्षेत्र में ठंडी एवं नम परिस्थितियों में मुख्यतया पाइनस, सिड्रस, बिटुला, क्वरकस, एबीज, एल्नस, सेलिक्स एवं कार्पाइनस से युक्त मिश्रित कोनिफर-चौड़ी पत्तियों वाले शीतोष्ण वन विद्यमान थे। बाद में 1900 से 1200 वर्ष पूर्व हालाँकि शीतोष्ण वन विद्यमान थे परन्तु पाइनस, बिटुला, क्वरकस, कार्पाइनस एवं एल्नस की संख्या कम हो गई थी परन्तु इसके विपरीत सेजों का आधिक्य हो गया था। वनस्पति में इस प्रकार का परिवर्तन जलवायु में होने वाले परिवर्तन का द्योतक है। सेजों की वृद्धि से झीलों का दलदली परिस्थितियों में बदलना इंगित होता है। इसके बाद पाइनस, सिड्रस एवं एबीज तथा अवृक्षीय अवयवों आदि की वृद्धि से पुनः जलवायु में परिवर्तन इंगित होता है।

COMPREHENSIVE data on the vegetation of Quaternary period is available through investigation of a large number of lacustrine deposits from western Himalaya, viz., Kashmir (Gupta *et al.*, 1984; Sharma & Gupta, 1985; Sharma *et al.*, 1985), Himachal Pradesh (Sharma & Singh, 1974a, 1974b; Sharma, 1985; Sharma & Chauhan, 1988; Bhattacharyya, 1988, 1989) and Kumaon (Vishnu-Mittre *et al.*, 1967; Gupta, 1977; Gupta & Khandelwal, 1982; Chauhan & Sharma, 1996). However, similar proxy data for Garhwal Himalaya, the sector between Himachal Pradesh and Kumaon, remain yet to be generated. Recently, Sharma and Gupta (1995) have studied a Late Holocene profile from Nachiketa Tal, Uttarkashi. The present paper is an effort in this direction to

deduce climatic sequence in the subalpine belt of Garhwal Himalaya covering the Late Holocene period. The present study deals with a 5 metre deep profile from Chharaka Tal of Sat Tal group of seven lakes in Uttarkashi. Seven lakes which constitute Sat Tal are Chharaka Tal, Mardung Tal, Dabur Tal, Ghunt Tal, Rikh Tal, Baman Tal and Lotia Tal.

Sat Tal, as the name indicates, is a group of seven mini lakes situated at an altitude of 3500-4500 m a.s.l., 78 km north-east of Uttarkashi and 7 km east of Harsil near Dharali Village (78° E long.; 31°10'N lat.). Sat Tal area is characterised by lofty mountain ranges with valleys and gorges having mostly the moraine deposits formed as a consequence of intense glaciofluvial activities in the region. The region



Text-figure 1—Sketch map of Garhwal Himalaya showing the area of study.

remains under thick snow cover for major part of the year. Chharaka Tal, a major constituent lake of Sat Tal group, at present is transformed into a big swamp. This lake, about 400 sq metres in area, has almost circular outline (Text-figure 1).

VEGETATION

Pure *Pinus wallichtiana* (blue pine) dense forests occur at the lower altitudes with occasional thickets of *Berberis* sp., *Rubus ellipticus*, *Zanthoxylum alatum*, *Crataegus* sp., *Indigofera* sp., etc. Herbaceous undergrowth marked by scanty patches of *Polygonum* sp., *Potentilla* sp., is seen in certain moist situations and shady depressions. The bluepine forests extend up to the subalpine zone. Pure stands of *Cedrus* and *Abies* also grow in the region.

