Vegetation dynamics in western Uganda during the last 1000 years: climate change or human induced environmental degradation?

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Abstract

A multi-proxy analysis of microfossils from sedimentary records, together with evidence from historical and archaeological data, has provided evidence of vegetation dynamics and human environment interactions in western Uganda for the last 1000 years. Pollen, fungal spores and phytoliths extracted from sediment cores obtained from a papyrus swamp at Munsa archaeological site indicate a relatively wet and forested environment in western Uganda prior to ca 1000 yr BP (cal 977–1159 AD). A subsequent decline in forest vegetation occurred from ca 920 yr BP (cal 1027–1207 AD). However, the deforestation period occurred during a wet period as registered in the River Nile water records, suggesting a human induced deforestation at Munsa rather than reduced precipitation. Increased numbers of herbivores, presumably domesticated cattle, postdeforestation are evidenced by the presence of dung fungal spores and broad accord with the archaeological evidence for initial occupation of the site at Munsa and the establishment of a mixed economy based on crops, cattle and iron working between 1000 and 1200 AD. From ca 200 yr BP (cal 1647–1952 AD), forest recovery occurred at Munsa site and appears to reflect abandonment of the site, as suggested by archaeological evidence, possibly following a period of prolonged drought and famine between 1600 and 1800 AD, as recounted in the oral rich traditions of western Uganda and also reflected by low water levels of River Nile.

Key words: environmental degradation, vegetation dynamics, western Uganda

Introduction

The relationship between environmental, including climatic, changes and development of complex societies and associated socio-economic and cultural changes within what is today Uganda has been the major focus of recent research studies in the region (e.g. Robertshaw & Taylor, 2000; Lejju, Taylor & Robertshaw, 2005; Ssemmanda *et al.*, 2005). Archaeological records in western Uganda, including historical linguistic research (e.g. Shinnie, 1960; Posnansky, 1969; Schoenbrun, 1993a,b, 1998; Sutton, 1993; Reid, 1996; Robertshaw, 1994; Robertshaw *et al.*, 1997) have provided evidence of demographic, political and economic history of the region for the last 1000 years. Palaeoenvironmental data in the form of pollen and charcoal records have also provided evidence of vegetation dynamics and landscape development in western Uganda (e.g. Taylor, Marchant & Robertshaw, 1999; Lejju *et al.*, 2005; Ssemmanda *et al.*, 2005). Previous attempts (e.g. Taylor, Robertshaw & Marchant, 2000) to link environmental changes to human interactions in the region have proven problematic, because of the spatial separation of the various sources of evidence. This study aims to solve the difficulties encountered in attempting to combine and interpret evidence from geographically and ecologically widely separated sources by providing new and comprehensive palaeoenvironmental data from a papyrus (*Cyperus papyrus* L.) dominated swamp situated within the perimeter of a major archaeological site at Munsa in western Uganda. The reconstruction of vegetation dynamics is presented based upon several proxies, encompassing the phase of human settlement at Munsa site and evidence of climatic changes based on water level changes available for River Nile.

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Materials and methods

Study site

The archaeological site at Munsa is located in the south-eastern part of the precolonial state of Bunyoro, Uganda (Fig. 1: 0°49′30′N; 31°18′00′E). The site occupies about l km^2 of land ranging in altitude from 1220 m above mean sea level (a.m.s.l) to the 1340 m a.m.s.l (Lanning, 1955). The site consists of settlement debris, burial site, rock-shelters and evidence of iron working and grain storage centred upon Munsa Hill and surrounded by three concentric rings of earthworks in the form of trenches.

Rainfall at Munsa is bimodal, with two wetter periods during the year determined by the annual cycle of circulation over the Indian Ocean (Hastenrath *et al.*, 1993; Hastenrath, 2001). Rainfall is also influenced by irregularly occurring ENSO-related phenomena (Phillips & McIntyre, 2000). According to the Atlas of Uganda (1967), Munsa receives a mean annual rainfall of 1331 mm. The vegetation surrounding Munsa is today characterized by a patchwork of small cultivated fields, interspersed with remnants of Medium Altitude Semi-Deciduous Forest (Lejju *et al.*, 2005). Patches of elephant grass (*Pennisetum purpureum* Schumach.) dominate the grassland in association with guinea grass (*Panicum maximum* Jacq.) and spear grass (*Imperata cylindrical* Beauv.), which represent abandoned farmland and an early stage in the recovery of forest.

