

Holocene vegetation and climatic changes in southeastern Madhya Pradesh, India

Studies on the origin and history of tropical deciduous forests distributed in central India have not yet received much attention, except for some information available on this aspect from the north-eastern parts of this region^{1,2}. Here, based on pollen proxy records, an attempt has been made to deduce the seral stages involved in the formation of the present Sal forests in relation to climatic changes during Holocene through the investigation of a sediment core from Dongar-sarbar swamp (81°42'N; 23°6'E), southeastern Madhya Pradesh. This area lies about 25 km east of Jaisinghnagar and 70 km northeast of Sohagpur, Shahdol District, MP. This perennial swamp is big in expanse and is fed by subterranean water.

The vegetation in the region is characterized by the presence of moist and dry tropical deciduous Sal forests³. Floristically, these forests are almost alike in composition. However, in the vicinity of the swamp moist Sal forests consisting of *Terminalia arjuna*, *Anogeissus latifolia*, *Adina cordifolia*, *Syzygium cumini*, *Lagerstroemia parviflora*, *Mitragyna parvifolia*, *Schleichera oleosa*, together with shrubby elements, viz. *Strobilanthes angustifrons*, *Nyctanthes arbor-tristis*, *Clerodendron viscosum* occur frequently. The dry Sal forests are confined to the drier plateau region, mainly comprising *Lannea coromandelica*, *Sterculia urens*, *Acacia* spp., *Boswellia serrata* and *Ziziphus mauritiana*. In addition, the other common trees in both forests are *Madhuca indica*, *Manilkara hexandra* and *Mumusop elengi*.

Materials for the present study include both surface and core samples. Five surface samples (moss cushions) were collected at 50 m intervals from the vicinity of the swamp to study modern pollen/vegetation relationship. A 1.5 m deep core, comprising 27 samples for pollen analysis and two radiocarbon dating samples was also taken from the swamp using Hiller's peat auger. The lithological details of the core are mentioned in Table 1.

Based on the two ¹⁴C dates, i.e. 9470 ± 130 yr BP (130–150 cm) and 3970 ± 70 yr BP (30–50 cm) available

for this core, the sedimentation rate is determined to 1 cm/57 years. This has been used to calibrate more dates, i.e. 9500 yr BP (150 cm), 6800 yr BP (120 cm), 4600 yr BP (80 cm) and 1800 yr BP (30 cm) for the precise delineation of vegetation shifts and climatic episodes in the region. The pollen/spores were extracted from surface and core samples by employing the usual technique of acetolysis⁴.

For surface and core samples, the pollen sum ranges from 200 to 400. The percentages of the recovered pollen taxa have been calculated in terms of total terrestrial plant pollen. The pollen taxa are arranged in an order of trees, shrubs, herbs and ferns in the pollen diagram.

Pollen analysis of five surface samples has shown the dominance of non-arbores (herbs) over arbores (trees and shrubs). The arbores are encountered in low frequencies compared to their actual composition in the forest floristics, except for *M. indica*. *Shorea robusta* (Sal), the dominant ingredient of the modern forests, is met with an average frequency of 3.5%. Similar representation of Sal has also been witnessed in the surface samples analysed from north-eastern MP⁵. The under-representation of Sal could be attributed to poor preservation of its pollen in the sediments irrespective of being a high pollen producer. Besides, *Terminalia*, *Emblica officinalis*, *Syzygium* and *Lagerstroemia* are also extremely sporadic. The erratic representation of these taxa could be inferred to their low pollen productivity, owing to prevalence of entomophily. Furthermore, a large number of trees are altogether absent in the sediments. This comparative database on pollen/vegetation relationship has been used for the appraisal of the pollen diagram in terms of past vegetation and climate from the region.

The pollen diagram (Figure 1) constructed from Dongar-sarbar swamp is divided into four pollen zones (DS-I, DS-II, DS-III and DS-IV), based on the changes in the representation of major arbores and non-arbores. The pollen sequence has shown that around 9500 to 6800 yr BP (DS-I), the tree-savannahs

grew in the region which chiefly comprised grasses, members of Asteraceae and Chenopodiaceae/Amaranthaceae along with a few sparsely distributed trees, viz. *M. indica*, *E. officinalis*, *Symplocos*, *Terminalia* and *Schleichera*. Such a vegetation mosaic implies that this region experienced a cool and dry climatic condition with an ameliorating trend during this phase. This is also substantiated by the presence of coarse-sand with little organic content in the lower part of the core. The adverse climatic and edaphic conditions might have been detrimental for the poor growth and spread of arboreal vegetation. The swamp was big in dimension and overgrown profusely with sedges and *Typha*. A more or less similar type of vegetation scenario was, however, inferred for the later period of 7000 to 5000 yr BP in north-eastern MP¹, possibly due to regional climatic variability.