Besides the overall dominance of bluepine forests, temperate broad-leaved forests comprising chiefly *Betula utilis*, *Alnus nepalensis*, *Quercus dilatata*, *Rhododendron campanulatum*, *R. barbatum*, *Salix elegans* and *Corylus colurna* occur in moist and shady depressions. Main shrubby associates of these forests are *Rosa macrophylla*, *Rubus niveus*, *R. biflorus*, *Viburnum* spp., *Berberis astatica*, *Ilex*

dipyrena, *Cotoneaster microphyllus*, etc. The luxuriant herbaceous vegetation comprises chiefly *Polygonum spectosum*, *Thalictrum chelidoni*, *Paeonia emodi*, *Geum elatum*, *Saussurea taraxifolia*, *Hypericum* sp., *Galtium* sp., *Primula* sp., *Androsace* sp., *Jasminum humile*, *Viola serpens*, *Rumex nepalensis*, *Geranium wallichtianum* and *Anemone rivularis*, etc.

MATERIAL AND METHOD

Material for the present study includes both surface samples and sedimentary profile. Eight surface samples (moss cushions) were collected in a transect at an interval of 50 m from the vicinity of Chharaka Tal to understand the modern pollen/vegetation relationship in the region. Sediments for pollen analysis were collected at 5 cm interval, from a 5 m deep profile from Chharaka Tal, using Hiller's peat auger. Samples for radiometric dating were also collected from this profile.

The sediments in the profile are mainly composed of fibrous peat and organic mud, intermixed with rootlets, silt and sand at different depths. The lithological details are as below:

Depth in metre	Lithology
0-1.00	Fibrous peat with rootlets
1.00-1.20	Fibrous peat with silt
1.20-2.00	Fibrous peat with rootlets
2.00-2.20	Water
2.20-2.50	Fibrous peat with rootlets
2.50-3.00	Fibrous peat with organic mud
3.00-3.50	Decomposed organic mud
3.50-4.00	Decomposed organic mud with charcoal pieces
4.00-4.30	Decomposed organic mud with sand
4.30-4.50	Decomposed organic mud
4.50-5.00	Decomposed organic mud with sand

The solitary radiocarbon date available for this profile at the depth of 3.65-3.75 m is BS-1287 2090±140 BP. Samples from other depths could not be dated owing to insufficient carbon content.

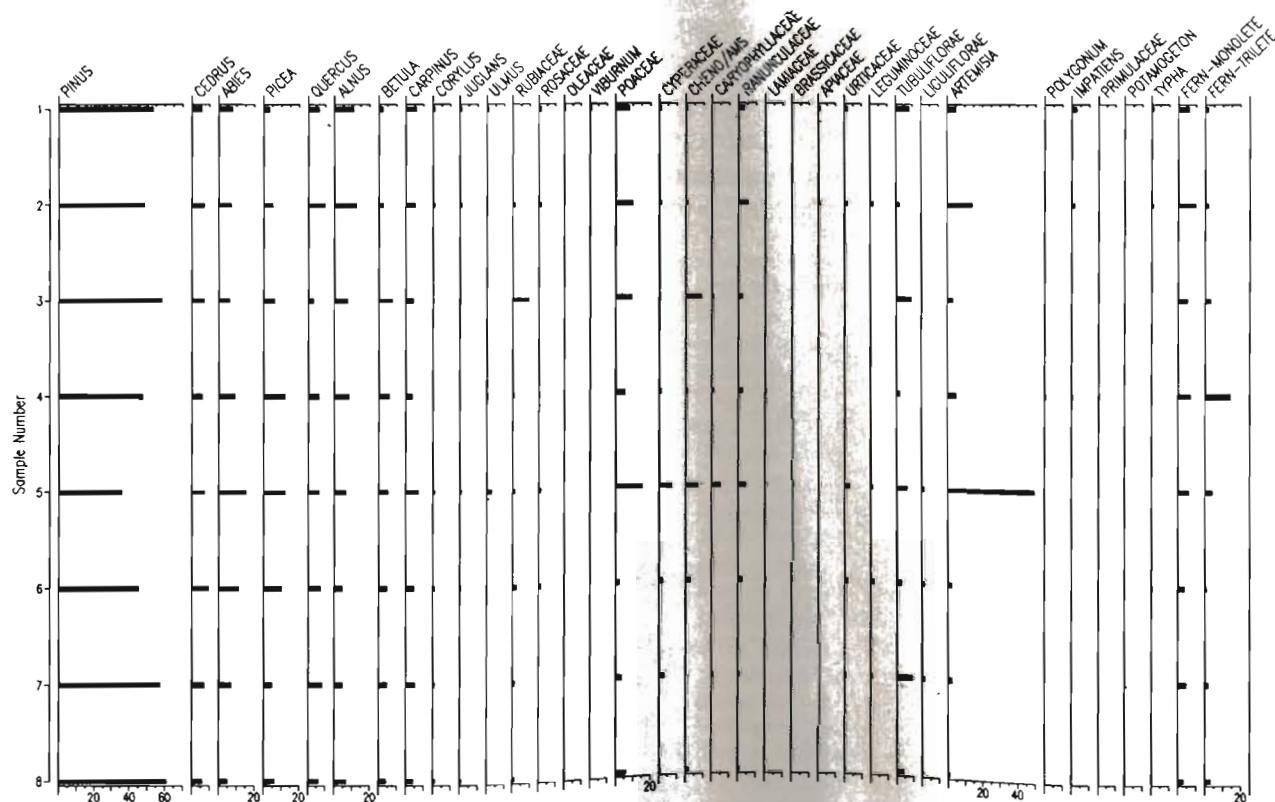
The conventional procedure of pollen analysis (Erdtman, 1943) was employed for extraction of pollen/spores from the surface and profile samples.