Archaeological evidence suggests that Munsa site was occupied from at least 1000 AD and ceased around the end of the 1800s AD (Robertshaw, 1997) noted that Robertshaw (1997, 2001), the earthworks at Munsa appear to have been constructed between ca 1400 and 1650 AD and,

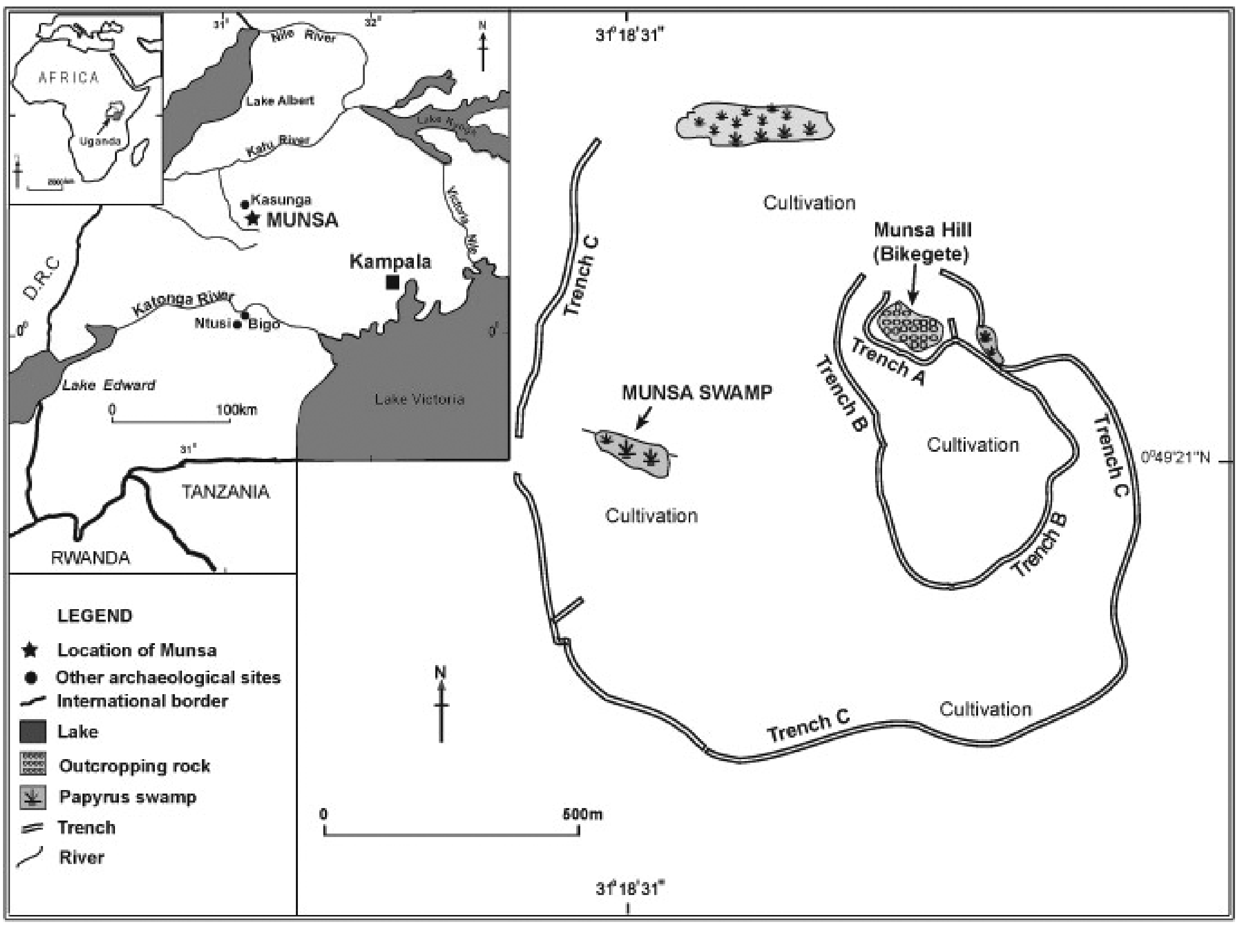

Fig 1 Location of Munsa study site in western Uganda; Inset is map showing the trenches surrounding Munsa Hill (Bikegete), photographed top right

their construction may relate to the emergence in the region of complex chiefdoms (Robertshaw, 1997; Robertshaw & Taylor, 2000), founded upon agriculture with some cattle keeping. Archaeological evidence also suggests that permanent settlement at Munsa ceased around the end of the 17th century AD and its abandonment is believed to have been part of major economic, political and social upheavals that brought about a shift in settlement patterns from nucleated villages to dispersed homesteads (Steinhart, 1981).

