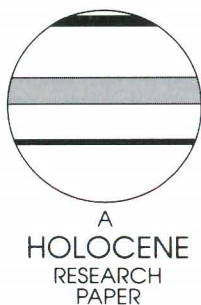


# Prehistoric fires and land-cover change in western Kenya: evidences from pollen, charcoal, grass cuticles and grass phytoliths

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Received 31 October 1996; revised manuscript accepted 8 May 1997



**Abstract:** High rates of sediment accumulation in Lake Simbi, western Kenya, has enabled fine-resolution fossil assemblages to reveal short-term changes in vegetation cover between  $4320 \pm 250$  yr BP and  $2880 \pm 90$  yr BP. Pollen analysis of a 4.2 sediment core covering this period reveals a vegetation change around 3300 yr BP. Analysis of charcoal shows that wildfires were prominent prior to the pollen-inferred vegetation change. Remains of grass cuticles and grass phytoliths show an expansion of grasslands and an increase in the diversity of grass types following the period of extensive fires. Also following the period of wildfires and the vegetation change, there were shifts within the grass flora to more Chloridoid grass types and less Panicoid grass types. This paper addresses one of the major problems of environmental reconstruction in lowland savannah: namely differentiating palaeoecological changes within the Gramineae.

**Key words:** Vegetation history, Gramineae, pollen, charcoal, grass cuticles, phytoliths, palaeoecology, lowland savannah, Kenya, East Africa, Holocene.

## Introduction

Western Kenya borders Uganda and Tanzania. Lake Victoria, the largest water body in Africa, is shared by the three countries and a small portion of it forms the Winam Gulf. Western Kenya is dominated by the Winam basin, which is an elongated depression east of Lake Victoria, with a length of 133 km and ranging in width from 25 km to 50 km in the west (Pickford, 1982). The Winam basin ends at the equator to form the western shoulder of the Gregory Rift. Most of the basin is comprised of graben, the remainder having at least one shoulder comprised of antithetically fractured monoclines (Pickford, 1986). The basin is marked by a number of volcanic complexes one of which forms Lake Simbi, situated at  $0^{\circ}22'S$  and  $34^{\circ}37'E$  and at an elevation of 1143 m above sea level.

Most of the palaeoecological data from East Africa has been obtained from altitudes higher than 2000 m above sea level. Within the lower altitudes palaeoecological records are too few to explain in detail the nature of vegetation changes in East Africa during the Quaternary. Kendall's (1969) record from Pilkington Bay in Lake Victoria at an elevation of 1134 m and Maitima's (1991) record from L. Naivasha at 1894 m are the only published

pollen records from habitats below the altitude of 2000 m. The Pilkington Bay record was, however, from a currently much more wooded vegetation than savannah environments that characterize East African lowlands. Lake Naivasha is at a relatively higher altitude of 1894 m and receives most of its drainage from the montane regions of Nyandarua mountains (Aberdares) whose better pollen production obscures inputs from the lowlands. Due to lack of suitable study sites and problems in identifying the dominating Gramineae pollen beyond family level, vegetation history of the vast East African grasslands is not well understood. There is a need to understand the interactions between the dynamics of African savannah ecosystems and the human activities in the region, particularly in connection with the use of fire. The question of whether the historical bush-burning practice as a hunting strategy has influenced the expansion of African savannahs can only be answered by comparing palaeoecological records related to the history of savannah ecosystems and those that show the history of anthropogenic and natural fires. This paper presents results of a palaeoecological investigation on a sediment core raised from Lake Simbi in Western Kenya (Figure 1), in which records of pollen, charcoal, grass cuticles and grass phytoliths analyses are used to reveal the history of savannah ecosystems in western Kenya in relation to impacts of fire.