POLLEN ANALYSIS

The pollen counts vary from 200-400 for surface as well as profile samples analysed here. The percentage frequencies of the recovered pollen taxa have been calculated in terms of total terrestrial plant pollen. The plant taxa have been categorised as trees, shrubs, herbs and ferns and are arranged accordingly in pollen spectra and pollen diagram.

Modern pollen/vegetation relationship

The pollen assemblage obtained from the study of 8 surface samples from the vicinity of Chharaka Tal (Text-figure 2) has an overall dominance of arboreals over non-arboreals. The high values of *Pinus* (35-62%) correspond with its present dominance in the region, whereas the moderate frequencies of other growing conifers, such as, *Cedrus* (5-9%), *Abies* (5-15%) and *Picea* (5-12%) reflect their patchy occurrence. The representation of some of the broad-leaved taxa, viz., *Quercus* and *Betula* (2-8% each), *Alnus* (5-15%), *Carpinus* (3-7%) too portrays their restricted distribution in the region. However, *Rhododendron*, *Juglans*, *Corylus*, *Ulmus*,



Text-figure 2—Pollen spectra from Chharaka Tal (Sat Tal), Garhwal Himalaya.

and certain other taxa, though growing frequently in the region, are recorded either scantily or absent in the pollen spectra.

Among the non-arboreals, Poaceae (2-15%), Cyperaceae (1-8%), Chen/Ams (1-6%) and Tubuliflorae (2-10%), despite their fluctuating frequencies, do exhibit a consistent representation. *Artemisia* is met with in good values, but its excessively high frequency in sample No. 5 is attributed to local abundance around the province. The frequent occurrence of monolete and trilete spores reveals profuse growth of ferns in the area.

Description of pollen diagram

The pollen diagram (Text-figure 3) constructed from Chharaka Tal has been divided into three distinct pollen zones (CH-I, CH-II and CH-III). The pollen zones are prefixed with "CH" after the name of the investigated site and are described below:

Pollen Zone CH-I (5.00-3.40 m): *Pinus-Betula-Quercus-Carpinus-Abies-Cedrus-Cyperaceae-Poaceae Assemblage*—This pollen zone, with solitary radiocarbon date of BS-1287 2090±140 BP in the upper part and encompassing the time span 2800-1900 BP, reveals the existence of mixed conifer-broad-leaved forests in the region. The major arboreals, *Pinus* (15-55%), *Betula* (8-20%), *Quercus* (8-30%), *Alnus* (2-10%), *Abies* (2-19%), *Cedrus* (4-10%) and *Picea* (2-5%) are represented consistently. Other components recorded in the zone are *Corylus*