Cores M2C1 (130 cm long) and M2C2 (177 cm long) were collected, respectively, at'O.5m and 5 m from the edge of Munsa II swamp using a Livingstone (piston). Munsa II swamp is a relatively small swamp (ca 130×26 m) in the westernmost part of the archaeological site enclosed by Trench C (Fig. 1). The samples constituting of macrofossil plant materials and bulk sediments (Table 1) were dated at Beta Analytic Inc. Miami, U.S.A. using AMS ^{14}C method and calibrated using the radiocarbon calibration program Calib 4.4 and calibration curve INTCAL 98 (Stuiver & Braziunas, 1993; Stuiver *et al.*, 1998).

Pollen and fungal spores were concentrated following the standard procedure described by Faegri and Iversen (Faegri & Inversen, 1989). Identification of pollen and fern spores was based largely on the reference collection of African pollen types in the Department of Geography at Trinity College, Dublin. Fungal spores were identified according to van Geel (van Geel, 1982, 1986). The level of confidence in identification follows the system of Stockmarr (1971). Variations in abundances of microscopic charcoal in samples previously prepared for pollen analysis and including a known quantity of exotic (*Lycopodium*) spores were quantified using the point count method (Clark, 1982). Enumeration of charcoal was restricted to black, completely opaque and angular fragments with a long axis >7.5μm (Clark, 1982; Patterson, Edwards & Maguuire, 1987; Clark, 1988).

Microfossil phytoliths were extracted from the core samples following a slightly modified version of the standard procedures described in Piperno (1988) and Pearsall (2000). Phytolith morphotypes were identified according to Twiss, Suess & Smith (1969), Rover (1971), Piperno (1988), Mbida *et al.* (2001) and on the basis of voucher material extracted from specimens collected in the study area. Collection of voucher specimens focused on agricultural plants, particularly those that are of economic importance locally, but are not usually recorded in pollen records.

Results

Sediment chronology and δ^{13}C values

AMS ^{14}C ages for Munsa II cores are stratigraphically consistent and range from 1590 ± 40 yr BP from a bulk sediment at the base of M2C1 to 180 ± 30 yr BP for macrofossils from 30–31 cm in the same core (Table 1). Calibrated dates (cal AD) shown in Table 1 and the extrapolated and interpolated ages depicted in Figs 2–4 are based on age–depth relationships for the two cores. According to the age–depth relationships, sediments in cores M2C1 and M2C2 contain a record of past environmental conditions at Munsa for the last ca 2000 and ca 1250 years respectively. δ^{13}C values established along with AMS ^{14}C dates are within the range expected for C_3 or C_4 sources for organic carbon 4. The most negative values indicate a predominantly C_3 source such as forest taxa for

Table 1 AMS radiocarbon dates and Ol3C %0 values for cores M2C1 and M2C2; AMS dates were calibrated using the INTCAL, 98 radiocarbon age calibration programme

Sediment core	Laboratory number	Depth (cm)	Conventional 14C age (yr BP)	Calibrated 14C age rAD :I: 201	13C/I2C (013C %0) values	Type of material dated
M2C1	Beta-185992	30–31	180:1: 30	1654–1949	−14.3	Plant macrofossils
M2C1	Beta-185993	50–51	750:1: 40	1212–1378	−13.2	Plant macrofossils
M2C1	Beta-185994	74–75	900:I: 40	1032–1217	−16.0	Plant macrofossils
M2C1	Beta-185995	106–107	1590:1: 50	356–599	−26.8	Bulk sediment
M2C2	Beta-185996	26–27	240:1: 30	1527–1947	−22.4	Plant macrofossils
M2C2	Beta-175374	50–51	430:I: 40	1412–1521	−13.4	Plant macrofossils
M2C2	Beta-175375	105–106	700:1: 40	1244–1393	−10.9	Plant macrofossils
M2C2	Beta-175376	134–145	940:1: 40	1019–1189	−28.8	Plant macrofossils

