# Late quaternary vegetation, climate and land-use history of the Horton Plains, Central Sri Lanka

Premathilake, T.R. Department of Quaternary Research, Stockholm University 10691 Stockholm/Postgraduate Institute of Archaeology, University of Kelaniya. and Epitawatta, D.S. Department of Geography, University of Sri Jayewardenepura, Sri Lanka.

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## Abstract

Two peat sequences from the Horton Plains, an elevated area lying at 2300 m above present sea level (a.s.l.) in central Sri Lanka, are analyzed in terms of pollen content and mineral magnetic properties. Radiocarbon dates indicate that the sequences provide an almost continuous succession of vegetation, climate and land-use history since 18,000 BP. A regional amelioration of the arid Late Pleistocene environment is indicated by the occurrence of herbaceous and summer forest communities. Xerophytic woodlands predominated at the termination of the Pleistocene, about 13,000 BP. At the very end of the Pleistocene an increase in precipitation is identified by the predominance of a montane rain forest (12,00-11,00 BP) Changes in the Holocene vegetation are reflected in two significant rain forest expansion and diversification phases suggesting an increase in precipitation, in the intervals 8000-7000 and 4000-3000 BP. In addition, an arid climate phase occurred from 6000 to 5000 BP and a short wet phase around 600 BP.

The first indications of human impact in the pollen diagram are dated to around 14,000 BP and may be a result of severe deforestation, forest clearance and grazing. The area may have been one of the ancestral homelands for cereal plants. A pre-farming/pastoral culture probably occurred from 14,000 to 10,000 BP, and changes in both human subsistence strategies and the climate, with the start of agricultural land use, are reflected in the presence of pollen of *Hordeum* sp. and *Avena* sp. from 9000 to 6500 BP. Only limited agricultural activity can be identified after this time. From around 3000 BP onwards the area was abandoned, until small-scale *Tritiicum* cultivation took place between approximately 800 and 200 BP.

**Key wards: Pollen, Vegetation, Stratigraphy, Peat, Holocene and Pleistocene**

## 1. Introduction

A joint research project started at the beginning of 1995 between the Postgraduate Institute of Archaeology (PGIAR), Colombo, the Department of Quaternary Research, Stockholm University and the Department of Archaeology and Ancient History, Uppsala University financed by the Swedish Agency for Research Cooperation (SAREC), for the purpose of studying environmental changes on the Horton Plains in the central part of Sri Lanka. The basic objective was to study changes in vegetation, climate and anthropogenic activities during the Late Quaternary (Late Pleistocene and Holocene). An interdisciplinary approach including archaeology, biogeography and the life and earth sciences was established in order to achieve a significant and sustainable capacity for present and future palaeoecological research in Sri Lanka. There is practically no tradition of studying Late Quaternary vegetation and climate history by palaeoecological methods in Sri Lanka, but brief investigations in Ratnapura indicate that myrtal forests were growing during the Middle Pleistocene (Mittre and Robert 1965) and data from a 5 m seiment core covering the last 800 years suggest that the southwestern part of the coastal zone was dominated by mangrove forests (Thanikaimoni 1985). A preliminary palynological study of sediments from the Potana cave site in Sigiriya indicates that slightly more humid conditions prevailed around 5000 BP (Premathilake and Caratini 1994). Evidence of climatic and vegetational changes in India has been obtained from several assessments of the movements of earlier vegetational belts (Vasanthy 1988; Singh *et al.* 1990; Sutra 1997) and palaeo-lakes (Swain *et al.* 1983) All of these were studied by means of pollen and oxygen and carbon isotope analyses of fossil-bearing Late Quaternary sediments in different parts of India. Research carried out in the Nilgiris Hills, southern India, and the salt lakes of Rajasthan, northwestern India, show a sequence of changes reflecting the history of monsoon precipitation. A $\delta13X$ record for the Nilgiris Hills covering the last 20,000 years shows that arid conditions prevailed around 20,000 BP and to a lesser extent around 4000 BP. A wet period culminated around 12,000 BP and to a lesser extent around 400 BP. A wet period culminated around 12,000 BP (Sukumar et al. 1993) Similar results were obtained from $\delta^{13}$ C,$\delta^{18}$O and chemival analyses of groundwater at Neyveli, southeastern India (Sukhija et al. 1998).