Grasses are abundant in East Africa with different species or associations of species occupying different ecological habitats

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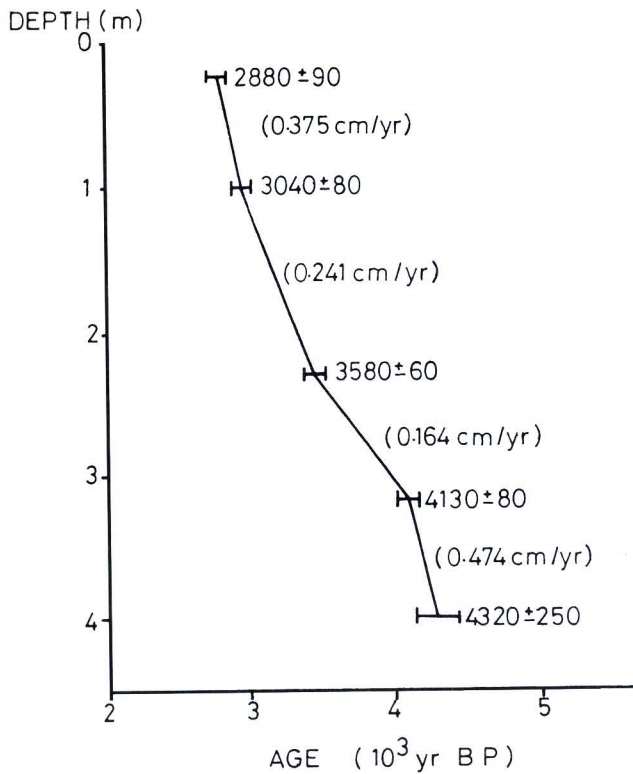


Figure 2 Radiocarbon chronology.

lake water was dated and gave an age of  $108 \pm 7$  yr BP (Beta Analytic Lab No. 32130). Given this big anomaly between the age of fresh material and the sediments at the top of the core, it appears that Lake Simbi might have been dry from approximately 2500 yr BP to a couple of hundred years ago.

Figure 3 shows a summary of the major terrestrial pollen taxa and their relative percentages. Based on changes in the pollen diagram, two assemblage zones were identified (zone I and zone II). Pollen zone I, that starts from before  $4320 \pm 250$  yr BP, shows an assemblage characterized by grass pollen percentages being consistently high, while most other pollen taxa, like *Podocarpus*, *Acalypha*, *Celtis* and *Olea*, show low percentages. Around a radiocarbon date of  $3580 \pm 60$  yr BP the pollen records show a stratigraphic change to an assemblage with increased diversity of pollen taxa, with lowland taxa becoming more prominent. Zone II is characterized by lower percentages of grass pollen. In this zone the pollen of *Podocarpus*, *Acalypha*, *Juniperus*, *Olea* and *Celtis* start to appear in relatively higher percentages. The pollen of *Hagenia*, an exclusively montane genus, appeared in the record during zone II. The assemblage in this zone shows a first-time appearance of several pollen taxa including *Tarenna*, *Rapanea*, *Cleome* and *Tapura*, which were not recorded in the zone I assemblage.

Figure 4 shows stratigraphic changes in the amounts of charcoal deposited in the lake during the same period that the pollen record presented above was accumulated. The stratigraphic change indicated by a horizontal line also corresponds to the stratigraphic boundary line between pollen zone I and zone II (Figure 3). The amount of charcoal was consistently low during the early part of zone I, but continuously increased during the later part of this zone before a sudden decline at the beginning of pollen zone II.

Figures 5, 6 and 7 show respectively the amounts of charred grass cuticles and grass phytoliths present in the core. Like in the charcoal stratigraphy, the horizontal lines in these diagrams are based on the stratigraphic boundary separating zone I and zone II of the pollen diagram (Figure 3). Following the shift in vegetation, there was an increase in both the amount of grass cuticles deposited into the lake and the number of grass types represented

in the sediments. Like pollen, grass cuticles in this core were not identifiable to specific taxonomic groups due to poor preservation. It was possible to identify two grass groups: the Panicoid and Chloridoid grasses based on their phytolith morphological features. Figure 7 shows that, following the shift in vegetation, there was a continuous increase in the abundance of Chloridoid grasses while the abundance of Panicoid grasses reduced. Figure 6 shows stratigraphic changes of the eight grass cuticle types analysed in this study and their relative abundance along the core. Following the vegetation change, records of grass cuticle types increased suggesting a possibility of an increase in the diversity of grass flora.