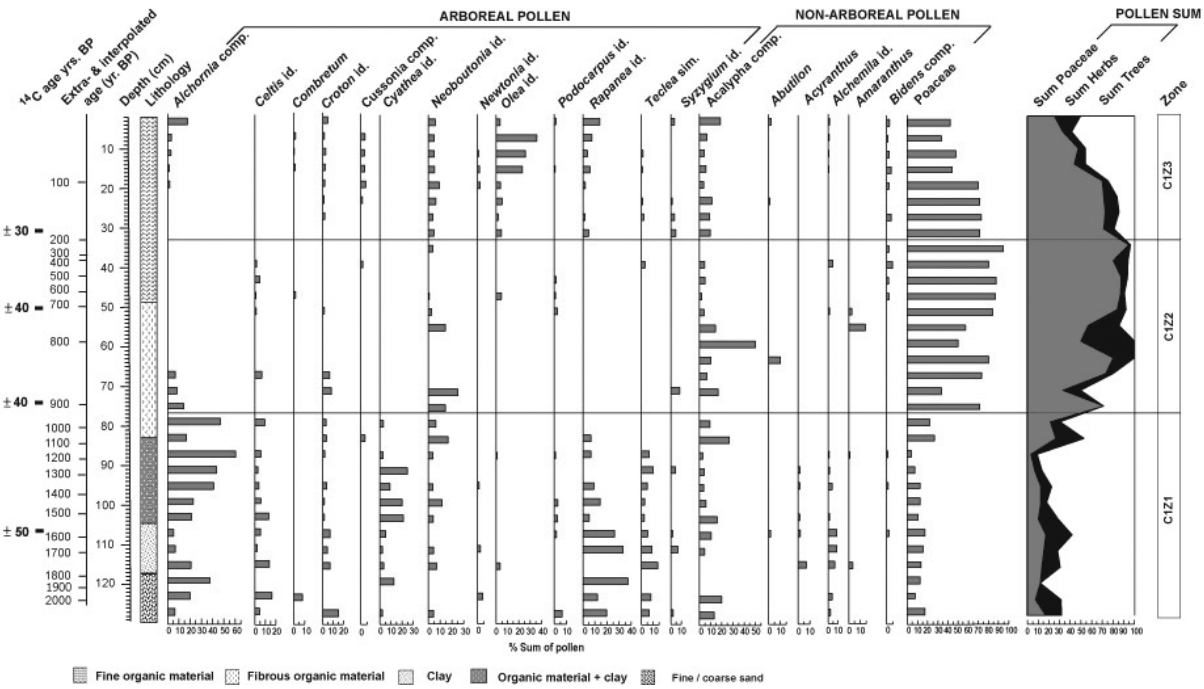

Fig 2 Summary of down-core variation in abundance of major subfossil pollen taxa for core M2C1