The background to the present work emanates from the results of a previous palynological investigation focused on past vegetation changes and human activities in the same area which revealed that the climatic variations ranged from arid to humid conditions and that the area had pre-historic human habitation during the Mid-Holocene (Premathilake 1997). The present work was designed to reconstruct a vegetation, climate and land-use history by bio-. litho-and chronostratigraphical methods, i.e by reference to pollen and spores, mineral magnetic concentrations and ratios, and radiocarbon dates based on two peat sequences.

## 2. Studyarea

### Geography

The Horton Plains, one of the most fascinating areas of Sri Lanka, have been studied by enthusiasts since the late 19th century. The area was designated a National Park for the Preservation of natural montane ecosystems and habitats in 1969. It is situated in the Central Hill region, on an elevated, windswept saddle at an altitude of 2100-2330 m (a.s.l.) and covers an area of 3159.8 ha located between $6^0 47'$ and $6^0 55'$N and between $80^0$ $46'$ and $80^0 51'$E. The Second and third highest mountain peaks in Sri Lanka, Kirigalpotta (2398m) and Totupola (2351 m) rise up from these plains. The area is characterized by a rolling landscape with mires, plains, forested hill tops, grassy slopes, precipices, brooks and waterfaalls. The major rivers in Sri Lanka, he Mahaweli, Kelani and Walawe, all rise on the Horton Plains, and the surrounding area serves as an important catchment for these rivers. The possibilities for finding long-term environmental archives in Sri Lanka are Limited, as the topograπhical situation with relatively steep slopes restricts the accumulation of sediment or peat. The undulating topography of the Horton Plains has allowed peat to accumulate, however.

### Geolgy

The Precambrian crystalline rocks of Sri Lanka occur mostly in the central part, where they comprise a complex of granulites, schists, gneisses, migmatites and granites. These rocks are sub-divided into (a) the Highland series, (b) the Southwestern Group and (c) the Vijayan Complex (Cooray 1978). The Highland series in the Horton Plains area is Pre-Cambrian in age, having been formed during the Archaean (5000-2500- million years ago) and uplifted during Post-Jurassic times (150-136 million years ago).

These rock types suffered folding and plication on vast scales during the Pre-Cambrian (Cooray 1984). The late, mature erosion surfaces or flats, at a mean altitude of 2338 m (a.s.l.), are highly distinctive. The southern boundary of the Horton Plains is formed by a well-defined mural fault scarp, where the Small and Big World's Ends are situated. The bedrock of the area considered here is composed mainly of highly metamorphic rocks belonging to the charnokitemetasedimentary series, consisting in general of metasediments composed of quartzites, garnetiferous gneisses, quartz and feldspar granulites, sillimanite and calciferous strata (Cooray 1991). The quartz-feldspar granulites are metamorphosed sand clays, a group of light-coloured rocks containing quartz and feldspar with varying amounts of mica. The calciferous consist of silica, alumina (clay), magnesium-iron silicate (greyish), calcium-magnesium-iron silicate (green) and mica containing calcium and magnesium (brown). These rocks are the metamorphosed equivalents of sedimentary rocks such as shales, sandstone, non-lithified sandy clays and sand (Fig. 1). The quartz grains may at times be highly elongated and the rock may contain a proportion of feldspar, which is so highly weathered that the material may crumble easily between the fingers (Cooray 1984).