## Interpretation

### Pollen zone I

Pollen zone I shows a unique assemblage in that several taxa, such as *Alchornea* and *Artemisia*, appear only in this zone. The lower part of this assemblage is relatively rich in pollen, but does not indicate a forest close to the lake. Although there is some pollen of *Podocarpus*, a typical montane forest genus with pollen that is produced in abundance and transported long distances by wind, the percentages are too low to indicate its presence in the local vegetation. The percentages of *Olea* and *Celtis*, also forest components, are very low. Pollen of *Artemisia* was interpreted by Coetzee (1967) as an indicator of dry conditions in the montane regions, when taxa with similar indications are present. *Cheno/Ams* (Chenopodiaceae/Amaranthaceae) are indicators of dry lake beds (Livingstone, 1980) *Alchornea* and *Urtica* are in the present vegetation found in forest edges and secondary vegetation in previously disturbed areas. *Alchornea cordifolia* is, however, currently common along the shores of Winam Gulf. The pollen categorized as Papilionaceae is strikingly abundant in this assemblage. The flora of tropical East Africa (FTEA) and the Lake Victoria regional vegetation mosaic described by White (1983) lists many legumes belonging to this family that have been recorded in the Winam basin. There is a remarkable presence of lowland woody taxa like *Bosqueia*, *Terminalia* and *Tephrosia* which, along with the relatively lower percentage of grass pollen, indicates a moderately wooded vegetation in the low altitudes.

The assemblage in pollen zone I, indicate a considerably dry montane vegetation and a moderately wooded lowland vegetation. Pollen zone I appears to represent a period dominated by open grasslands. The low percentage of highland pollen taxa indicate a reduced extent of highland forest. *Podocarpus* had very low pollen percentages during this period, while *Celtis* and *Olea*, which are highland forest indicators, were absent. The conspicuous pollen in this assemblage is mainly from riparian genera like *Sesbania*, *Aeschynomene* and *Macaranga*. Highland vegetation show little change in relative percentages, but within the lowland taxa a trend towards more wooded vegetation can be observed. The pollen taxa that show an increase include *Meytenus*, *Grewia*, *Terminalia*, *Pygeum*, *Diospyros*, *Ficus*, *Acacia* and *Solanum*. These indicate wooded vegetation.

### Pollen zone II

Pollen assemblage in zone II appears quite different from that of zone I. A remarkable change within the highland forest is indicated by an increase of *Podocarpus*, *Celtis* and *Olea* pollen. The increase of the forest edge taxa *Acalypha* and *Pyllanthus* that started in the upper part of the zone I continues in this zone as well. This could be an indication of an expansion of the savannah-forest ecotone suggesting a degrading forest. Pollen of *Juniperus* became prominent in the pollen record of zone II. This zone can be characterized as an *Olea-Celtis-Podocarpus* zone due to the abundance of their pollen in the record. The assemblage in zone