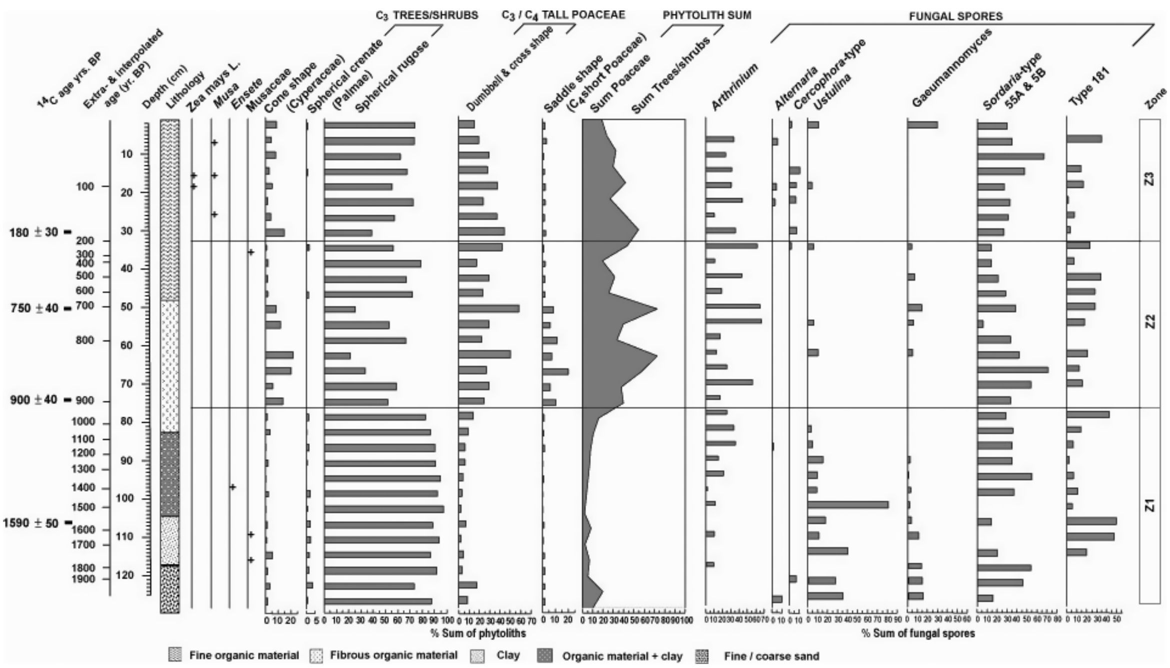

Fig 3 Summary of down-core variation in abundance of subfossil phytoliths for core M2C1

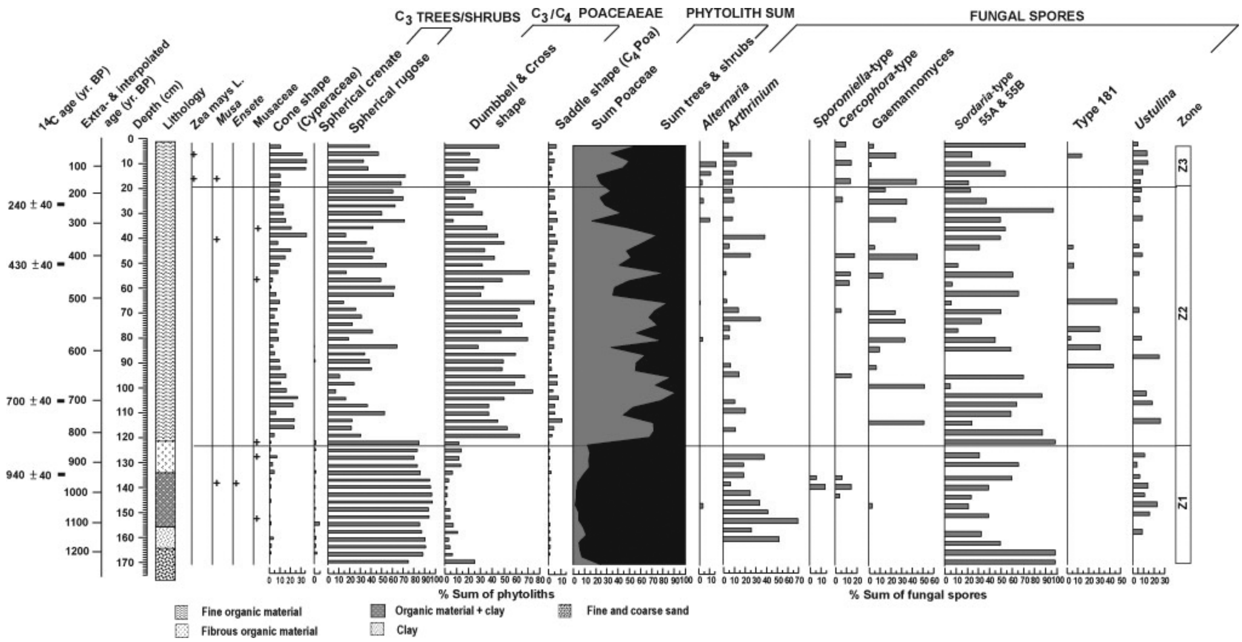

Fig 4 Summary of down-core variation in abundance of subfossil phytoliths and fungal spores for core M2C2

organic carbon from towards the base of the two cores. Less negative values are generally associated with the uppermost organic-rich sediments and appear to represent a C_4 source, such as grasses and papyrus, or the incorporation of aquatic material.