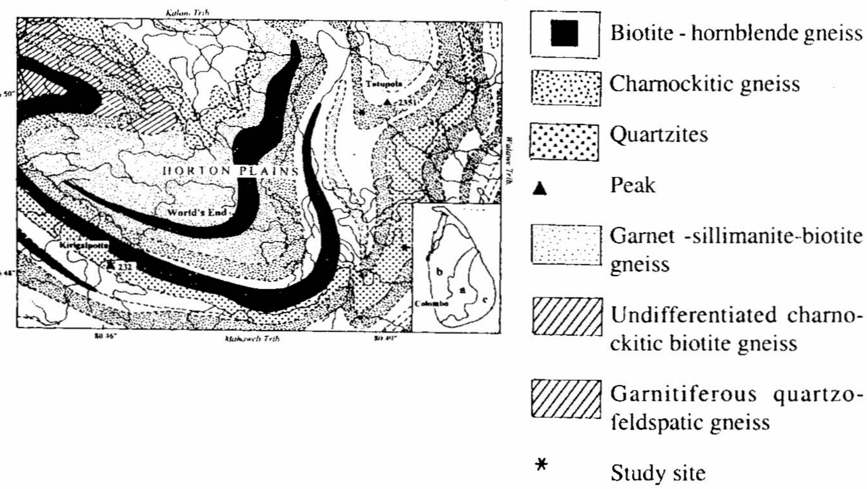


Figure1. Geographical and geological setting of the Horton Plains

## Soil

The dominant soil type of the area is classified as Red-Yellow Podzolic, derived *in situ* from the parent metamorphic rock in the region, and three soil horizons ($A_1$, $A_2$ and B) are prominent (Moormann and Panabokke 1961). The dark brown $A_1$ horizon is less prominent in the forests, where the yellowish-brown A2 horizon is more striking, but on the grasslands it is almost 90 cm deep, acid (pH 4.5-4.7), dark brown in colour and often of colluvial origin (James *et al.* 1968). The B horizon, both in forests and on grasslands, is yellowish-red. The organic carbon content is slightly higher in the uppermost part of the soil.

## Climate

The Horton Plains region is climatically unique in the sense that all varieties of climate represented on the island are reproduced within a small compass, ranging from extremely wet to dry. The area has a mesothermal climate, with a mean February temperature of $12^0$C and rainfall amounting to 2100-2200 mm per year (Thambyapillay 1954, Mueller - Dombois and Perera 1971). Frost is frequent in January and February. Because of the cloudy skies, evapotranspiration is low. Both the southwestern and north-eastern monsoons bring precipitation to the area, the former involving a higher rainfall, which reaches its peak in June, July and August. Since the island is peripheral to the Indian monsoon system, sudden inter-monsoons rains occur in addition to the normal convection controlled by afternoon rains. The northeastern monsoon has hardly any impact upon the plains.

## Vegetation

The vegetation of the Horton Plains consists of upper montane rain forest and grassland. A total of 54 woody species belonging to 31 families have been encountered, 50% of which are endemic to Sri Lanka. Lauraceae, Symplocaceae and Myrtaceae are the dominant families and *Syzygium revolutum, Neolitsea fuscata, Cinnamomum ovalifolium, Symplocos elegans and Calophyllum walkeri* the dominant species (Werner and Balasubramaniam 1992, Balasubramaniam *et al.* 1993) Small and large tree trunks and branches carry thick coats of mosses, such as *Frullania* sp., *Bazzania* sp. and *Sphagnum zeylanicum. Cyathea cinuata* is one example of large tree fern species, and *Lycopdium zeylanicum* and *Psilotum* sp. are also present. The lichen *Usnea barbata,* called "old man's beard", can be seen hanging from the branches of the trees, indicating very clean air. The undergrowth of the forest often consists of dense masses of *Strobilanthes* sp. and is characterized by *Coleus* sp., *Osbeckia parvifolia, Impatiens* spp, *Pseudozytenanthera monadelpha, Davidsea attenuata, Ochlandra stridula* and Poaceae. The grasslands are dominated by *Chrysopogon zeylanicum, Andropogon lividus, Garnotia tectorum and Arundinella villosa.* The "dwarf bamboo", Arundinaria densifolia, an endemic species restricted to the Horton Plains, is among the most frequent species in the moist, shallow valleys. An up-slope movement of the grassland/forest boundary has recently been observed in some areas, a phenomenon referred to as forest die back, and there has been some debate as to whether it can be attributed to human activity, climate or other causes (Balasubramaniam *et al.* 1993.)