LAKE SIMBI TERRESTRIAL POLLEN SUM

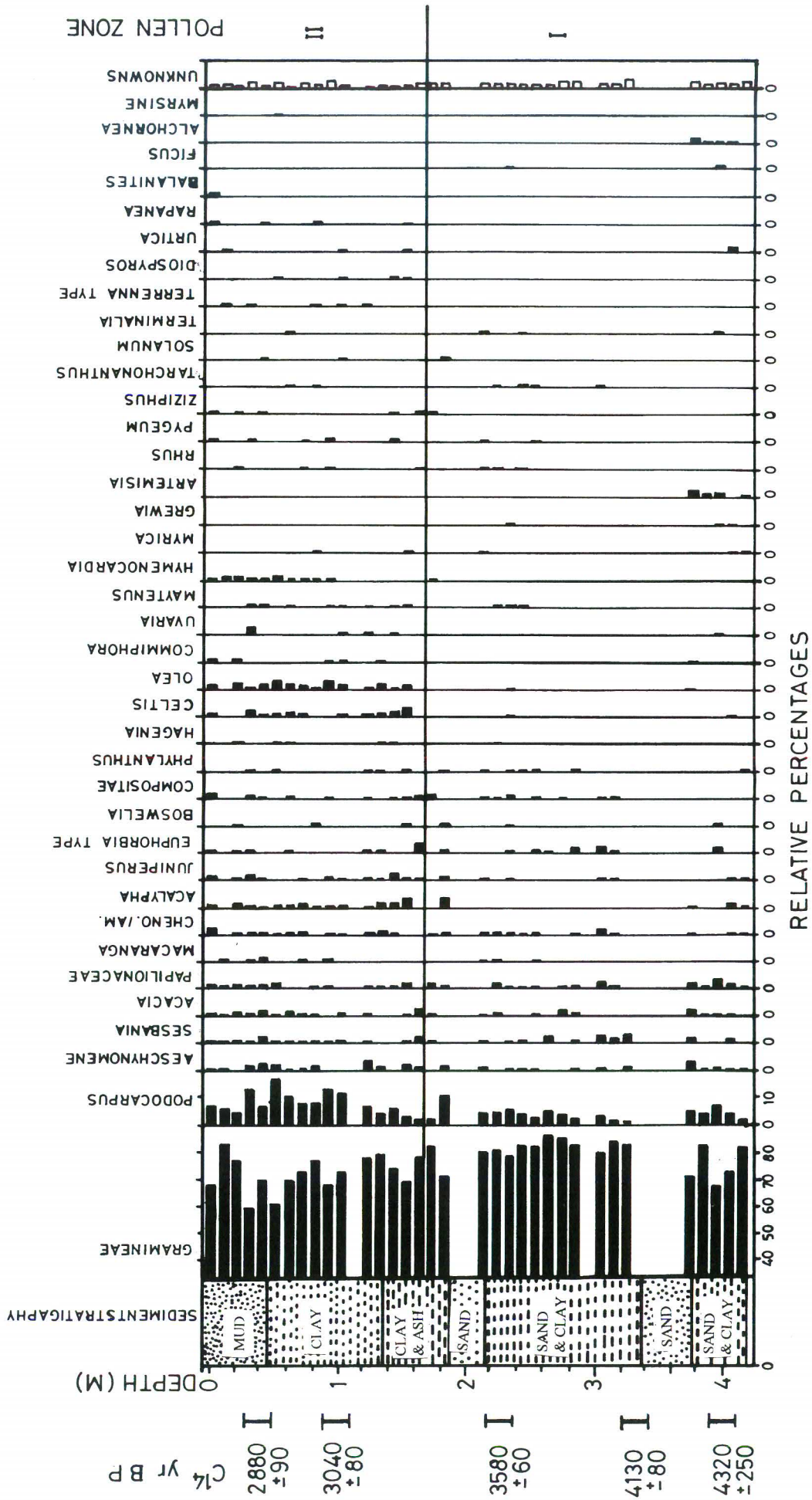


Figure 3 Relative percentages of major terrestrial pollen.



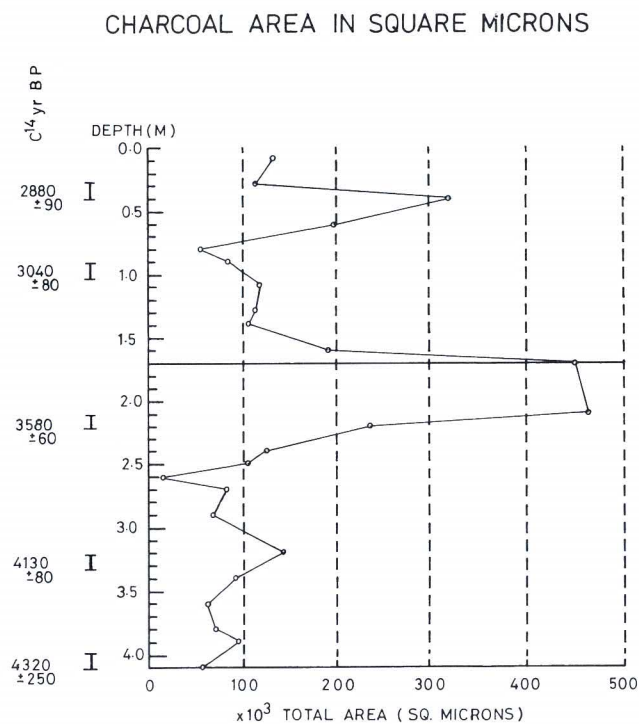


Figure 4 Stratigraphic changes in charcoal deposition.