Microfossil pollen, spores, phytoliths and charcoal

Down-core variations in sub-fossil data are illustrated in Figs 2–4 and have been zoned according to the differences in pollen content. Three major pollen zones (Z1–Z3) are recognizable across the two cores analysed and are grouped into two major phases of environmental changes at Munsa.

Vegetation dynamics at Munsa from ca 2000–1000 yr bp

This period is represented by *Pollen Zone, Z1* dated ca 2000–1000 yr BP in M2C1, and ca 1300–830 yr BP in M2C2. The zone represents the occurrence of forested environment at Munsa prior to the development of a papyrus-dominated swamp, with relatively little burning of vegetation locally. The zone is characterized by relatively high proportions of pollen (>50% of the pollen sum) from taxa that are today associated with medium altitude semi deciduous forest, such as *Alchornia*, *Celtis*, *Crotfon*, *Neoboutonia*, *Olea*, *Podocarpus* and *Teclea.* Relatively small amounts of *Acalypha* and Poaceae characterize nonarboreal pollen counts. *Ustulina* dominates fungal spore counts and supports the presence of forest environment as it is associated with forest trees and causes soft-rot of dead wood (van Geel, 1986).

Charcoal concentrations are generally very low, reflecting a low incidence of burning, although they increase from ca. 1400 yr BP (ca 562–689 AD) in M2C1. Phytolith assemblages in pollen zone Z1, resembling those produced by forest taxa (spherical rugose morphotypes), are abundant, thus supporting the pollen evidence for the presence of forest in the catchment at Munsa (Figs 3 and 4). The proportions of morphotypes associated with members of the Palmae (spherical crenate) and C4 members of the Cyperaceae (cone-shaped) are very low. Poaceae morphotypes are also poorly represented in zone Z1. Phytoliths with morphologies similar to those of *Musa* and *Ensete* were occasionally recorded in samples dating to this zone.

Vegetation dynamics at Munsa ca 1000–200 yr bp

Pollen zone Z2 is dated ca 920–200 yr BP in M2C1, and ca 830–180 yr BP in M2C2. According to the pollen and spore data (Fig. 2), the zone appears to represent the replacement of forest with more open forms of vegetation in which members of the Poaceae make an important contribution, superimposed upon which were relatively minor phases of forest recovery. Spores of the fungi *Ustulina* decline relative to zone Z1; counts in the lower part of zone Z2 are instead dominated by fungal spores from *Cercophora* and *Sporomiella*, which today are associated with the dung of herbivores (van Geel, 1982, 1986; Davies, 1987). The phytoliths indicate similar fluctuations to the pollen; varying though generally lower abundances of spherical rugose morphotypes than zone Z1 reflect a significant reduction in the extent of forest around Munsa interrupted by phases of forest recovery. The abundances of Cyperaceae phytoliths and pollen increase in this zone, representing the occurrence of papyrus-dominated swamp at the coring sites, as does the dumbbell bilobate morphotype of tall members of the Poaceae (both C_3 and C_4 types). Phytoliths with morphological similarities to Musaceae are absent from the lower part of this zone and only reappear after ca 700 yr BP (cal 1244–1393 AD). Evidence of increased abundances of charcoal overall suggests that fires were associated with the reduction in forest cover possibly because of increased agricultural activities.

Vegetation dynamics at Munsa ca 200 yr bp to present

Pollen zone Z3 is dated from ca. 200 yr BP (ca 1647–1948 AD) in M2C1 and from 180 yr BP (ca 1654–1949 AD) in M2C2 to the present. The zone represents some recovery of forests around Munsa and a reduced importance of burning. Pollen and spore assemblages are marked by increases in pollen and spores from taxa associated with medium altitude semi deciduous forest and some form of riverine/swamp forest in the area today, including *Alchornia*, *Combretum*, *Cyathea*, *Olea* and *Rapanea*, together with a decline in pollen from nonarboreal sources, notably *Acalypha* and Poaceae. The fungal spore and phytolith data provide further evidence of forest recovery, while reduced abundances of charcoal indicate a decreased importance of vegetation fires. Spores of *Cercophora* and *Sporomiella* become scarce, while those of *Ustulina* become more abundant. Phytoliths produced by forest taxa are common, while those representing members of the Poaceae are less abundant than in zone Z2. Also present in this zone are phytolith's from members of the Musaceae (Munsa) and maize are also present in the sequences.