Subsequently, between 6800 and 4600 yr BP (DS-II), the open mixed deciduous forests succeeded the tree-savannahs with the sporadic invasion of moist tree taxa, viz. *Lagerstroemia*, *Syzygium*, Sapotaceae, *Mitragyna* together with dry ones such as *Aegle marmelos*, *Buchanania* and *Holoptelea*, as well as better representation of *M. indica*, *Terminalia* and *E. officinalis*. The forests seem to be moist deciduous type as evidenced from the frequent occurrence of moist elements. The gradual formation of organic-rich soil might have been conducive for the invasion of these arboreal taxa. Thus, the arrival of more arbores and the expansion of the forest

Table 1. Lithology of the core from Dongar-sarbar swamp

Depth (cm)	Lithology
0–30	Fine sand with blackish organic mud and rootlets
30–80	Blackish organic mud with fine sand, charcoal pieces and plant debris
80–120	Blackish organic mud with coarse sand
120–150	Coarse sand with little organic mud

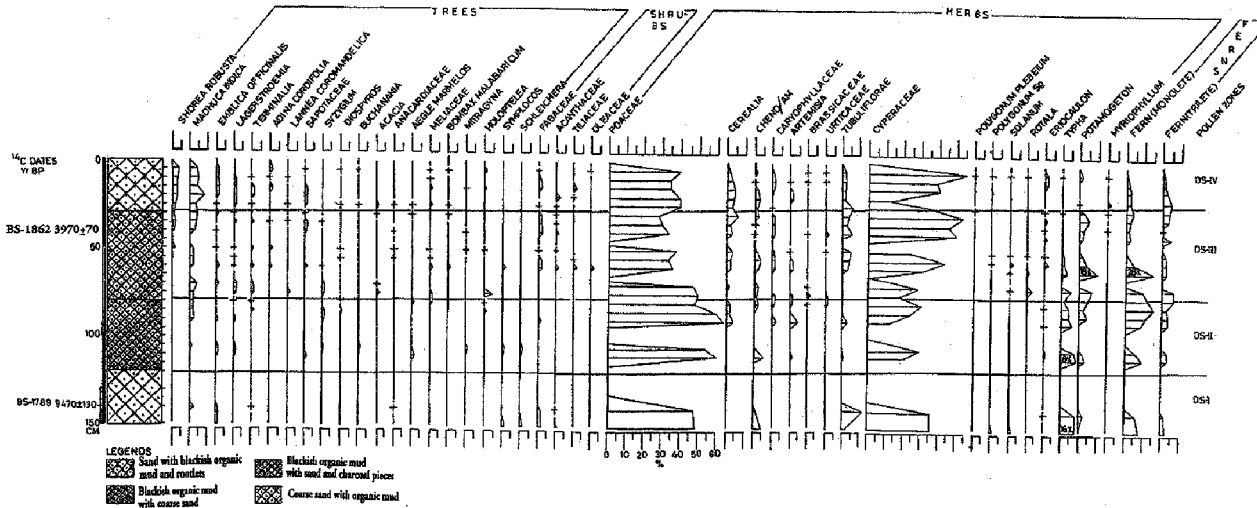


Figure 1. Pollen diagram from Dongar-sarbar swamp, Shahdol District.

floristics obviously envisage the change in climate, which turned to warm and moist. The improvement in the marshy taxa and aquatic element *Potamogeton* denotes the swamp was larger in expanse and highly waterlogged. Chronologically, this phase of the transformation of tree-savannahs into mixed deciduous forests coincides with the Period of Climatic Optimum⁶, which has been witnessed globally around 7000 to 4000 yr BP.

Around 4600 to 1800 yr BP (DS-III), the mixed deciduous forests got enriched with the immigration of some more arbores, viz. *A. cordifolia*, Meliaceae, *Lannea coromandelica*, *Bombax malabaricum*. Besides, other trees such as *M. indica*, *Lagerstroemia*, *Terminalia*, Sapotaceae and *E. officinalis* also became more frequent than before. The most important event of this phase is the advent of Sal, the dominant constituent of modern deciduous forests, in the latter part of this phase, i.e. around 3000 yr BP, though sporadically. This proliferation of the forests with increased diversity and immigration of Sal signify the onset of a regime of active southwest monsoon and consequently moist climate with increased rainfall prevailed in the region.

The tropical deciduous Sal forests came into existence since 1800 yr BP onwards (DS-IV), as clearly manifested by the steady increase in *S. robusta*. It has also become noticeably apparent that the *M. indica*, *E. officinalis*, *Lagerstroemia*, *Terminalia*, *A. cordifolia*, Meliaceae and Sapotaceae were the prominent associates of sal. During this phase of the maximum expansion of these forests, more active inception of southwest monsoon played an important role. It is important to perceive that timely arrival of monsoon contributes favourable conditions, especially for the germination of Sal seeds immediately after their shedding⁷. This becomes of particular significance in view of the limited viability period of the seed of *S. robusta*, only for the duration of about a week after their shedding. The coincidence of the advent of monsoon thus becomes a crucial and decisive factor for the regeneration and proliferation of Sal forests. In the analysis of facts, one may surmise that a warm and moist climatic condition prevailed in the region with high rainfall during this phase of about 1800 years, strikingly in contrast to the preceding times. More or less similar conditions prevail even in the present.

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