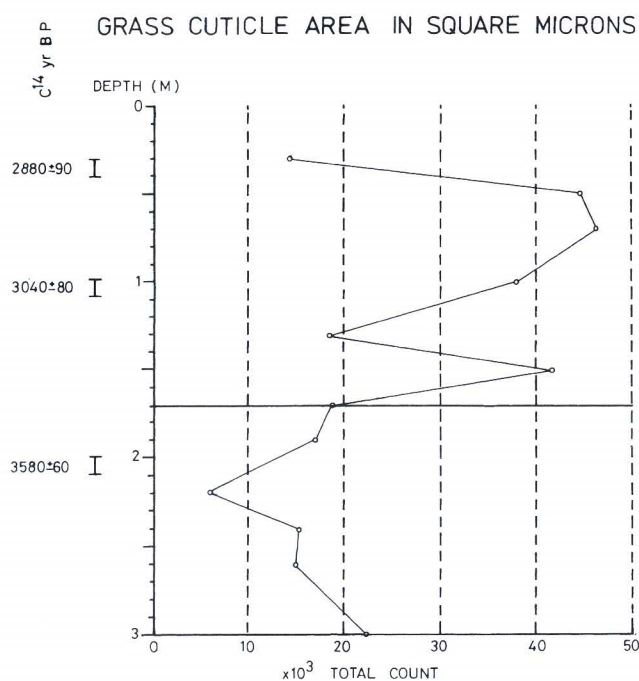


Figure 5 Stratigraphic changes in the abundance of grass cuticles.

II indicates drier conditions than that represented by zone I. The slight change in some pollen types between 0 and 0.4 m depths may be attributed to more intensive human activities in vegetation clearance. Increase in the pollen of Gramineae and *Juniperus*, for example, might be due to a reduction of the proportions of *Podocarpus* pollen type.

#### Charcoal stratigraphy

Charcoal deposition was consistently low during the early part of the record showing a small peak around  $4130 \pm 80$  yr BP. Following a short period of relatively low deposits, the rate of deposition progressively increased to a maximum at around  $3580 \pm 60$  yr BP. This period of progressive increase in charcoal deposition indi-

cates an increase in the intensity and frequency of wildfire in the surrounding vegetation. The decline in charcoal deposition rates was contemporaneous with the period of vegetation change as indicated by the stratigraphic boundary that separates pollen zone I and pollen zone II (Figure 3). From this observation it can be deduced that the vegetation change revealed by the pollen record was at least influenced by fire, due to the consistency of high charcoal deposition that terminated at a time when pollen record shows a change between the two assemblages.

#### Grass cuticles

Figure 5 shows stratigraphic changes in the deposition of charred grass leaf cuticles. Analysis of grass leaf cuticles shows that there was a much higher deposition of grass cuticles during zone I. The change from low to high rates of deposition of charred grass cuticles coincides with the vegetation change that separates pollen zone I and zone II. This observation implies that grass flora was more prominent in the local vegetation during the period of pollen zone II than during the period of pollen zone I. The diversity of grass flora appears to have increased during the period of pollen assemblage II (Figure 6). The three sources of evidence, i.e. pollen, charcoal and grass cuticle, show that a vegetation change into more widespread grassland around Lake Simbi occurred around an inferred date of 3300 yr BP and that the change was to a great extent influenced by wildfires.