Discussion

Environmental conditions at Munsa ca 1000 yr BP to present

Sediment-based proxies from Munsa II provide evidence that reflects significant changes in the vegetation cover for the last 1000 years. Changes in the proportion of pollen and phytoliths during the last 1000 years indicate a shift from the forest-dominated vegetation cover to grassland dominated community around the time Munsa site was first occupied (Robertshaw, 1997). The timing of deforestation also corresponds with archaeological evidence (e.g. Sutton, 1993; Robertshaw, 1997) as well as historical linguistic evidence (e.g. Schoenbrun, 1993b; Schoenburn, 1998), that suggest considerable immigration to western Uganda by pastoralists and farmers who were reliant on cattle and food crops and thus demanding land for farming.

Decreased abundance of arboreal taxa, especially *Alchornea* and *Rapanea* is accompanied by an increase in pollen from nonarboreal sources as *Acalypha* and Poaceae. These changes reflect a disturbance period presumably caused by human activities rather than reduced precipitation as reflected by higher water levels in the Nile River Nile River records (Fig. 5). A prolonged period of increased aridity during the early part of the second millennium AD is not apparent in records of Nile River discharge minima that Nicholson & Yin (2001) maintain largely reflect Lake Victoria levels, and therefore rainfall in the Lake Victoria catchment (Nicholson, 1996, 1998). Instead, Nile River discharge minima indicate climatically relatively dry conditions 940–1040 AD, followed by a period of enhanced precipitation. Increased charcoal abundance in the sediment record from ca 1000 yr BP, suggests increased fire activity during the period of forest clearing, correlating with the main period of occupation of the site at Munsa as evidenced in archaeological data (Robertshaw, 1997).

The local presence of food plants indicated by the occurrence of phytoliths produced by the members of the Musaceae (both *Musa* and *Ensete*) probably suggests that bananas were being grown on forest margins and within relatively small forest gaps in the period preceding the main occupation phase at Munsa, although plants found naturally within surrounding areas of forest could have produced the phytoliths identified as *Ensete*. The present-day range of *Ensete ventricosum* (Welw.) E.E. Cheesman, which occurs in forested and riparian forest between 1000 m and 3000 m a.m.s.l, extends north of the northern shoreline of Lake Victoria (de Langhe et al., 1994–5).