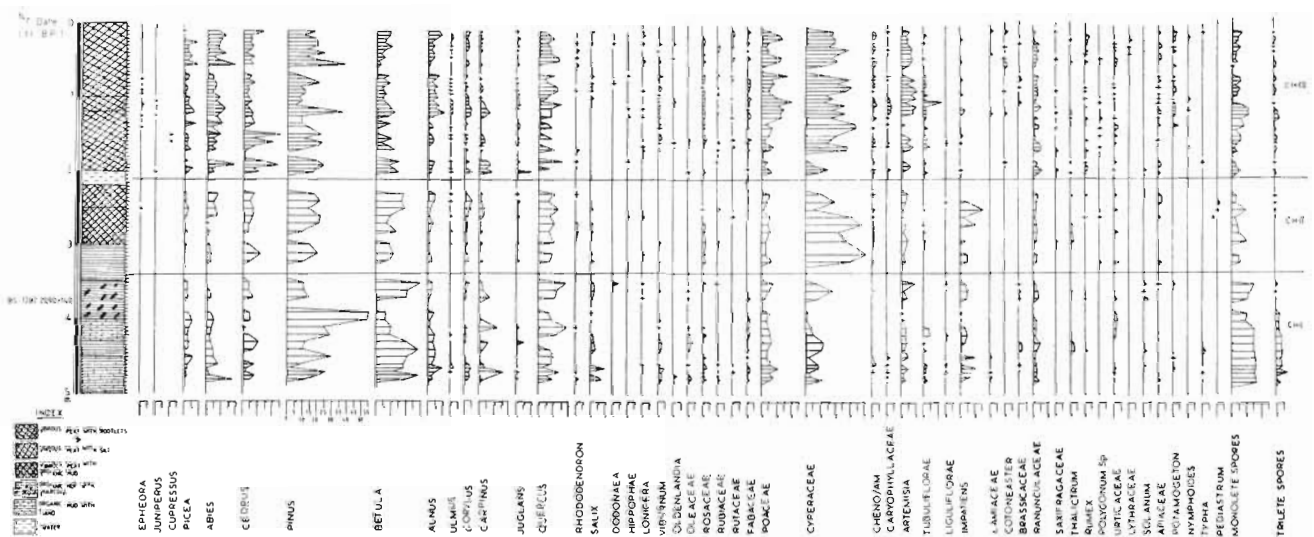
and *Salix* (0.5-5% each) together with shrubby elements—*Viburnum* and Rosaceae.

Among the non-arboreals, sedges (2-11%), Poaceae (3-12%), *Impatiens* (0.5-11%), *Artemisia* (0.5-8%) and Ranunculaceae (2-5%) are the chief constituents. Tubuliflorae (5%), Brassicaceae, *Thalictrum*, Chen/Ams and Urticaceae (2% each) are also represented. Fern spores are present in fairly high frequencies.

Pollen Zone CH-II (3.40-2.10 m): *Pinus-Betula-Quercus-Cedrus-Abies - Alnus-Corylus-Cyperaceae-Poaceae Assemblage*—This phase covering the time span 1900-1200 BP has an almost similar floristic composition as in Pollen Zone CH-I. However, right from the commencement of this pollen zone, an overall decline in most of the arboreals, such as, *Pinus* (7-25%), *Betula* (6-18%), *Quercus* (8-14%), *Abies* (1-7%), *Picea* (2-4%) and *Carpinus* (1-6%) is recorded. *Cedrus* (5-13%), on the other hand, shows an increasing trend.