#### Grass phytoliths

Figure 7 shows relative percentages of two grass groups (Panicoids and Chloridoids) identified from their phytoliths and grouped according to their morphological affinities. Also shown are the phytoliths that could not be assigned to a specific taxonomic group but never the less showed some anatomical identities and stratigraphic consistency. The diagram shows that Panicoid grasses were reducing in percentage during zone II while the Chloridoid grass percentages were on the increase. The single sample that yielded the two groups during zone I shows a much higher representation of Panicoids than Chloridoids. Panicoid grasses are known to inhabit shaded areas with higher soil moisture content than the more xeric adapted Chloridoid grasses commonly found in open grasslands. This observation suggests that there was a remarkable reduction in soil moisture content, probably as a result of higher rates of evaporation from exposed soils.

An integrated interpretation of pollen, charcoal, grass cuticles and grass phytoliths records reveals a very interesting correlation in the timing of the pollen inferred vegetation change and the start of the decline of charcoal, and the onset of higher rates of grass cuticle deposition. Put together, the fossil records show a systematic sequence starting with an increase in charcoal deposition, change in pollen assemblage, and a remarkable increase in grass cuticle deposition. This pattern of stratigraphic changes has been interpreted to indicate a prolonged period of wildfires, followed by vegetation change to more grasslands. Although there might have been other contributing factors, like climate change, widespread wildfires were the main cause for the vegetation change. The increase in the total amount of grass cuticles during the period of pollen zone II has been interpreted to indicate an expansion in grasslands. This interpretation is also supported by grass phytolith analysis that also show higher deposition percentages. The grass cuticle records show more cuticle types during the period of pollen zone II than that of pollen zone I. The records of grass phytoliths do not only confirm an increase in deposition rates but also a shift to the dominance of the xeric Chloridoid grass types at the reduction of the more mesic Panicoid grasses. This change has been interpreted to be due to a reduction in soil moisture content in a drier climate and probably more open vegetation around Lake Simbi.