**Biotic impact on the vegetation**

The archaeology of the Horton Plains has been examined by Pole (1913), Sarasin (1926), Noon and Noon (1940), Mueller-Dombois and Perera (1971) and Deraniyagala (1972, 1992), who suggest the presence of a Mesolithic culture on the basis of the lithic typology. No detailed archaeological excavations have been conducted in this nature reserve, but Pemadasa and Amarasinghe (1982) suggest on floristic evidence that man has had the most severe deleterious impact, although wild animals (*e.g. Cervus unicolor,* the sambhur) have also played a critical role in the ecological balance of certain communities. The grasslands are probably the most disturbed terrestrial ecosystems within the Horton Plains. A large potato farm was established on the grasslands in 1961, whereupon vast areas were ploughed and prepared for cultivation. Farming continued for almost two decades, but came to an end in 1979, mainly due to protests by environmentalists. Destruction of the grass cover, which was cleared for agricultural purposes *(i.e. potato cultivation),* burning, removal of herbage for animal fodder and grazing by *Rusa unicolor and muntiacus malabaricus* have caused increased erosion and soil impoverishment. A change in the mechanical composition and water relations in the soil has facilitated colonization by weeds (Pemadasa and Amarasinghe 1982), so that the native grass cover has very often been overtaken by many Composition and graminaceous species, the most noteworthy among them being *Eupatorium riparium, Centella asiatica, Anaphalis fruticosa, A. thwaiitesii and A. Pelliculata.* This habitat is a result of human interference. The emergence of *Symplocos spicata and Rhodomyrtus tomentosa* indicates that recent disturbances and clearing have occurred (Perera 1969).

## 3. Material and methods

The aim of this section is to give an overview of the site selection procedure, the materials used and the methods employed. Two sites (mires) were selected for lithostratigraphical and biostratigraphical investigations after a reconnaissance survey within the Horton Plains area. The peat deposits were mapped at 30m intervals along the valleys uning a Russian sampler (Jowsey 1966). The selected sites are characterized by relatively different local conditions, in spite of the short distances between them. Site 1 (Fig 1) is relatively open; so that the pollen spectra obtained can be expected to represent a large pollen source area covering great variety of the habitat contexts (Moore *et al.* 1991 and Lagerås 1996). The lithostratigraphy was investigated at 50 coring points, 36 at Site 1 and 14 at Site 2, and five sediment profiles were produced for Site 1 and four for Site 2. Preliminary sediment an peat classifications were made in the field, and it was noted that herbaceous peat was frequent. Detailed determinations were made in the laboratory on the basis of macroscopic observations. Colour was described by using Munsell Soil Color Charts (1988). Site 2 is relatively small, so that the pollen spectra can be expected to contain a high proportion of extra-local components. All the cores taken were placed in plastic tubes, wrapped in plastic film and stored in a cold room to await further treatment.

**Pollen analysis**

Pollen analysis is one of the most important tools for the palaeoecological reconstruction of geological deposits, particularly organogenic ones, largely on account of the excellent properties of pollen grains, notable (1) their morphological complexity and their resistance and preservation as fossils in geological deposits, (2) the fact that small samples may provide pollen spectra that are statistically representative of specific levels, (3) the well-established taxonomic levels of pollen grains, (4) the ability of pollen spectra to reflect the vegetation and indirectly the climate, human impact and other factors that may affect the vegetation (moore *et al.* 1991). Pollen analysis was considered to be the most suitable method for reconstructing the long-term history of the vegetation of the Horton Plains.

**Radiocarbon dating**

The sequences analyzed at Site 1 and Site 2 were $C^{14}$ dated to obtain independent absolute chronologies. Two techniques were employed: AMS dating of ten bulk samples of sandy peat and conventional dating of three samples (Table 1). The chronology and its reliability are discussed under the section on chronology.