The herbaceous taxa, such as, Cyperaceae (10-40%) and *Impatiens* (3-15%) also exhibit an increasing trend, whereas Poaceae (4-7%), Caryophyllaceae (2.5-7%) and Ranunculaceae (1-2%) show reduced frequencies than in the Pollen Zone CH-I. Fern spores too are recovered in comparatively lower values.

Pollen Zone CH-III (2.10-0 m): *Pinus-Cedrus-Betula-Quercus-Picea-Alnus-Cyperaceae-Poaceae-Artemisia Assemblage*—This pollen zone covering



Text-figure 3—Pollen diagram from Chharaka Tal (Sat Tal), Garhwal Himalaya.

the time span 1200 BP to the present shows an overall improvement in the non-arborescences with a simultaneous decline in arborescences, particularly the broad-leaved elements—*Betula* (2-15%), *Quercus* (3-13%) and *Salix* (2%). *Alnus* (2-10%) and *Carpinus* (1-10%) too show increased frequencies. The non-arborescences become more frequent in this pollen zone. Cyperaceae (3-35%) maintains its dominance. Poaceae (2-28%), *Artemisia*, Tubuliflorae (2-10% each) and Ranunculaceae (1-7%) exhibit a rising trend. Fern spores are recorded frequently.

HISTORY OF VEGETATION AND CLIMATE

The lithology of the profile from Chharaka Tal shows no variation as it is mainly composed of fibrous peat and decomposed organic mud. Assuming modern age for top of the profile and more or less uniform rate of sedimentation which is approximately 1 cm/5.65 yrs, it could be possible to extrapolate dates at other depths from this profile. The bottom of the profile might be dated to around 2800 BP. Likewise, two more dates, i.e., 1900 BP at 3.40 m depth and 1200 BP at 2.10 m depth have also been extrapolated for the demarcation of the temporal changes in the floristic composition in the region.

The pollen sequence in the investigated profile has brought out vegetational succession and contemporary climatic fluctuations in the region, covering the last 2800 years. It has unravelled that between 2800 to 1900 BP luxuriant mixed temperate conifer-broad leaved forests comprising chiefly *Pinus*, *Betula*, *Quercus*, *Abies* and *Cedrus*, in order of their dominance, existed in the region. Thermophilous broad-leaved elements, such as, *Corylus*, *Alnus*, *Juglans*, *Rhododendron* together with bushes of *Viburnum*, Oleaceae and Fabaceae were other noteworthy associates of these forests. The overall vegetational composition demonstrates that the region during this period was under the influence of moist temperate climate. This is also corroborated by the marked preponderance of fern spores.

Between 1900 and 1200 BP these mixed temperate conifer-broad leaved forests continued to grow in the region without any major change in floristic composition. However, reduced frequencies of major forest ingredients namely *Pinus*, *Betula*, *Alnus*, *Quercus*, etc. denote that the forests became sparse during this period. The decline in forest density

probably resulted as a consequence of deterioration of climate which turned cooler but less moist. This is further supported by sharp decline in ferns. As a consequence to this harsh climatic change, the lowering of lake level and simultaneous transformation of the lake into swampy land commenced. This is quite apparent from the marked expansion of sedges in the area.

For the past 1200 years, mixed temperate conifer-broad-leaved forests have existed in the region except that the conifers like *Abies*, *Picea*, *Cedrus* and *Pinus* have become more prominent. However, most of the broad-leaved taxa, such as, *Betula*, *Quercus*, etc. correspondingly declined except for *Alnus* which improved during this period. The evident expansion of conifers and simultaneous reduction in the broad-leaved taxa demonstrate further deterioration in the climate. The prevailing climatic regime has also led to the transformation of the lake into a swamp, which at present supports copious growth of sedges.

Improvement of grasses together with other ruderal/culture plant taxa, such as, Caryophyllaceae, Chenopodiaceae/Amaranthaceae, *Artemisia*, Tubuliflorae is indicative of increased anthropogenic pressure on the natural vegetation during recent past.

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