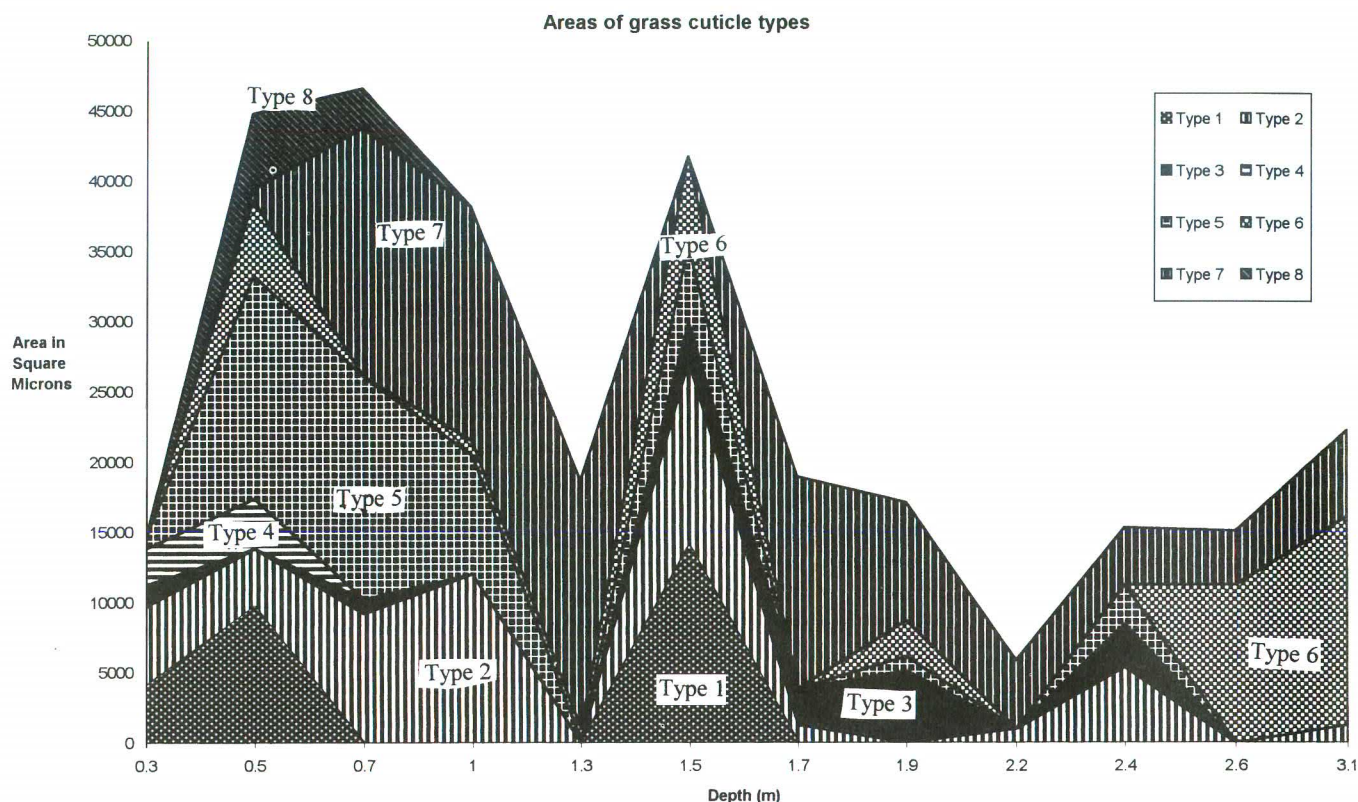


Figure 6 Changes in the abundance of the grass cuticle types named in Table 1.

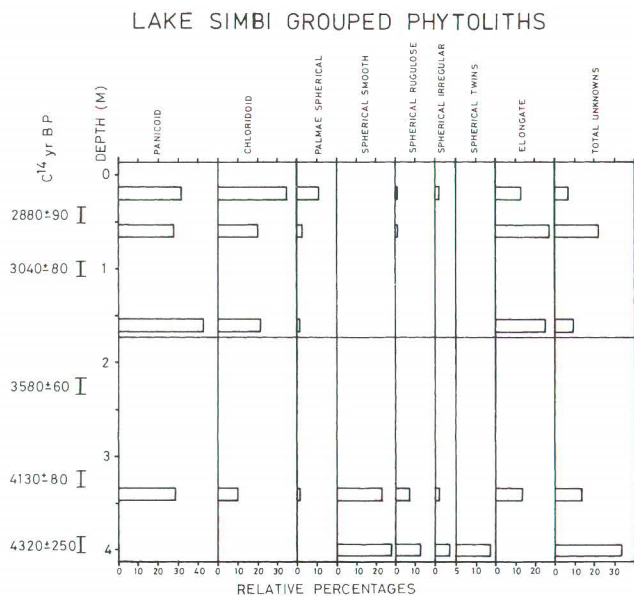


Figure 7 Stratigraphic changes in the deposition of Panicoid and Chloridoid grass phytoliths.

### Discussion

Palaeoecological investigations done during the last three decades have shown that the climate of East Africa has changed from a relatively wet early Holocene through dry mid-Holocene to the modern climate which may have been attained as early as 3000 years ago (Ambrose, 1984). Vegetation responses to these changes are now broadly understood, but are mostly based on data obtained from high-elevation sites where cooler temperatures and moist soils have maintained a very different type of vegetation from that found within lowland areas. There is a lack of information about responses of the lowland vegetation to these

changes. Most East African vegetation consists of savannah grasslands which for many millennia have been the home of mankind. Vegetation changes within the lowlands should therefore be expected to show response not only to regional and global climatic changes, but also to changes inflicted by man throughout prehistoric times.

The Simbi records described here show a remarkable vegetation shift around 3300 yr BP. A striking feature in the Simbi pollen record is the increase in the pollen of *Podocarpus*, *Olea* and *Celtis*. This increase might have been due to better dispersal of long-distance pollen in a more open vegetation around the lake. Kendall (1969) observes that during the last 3000 years forests around Lake Victoria were greatly reduced, and he points out that human activities rather than climate change seem to have been the cause. At much higher elevation sites Livingstone (1967) and Coetzee (1967) observed striking increases in *Podocarpus* pollen in western Uganda and Mt Kenya respectively, which appear to have been contemporaneous with that of Lake Simbi reported in this study. Within the montane regions these changes were interpreted to indicate minor climatic fluctuation and a signal to drier climate. The increase in sedimentation rates during the period of pollen zone II may have been due to erosion on more exposed and drier soils.