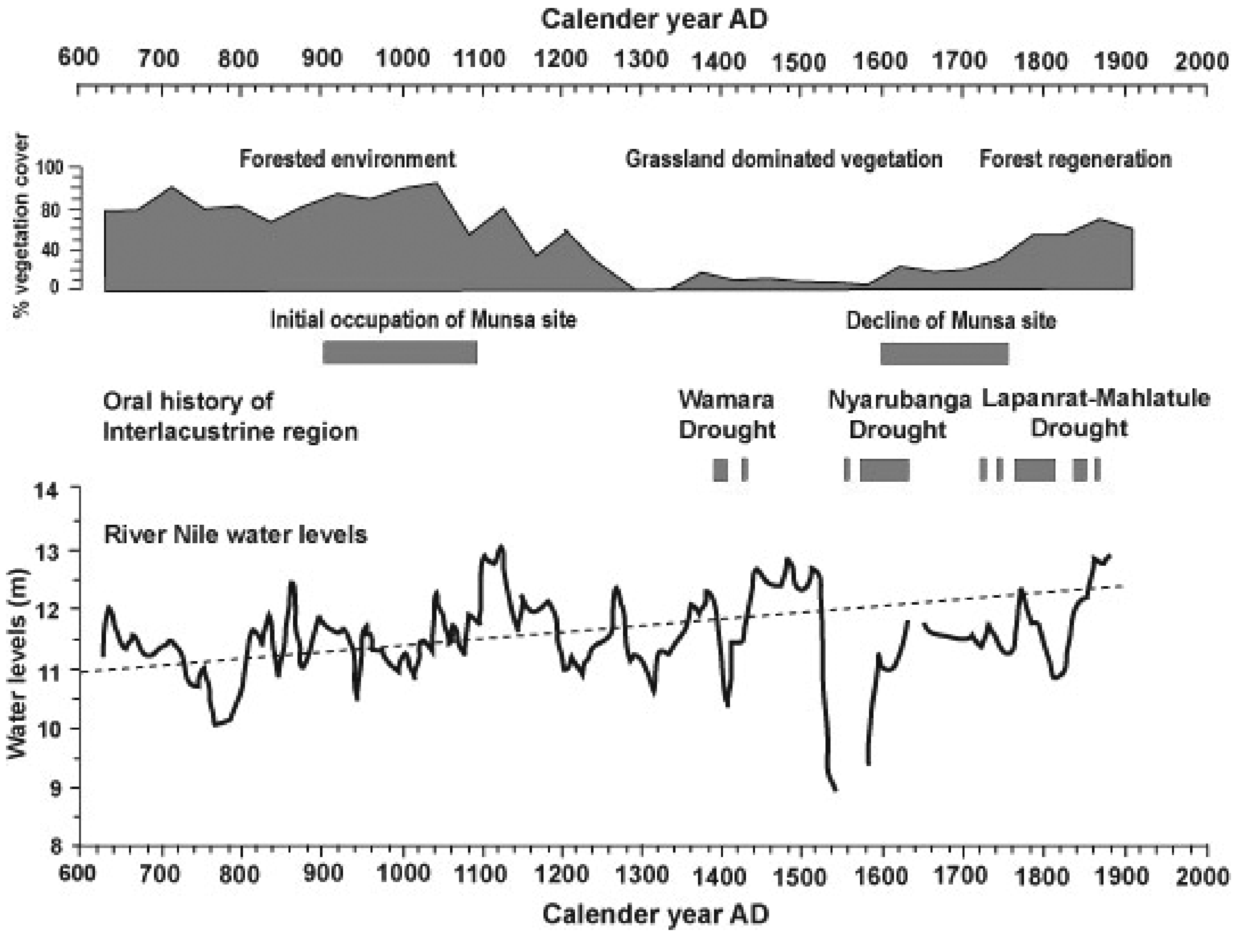

Fig 5 Summary of vegetation, climate and cultural changes in western Uganda for the last 1000 years

Some forest recovery was apparent around Munsa from ca 200 yr BP (cal 1647–1948 AD), indicating reduced human activities and appears to coincide with the archaeological evidence for the abandonment of the site (Robertshaw, 1997). Relatively recent forest recovery is also recorded about the same time in mid-altitude parts of western Uganda at Kabata Swamp postdating ca 400 ± 60 yr BP (cal 1426–1637 AD) (Taylor *et al.*, 1999, 2000) and around Lake Kasenda and Wandakara postdating 655 ± 40 yr BP (cal 1282–1393 AD) and around cal 1700–1750 AD (Ssemmanda *et al.*, 2005).

The presence of phytoliths from bananas and maize suggests that some agricultural activity continued in the catchment of Munsa, postforest recovery. By the late 18th century, much of western Uganda had been politically united into the kingdom of Bunyoro, whose peripatetic rulers managed to hold together a state polarized by pastoral nobility and an agricultural peasantry. Agriculture, however, became more important in the 20th century AD following the colonial wars and disease epidemics (Robertshaw *et al.*, 2004).

In conclusion, sedimentary data from Munsa swamp, in conjunction with the available archaeological and palaeoclimatic evidence, indicate that the area was relatively wet and largely forested prior to ca. 1000 yr BP. Deforestation, in association with increased burning of vegetation and concurrent with archaeological evidence for the first occupation of the site, commenced during the early part of the second millennium AD, and occurred during a phase of moist environmental conditions. The period ca 1000 yr BP to ca 200 yr BP is characterized by evidence for increased densities of herbivores, presumably cattle. Climatic conditions during the period show at least two major periods of moisture stress as reflected in the River Nile records (Fig. 5) and also as evident from the Lake Naivasha records (Verschuran, Laird & Cumming, 2000). Forest recovery from ca 200 yr BP concurs with archaeological evidence for the abandonment of the site and other major settlement sites in Uganda. The widespread abandonment of settlements appears to have occurred during a period of prolonged drought that is widely recounted in the oral tradition in the region (Robertshaw *et al.*, 2005; also see Fig. 5) and also recorded in the Nile River records for the ca 200 years up to the late 1700s AD.

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Conflict of interest

The author received a research grant from National geographic and British Institute in Eastern Africa to carry out this research.

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