Tabel 1 Radiocarbon dates obtained for Sites 1 and 2, and from a road cutting about 300 m south of Far Inn.

| Depth (cm) | Lab. Nr | Fraction | Age yrs BP | δ 13C | Material |
|---|---|---|---|---|---|
| **Site 1** | | | | | |
| 80 | Ua-16393 | INS | 1025±70 | -24.2 | Peat |
| 160 | Ua-16394 | SOL | 2675±60 | -23.0 | Sandy peat |
| 230 | Ua-16395 | SOL | 3120±70 | –25.7 | Sandy peat |
| 305 | Ua-16396 | SOL | 7935±80 | 18.1 | Sandy peat |
| 420 | Ua-16397 | SOL | 12,970±115 | -25.5 | Peaty sand |
| 487 | Ua-16398 | SOL | 15,045±140 | -25.5 | Peaty sand |
| 540 | Ua-16399 | SOL | 15,045±140 | -25.5 | Org. clay |
| Site 2 | | | | | |
| 170 | Ua- 11126 | SOL | 3865±80 | -26.2 | Peat |
| 245 | Ua-11127 | SOL | 4550±90 | -25.9 | Peat |
| 310 | Ua-11128 | SOL | 6610±45 | -213. | Peaty sand |
| Road cut | | | | | |
| 40-43 | ST14039 | INS | 1320±60 | -12.5 | Sandy peat |
| 40-43 | ST13783 | SOL | 2125±70 | -13.4 | Sandy peat |
| 53-56 | ST13782 | SOL | 6970±80 | -14.6 | Sandy Peat |

### Mineral magnetic analysis

The sequence from Site 1 was analyzed for mineral magnetic properties ($x$, ARM, SIRM, Sratio), with the aim of obtaining information the history of soil erosion, which can be interpreted in term of human activities and/or variations in precipitation.

### Organic carbon and water content

The known volume of bulk material was used to determine organic carbon and water content, using an ELTRA CS 500 simultaneous carbon sulphur analyzer and a freeze dryer respectively.

## 5. Results

### Chronology

The aim here is to highlight the differences in the changes in vegetation, climate and land-use history in space an time within the region. The coring revealed sequences consisting of partially decomposed plant remains and humus, occasionally mixed with fine and/orcoarsegrainedd minerogenic material. The ground vegetation consiists mainly of Poaceae, Cypraceae and *Sphagnum* sp. The peat thickness does not in general exceed 3 m. The stratigraphic profiles were dated by means of the ten radiocarbon determinations reported in Table 1, and the sediment accumulation rates inferred from the radiocarbon records were used to date the intermediate levels by interpolation and extrapolation. The bottom of the sequence at Site 1 is estimated to date from the last glacial maximum (LGM), at 18,000 BP, and the sequence analyzed for Site 2 is correlated with that for Site 1.

### Mineral magnetic analysis

The low ARW/SIRM ratios of 0.05 for the entire core apart from the uppermost 40 cm, where the values reach around 0.075, indicate that all the material is of detrital origin. Similarly, the low, SIRM/$\chi$ ratios ratios point to a coarse, multidomain character for the magnetic grains (Fig 3). Based on these general conclusions, the core was divided into three main units in terms of magnetic concentration (as reflected by $\chi$, ARM and SIRM) and variations in magnetic mineralogy (as reflected by the S-ratio). Magnetic unit 1 probable features various degrees of dissolution of harder magnetic grains, as reflected by the low -Sratios. The middle part (magnetic units 2b and 2c) has higher overall magnetic concentrations, suggesting mineral input to the site caused by the high precipitation.

## Organic carbon content and water content

The organic carbon (Fig. 2), water content and total pollen concentration values are low, indicative of an oxidizing depositional.

## Pollen and spore analysis (Sites 1 and 2)

The analyses of the core sequences from Sites 1 and 2 are shown in a simplified diagram (Figs. 2 and 3). In general, both sites contain a high diversity of pollen types. More than 200 taxa were identified, most of them occurring at low frequencies. Pollen preservation is generally good throughout both sequences, except for two intervals at Site 1 Pollen concentration values are calculated as additional parameters for both sites, and organic carbon curves are also shown (Figs 2 and 3).