There is a very strong correlation in the timing of the peak of the charcoal deposits in Lake Simbi with the onset of vegetation change. It may be possible that lowland savannah grasslands with their drier ecosystems respond to climate change much earlier than the wetter highland ecosystems, such that the lowland vegetation was more susceptible to wildfires. Although it was difficult to identify the grass cuticle types described here, the distinctiveness and consistency of their anatomical features along the core suggests that they represent definite taxonomic groups in the grass flora.

The palaeoecological records reported here reveal clearly that widespread fires played part or influenced the nature of vegetation change observed at around 3300 yr BP. The fire regime revealed



in this record appears to have been quite consistent over a relatively long period of time suggesting an anthropogenic source (Patterson *et al.*, 1987). Distinguishing between anthropogenic fires and natural fires in a short record like the one described here is not easy. Based on the duration of charcoal deposition period prior to the vegetation change and the archaeological evidences of human presence in the area during the time, this fire regime might have an anthropogenic source. However, it is difficult to rule out the possibility of lightning-induced fires, especially in a dry environment like the one described to have prevailed in the region at that time. Whether with an anthropogenic or a natural source, fire has influenced the changes in vegetation around Lake Simbi. Wildfires alone might not have been the only cause of this vegetation change. It is unlikely that the rise in *Podocarpus*, *Olea* and *Celtis* pollen observed in this record was due only to the effect of fire. Within the lowland areas where most of the human communities lived, a reduction in ecological diversity due to climate change might have reduced wild food resources, forcing man to adapt to severe hunting strategies such as bush-burning. Contemporary hunter/gatherer communities in East Africa still practise bush-burning as a means to increase visibility of the wild game and to induce grass regeneration in order to attract the grazers.

There is sufficient evidence that late Stone Age man lived in the Winam basin throughout the period covered by the Simbi record (Robertshaw *et al.*, 1983), and that, although his diet consisted of fish, he frequently supplemented it by hunting from wild game and harvesting of vegetable products. It appears that, prior to the iron-smelting technology that enabled manufacture of more articulate iron implements, man in the Winam Gulf had adapted to the use of fire, probably for hunting. This human adaptation led to widespread wildfires that have encouraged the expansion of grasslands.

This paper addresses an important area of palaeoecological reconstruction in lowland East Africa, which is differentiating paleoecological changes within grass flora. Analysis of grass cuticles in lake sediments has shown a promise to provide this much-needed information. The current study has stratigraphically isolated eight grass cuticle types which, based on their anatomical and morphological distinctiveness throughout the core, quite clearly represent part of a taxonomic group within the grass flora. The study has shown that there is a remarkable variability in the relative abundances of these grass cuticle types over the period represented in the record. The observed changes in the patterns of deposition of these grass cuticles into the lake must have some ecological significance in the distribution and composition of the grass flora at the time of deposition. Due to fragmentation of the grass cuticles, the surface areas of the pieces analysed were too small to provide sufficient diagnostic features adequately to match the fossil records with modern reference materials. To realize the full potential of fossil grass cuticle analysis, further work needs to be done to develop a laboratory procedure for extracting these leaf fragments from lake sediments, or other sedimentary deposits. This work may enable recovery of larger pieces of fossil grass cuticles, thereby increasing the number of anatomical features for taxonomic identification.

## Acknowledgements

This study was made possible through grants from National Science Foundation INT-8822036, Wenner Gren Foundation, L.S.B. Leakey Foundation and Kenya Museum Society. Throughout the study I received invaluable advice and assistance from D.A. Livingstone. The study was done using facilities provided by the National Science Foundation in the Laboratory of D.A. Livingstone in the Department of Zoology, Duke University. I

would like to express my appreciation of the assistance offered by Stephen Mathai during the field operations for this study and the initial processing of core materials. I also thank Jennifer Njogu who typed the original manuscript and the anonymous reviewers who offered useful ideas.

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