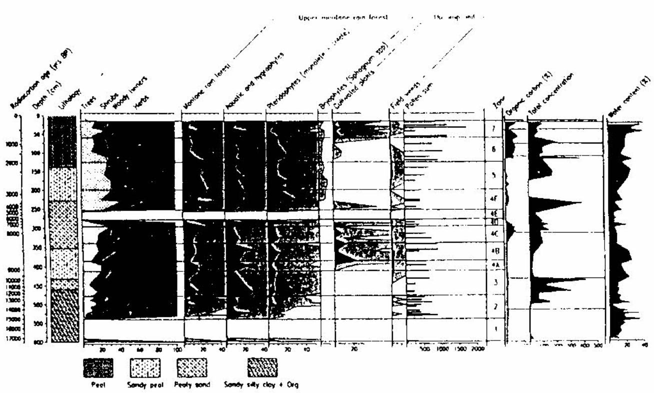

**Figure 2. Simplified pollen diagram for Site 1, together with value for organic carbon, charcoal particles, and water content**

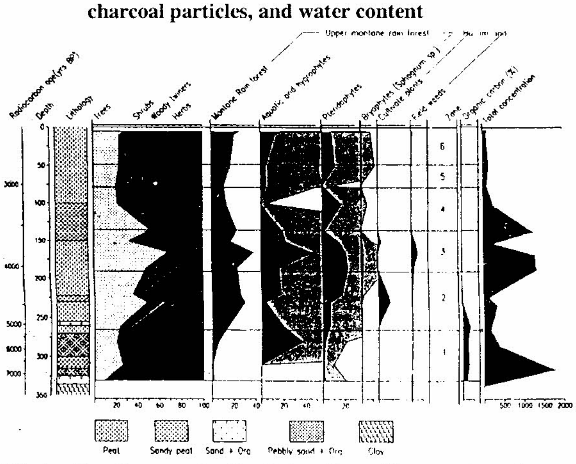

**Figure 3. Simplified pollen diagram for Site 2, together with organic carbon values for the interval 225-330 cm.**

## 6. Discussion

The section is a discussion and synthesis of the results obtained at the site investigated on the Horton Plains. Its aim is to present the changes in vegetation, climate and land-use history of the region. The lithostratigraphical and biotratigrapical evidence presented here reveals a seriies of palaeovegetational patterns, climate changes and phase of land-use from the late Pleistocene to the present. Details of the interpretation were made on full pollen diagrams of both sites.

*Late Pleistocene, >10,000BP*

Both the lithostratigraphy and pollen data indicate an arid and relatively species-poor environment during the Late Pleistocene. The data sets agree with other palaeoenvironmental records for southern and southeastern Asia, which revela an arid and distinctly seasonal Late Pleistocene climate due to the steeper temperature gradient creating a stronger northeasterly monsoon (NEM) (Vasanthy 1988; Sinhg *et al.* 1990; Sukumar *et al.* 1993; Sukhija 1998; Andrews et al. 1998; Van Campo 1986; Overpeck et al 1996; Stuijts et al. 1988; Kealhofer and Penny 1998; Van Campo 1986; Overpeck *et al.* 1996; Stuijts *et al.* 1988; Kealhofer and Penny 1998; Hope and Tulip 1994; Kaars *et al.* 2000). The low pollen frequency of the Late Pleistocene vegetation seems to represent a measure of seasonality, which could be evidence for the orbital forcing events suggested for adjacent regions (Kanari *et al.* 1984; Sukumar et al. 1993; Overpeck et al. 1996). The diversification of dry forest at the termination of the Pleistocene, around 13,000 BP (xerophytic woodlands: LPAZ 2, Site 1), indicated by the pollen data presented in Site 1 would suggest an easing of this temperature gradient. The abrupt increase in humid forest reveals a high availability of moisture up to about 11, 750 BP (lower boundary of LPAZ 3 at Site 1). Van Campo (1986) and *Overpeck etal.* (1996) report a similar climatic amelioration based on pollen data from the Arabian Seaindicating a peak in the SWM. The decline in the humid forest around 10,400 BP points to a cooler climate and a significant reduction in SWM preciptiation. Similarly, Van Campo (1986), Sukumar *et al.* (1993) and Sukhija (1998) Provide palaeoclimatic data based on pollen studies that indicate weak SWM precipitation.

*Early Holocene 10,000-7000 BP*

The diversification of the temperate rain forests between 10,000 and 7000 BP suggested by the pollen data presented here would imply an increase in precipitation (LPAZ 4B-C). This period was followed by several dry, cool episodes. This observation matches with the strengthening of the SWM and higher mean temperature reported for this period by Sukumar *et al.* (1993) and the cool, arid to semi-arid climatic conditions reported for the Indian landmass by Srivastava *et al.* (1998). Similarly, Sukhija (1998) mentions this palaeoclimatic change from arid to humid conditions.

*Mid-Holocene 7000-4000 BP*

The decline in the montane rain forests reflects change in climate from humid to arid (LPAZ 4 D-E, Site 1, and LPAZ 1, Site 2). The most probable time for this arid climate was between 6000 and 5000 BP, especially in view of the corresponding climatic conditions recorded by Sukumar et al. (1993) and Srivastava et al. (1998) in the Indian subcontinent during the period 5000 - 3000 BP and around 6,500 BP respectively. Yonebayashi and Minaki (1997) report dry and wet phases in eastern Nepal in the period between 11,000 and 1,600 BP, and the present results are in quite good agreement with these records as far as the weakening of the SWM over the central part of Sri Lanka is concerned.

*Late Holocene 4000 BP - Present*

The hydrological changes posited on the basis of the rapid development of humid forests indicate an increase in SWM rains around 3000 BP, and coincide with observations by Kealhofer and Penny (1998) suggesting the rapid development of herbaceous swamps in northeastern Thailand during the Late Holocene. A decrease in humid forest around 1000 BP reveals a weakening of the SWM monsoon rains and prevailing cool, dry conditions.

Bonnefille and Mohammed (1994) provide evidence of cooler climatic conditions is the mountains of southeastern Ethiopia during the period 3000-2000 BP, and Vasanthy (1988) reports similar palaeoclimatc data for Nilgiris. The general increase in humid forests indicates higher precipitation, while the great abundance of humid forest around 600 BP suggests a major increment in the monsoon rains.

**Land - use history**

The first indications of human impact in the composition of the pollen diagram are dated to approximately 14,000 BP (LPAZ 2 at Site 1), where pronounced fluctuations in both arboreal and non-arboreal taxa point to forest clearance and grazing, which may be aresult of human activity at that time. The occurrence of pollen of *Plumbago zeylanica,* a very characteristic species in anthropogenic localities, provides further evidence of a human presence. The occurrence of "uncertain" cereal-type pollen in LPAZ 2 could be discussed in relation to the process of domestication of cereal plants. The identification of these grains as cultivated types must be based on several criteria. Domestication process played an enormous rde in te development of prehistoric man and his material culture.Several authors have discussed the presence of humans in the central part of Sri Lanka during the Mesolithic, but without giving any information regarding the exact time (Pearson 1899; de Rosayro 1946; Chapman 1947; Holmes 1951; Szechowycz 1954; Koelmeyer 1957; Deraniyagala 1972, 1992; Manatunga 1994). The present findings support these statements, since the domestication of cereal plants demands the presence of humans. Uncertain cereal-type grains do not necessarily pont to "cereal cultivation", which took place around 14,000 BP on the Horton Plains, but a certain relationship can be traced in connection with the process of heredity reorganization in wild and domestic plants, possibly marking the beginning of the process of domestication of cereal plants *(Hordeum sp. and Avena sp.)* and a primitive stage of farming/pastoral cuture. It would also be valuable to discuss the transformation from wild plants to domestic ones, i.e. the transition from a Mesolithic to Neolithic culture. The theories advanced by Trimen and Hooker (1890), Reman (1988) and Senewiratne and Appadorai (1966) support a detailed discussion of the process of domestication on the Horton Plains. Several authors (Gupta and Prasad 1985, Singh 1971; 1990, Hope and Tulip 1994, Michaels 1999) have a;sp siggested that different stages on far,omg activities were observable on the Indian sub-continent and in Irian Java and Taiwan during the period between 14,000 and 10,000 BP. Similarly, the pollen records for the Horton Plains are in quite good agreement with the notion of a pre-farming cultural transformation on the Horton Plains, more investigations would be needed into cytogenetic, and particularly genetic, aspects of the cereal plants, and also detailed archaeological and palaaaeoecological investigations.

The first "real cereal" cultivation detected here is dated to about 9000 BP, from which point onwards the pollen diagram for Site 1 (LPAZ 4A-D) shows cereal cultivation up to around 6500 BP. This matches with the decline in woody vegetation corresponding to forest cleaarance and deforestaiton. The evidence of grazing indicates that animal husbandry occurred alongside cereal cultivation. The start of farming in India is similarly observed around 9500 BP (for swiddening in Rajasthan), 8000 BP (the Neolithic at Koldihwa, near Allahabad), or 6400 BP (Bagor; Singh 1971 and Agrawal et al. 1975). The period between 6500 and 3000 BP in LPAZ 4F at Site 1 and LPAZ 2 at Site 2 shows a weak representation of cereal pollen types and other indicators of human impact, suggesting a decline in agricultural activity, although this may have persisted on a small-scale and/ or at an extra-regional level. Parallel with this there is an increase in the rain forest cover over the area, culminating around 3000 BP, apparently due to the lowering of the human pressure and an increase in precipitation. The occurrence of high concentrations of magnetic minerals also provided evidence of soil erosion.

The pollen diagrams for the two sites contain no indication of cereal cultivation between 3000 and 800 BP, suggesting that the Horton Plains area was abandoned then. This could also be explained by the climatic conditions, *i.e.* high precipitation, which could have badly affected the cereal plants. After this period, however, an important change in the agrarian context can be observed in the pollen diagram for Site 1 (LPAZ 7), with the introduction of *Triticum* cultivation, dated to around 160 BP. This is supported by evidence of small-scale deforestation and soil erosion traceable in the pollen diagram, combined with a significant appearance of *Berberis* sp. and *Nandina domestica.* It is *possible* that small- scale *Triticum* cultivation had started on a regional and extra-regional basis.

## 7. Conclusions

The broad trend in palaeoenvironmental evolution seems to have been captured in the peat sequences analyzed here from the Horton Plains, providing a key to the climatic shifts and human activities that took place since the LGM (18,000 BP). The pollen records suggest an arid, relatively spcies-poor environment during the late Pleistocene, while dry forests (xerophytic woodlands) predominated at the termination of the Pleistocene about 13,000 BP. At the very end of the Pleistocene an increase in precipitation is identified by the predominance of a montance rain forest (12,000 - 11,000 BP). The two significant rain forest expansion phases during the Holocene, dated to 8000-7000 and 4000-3000 BP, suggest increases in precipitation. In addition, an arid climate phase was observed from 6000 to 5000 BP, and a short wet phase around 600 BP.

The first indications of human impact are dated to around 14,000 BP, reflecting forest clearance and grazing. It is possible that the Hrton Plains acted as one of the ancestral homelands for creal plants (*Hordeum* sp. and *Avena* sp.) A pre-farming/pastoral culture prevailed from 14,000 to 10,000 BP, but the first real agricultural land use is suggestedfrom 9000 to 6500

BP. After this time only few agricultural activities acan be identified, continuing until about 3000 BP. Then the area was abandoned for some time, until it was used for small scale Triticum cultivation between 800 and 160 BP. Lauraceae, one of the dominant families in the present vegetation, could not be recognized in the samples, possibly because its pollen grains have a very thin, fragile exine, which is not preserved as fossil. Finally, the work provided answers to some questions related to natural and cultural changes and certain archaeological findings in the central part of Sri Lank. Many problems remain to be answered in future research, however, such as the diversity of the prehistoric environment in different topographical and environmental areas in Sri Lanka.

## 8. Acknowledgements

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