Kenyan ecosystem dynamics: perspectives from high and low altitude ecosystems

Rucina, S.M.

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CHAPTER 1

INTRODUCTION

1. Introduction to East Africa palaeoenvironments

Although there are numerous records from montane ecosystems, records from savanna ecosystems are relatively few; this scarcity is likely to be largely due to the lack of suitable sedimentary basins. High altitude lakes and bogs have been the focus of palaeoecological investigations (Coetzee 1964; 1967; Hedberg, 1954; van Zinderen Bakker, 1964; Kendall, 1969; Hamilton, 1979; Harvey, 1976; Johannessen, et al., 1985; Hamilton, et al., 1986; Maitima, 1991; Street-Perrott, et al, 1993; Johnson, et al., 1996; Beuning, 1997; Street-Perrott, et al, 1997; Karlen, et al., 1999; Barker, et al., 2001; Ficken, et al., 2002; Lamb, et al., 2003). Many high altitude records show a shift of high altitude vegetation to lower altitudes during the last glacial period reflecting cold and dry climate with temperatures estimated to be 4°C colder than the present on Mt Kenya (Coetzee, 1964). Natural fires have also shown to be important controls on ecosystem composition, for example fires were common in the areas of Sacred Lake at 2400 m and Rumuiku Swamp at 2154 m on Mount Kenya (Rucina et al., 2009; Wooller, 2000) (Figure 1). From 26,000 to 19,000 cal yr BP montane forests comprised taxa from the ericaceous belt dominated by C3 plants reflecting a dry and cool climate throughout the last glacial period (Rucina et al., 2009). Low lake levels recorded from 25,000 to 15,000 cal yr BP throughout East Africa pointing to cool conditions and a prolonged dry period (Kendall, 1969; Beuning et al., 1997). Low abundance of Cyperaceae and Poaceae pollen from sediments recovered from Kashiru Swamp at 2104 m in Burundi suggest this period was relatively wet and warm (Bonnefille and Riollett, 1988). Sediments from Muchoya Swamp (2260 m) in Uganda record the establishment of taxa from the ericaceous belt until 19,000 cal yr BP, coeval with lowering of temperature and rainfall in the region (Taylor, 1990). Lake Victoria (1134 m) sediments record presence of gastropods in the core.
sediments suggesting a low stand from 13,500 cal yr BP onwards indicating a drier period with oxidation of sediments under extremely low lake levels (Stager et al., 1997). Pollen record from Sacred Lake on Mount Kenya records this period as drier around 13,500 cal yr BP (Coetzee, 1967). The transition from the glacial period to the early Holocene is a period of rapid environmental change reflecting the climate became relatively warm and wet. Montane forests shifted to higher altitudes replacing grasslands that were much more extensive during the Last Glacial Maximum (LGM) (Wooller et al., 2003; Rucina et al., 2009). This replacement of ecosystems is recorded by pollen from Kashiru Swamp (2104 m) sediments in Burundi between 11,500 and 5700 cal yr BP (Roche and Bikwemu, 1989). This transition was punctuated in many lake records from East Africa by low water stands pointing to relatively arid conditions at the Pleistocene-Holocene transition (Williamson et al., 1993). Carbon and nitrogen isotopic composition and bulk organic matter in sediment cores from Lake Bosumtwi (150 m) in Ghana, also reveal a dry phase (Talbot and Johannessen, 1992).

Pollen studies from sites throughout East Africa during the late Holocene show distinct vegetation changes that record a combination of climate change and events of human impact. During the Holocene climatic conditions became moister with forest in Central Africa continuing to expand, reaching the equivalent of its present range and density about 10,700 cal yr BP (Hamilton, 1988). In the mid Holocene, from around 5500 cal yr BP onwards, tropical African sites show a lowering of lake levels (Stager et al., 1997) and an abrupt decline in arboreal pollen percentages reflecting drier conditions all pointing to a relatively abrupt shift toward arid conditions (Jolly et al., 1994; Ricketts and Johnson, 1996; Wooller et al., 2000). These changes culminated towards a 4000 cal yr BP drought period that was recorded across the African tropics (Marchant and Hooghiemstra, 2004). Changing lake levels during the late Holocene (Rickets and Johnson, 1996; Alin et al., 2003; Russell and Johnson, 2005) record the magnitude of a variable climate. For example, a high stand was recorded at Lake Edward (920 m) (Russel et al., 2004) and Lake Tanganyika at (773 m) from 1750 to 1450 cal yr BP (Alin and Cohen, 2003). Arid to wet climate oscillations continued through the late Holocene and intensified after 1500 cal yr BP when forests were replaced by grasslands such as recorded in Lake Tanganyika catchment (Msaky et al., 2005). In
the catchment area of Lake Masoko *Ricinus communis* pollen became more abundant from 1650 to 1550 cal yr BP (Vincens et al., 2003). Lake levels of Lake Naivasha (1884 m) and Lake Tanganyika lowered by some 40 m during the last 1000 years (Alin and Cohen, 2003; Verschuren et al., 2000). Diatom and midge evidence from Lake Naivasha indicate that the period from 1000 to 740 cal yr BP was notably drier than at present (Verschuren et al., 2000) while the period from 740 to 160 cal yr BP was relatively wet. Other lakes, such as Lake Victoria, Lake Chibwera (970 m), Lake Kanyamukali (1150 m) and Lake Baringo (1050 m) suggest the period from 460 to 160 cal yr BP was dry (Bessems et al., 2008).

The late Holocene is increasingly characterized by signals of human activity. Initially it is likely that these early inhabitants exerted low-level impacts upon the landscape. Microscopic charcoal particles and pollen from food crops in sediments show human ecosystem interactions were increasingly prevalent throughout the late Holocene (Kiage and Liu, 2009; Rucina et al., 2009; 2010; Taylor et al., 2005; Lamb, 2003).

Namelok pollen record documents presence of *Cannabis sativa*, cereal and *Ricinus communis* since 2650 cal yr BP. This reflects an early settlement in the Amboseli Basin (Rucina et al., 2010). Regionally starting at 2200 cal yr BP there is pollen evidence for forest clearance at Muchoya (2260 m) and Ahakagyezi swamps (1830 m) in the Rukiga Highlands (Taylor, 1990). This conclusion is based on the replacement of forested areas by open vegetation and degraded scrubland. For example, within the Lake Tanganyika catchment there is evidence of widespread deforestation and increased erosion from the late 18th century onwards (Alin et al., 2003).

At Lake Naivasha, maize (*Zea mays*) pollen appears in the record after 300 cal yr BP (Lamb et al., 2003).

Human-ecosystem climate interactions are inherently dynamic and complex (De Fries et al., 2004), particularly given the diversity of the Eastern African landscapes, ecosystems and cultures that interact. People and ecosystems have responded and adapted to past change in a variety of ways. During droughts a diverse range of adaptation strategies of people can reduce vulnerability to climate change by making communities better able to adjust to climate change and variability, moderating potential damages, and helping them cope with adverse consequences (Robertshaw et al., 2004). For example pastoral communities maintain wealth and their environmental ‘buffer’ in herds of cattle; during extreme periods of drought
these ‘stores’ can be massively impacted on. Agricultural communities will turn to more drought-resistant crops such as millet and sorghum, crops that were grown much more extensively prior to the relatively recent import of maize (Håkansson, 2008) and banana (Neumann and Hilderbrand, 2009) which form the stable crops of today for large parts of East Africa. Due to these relatively new recent focus of agriculture, compounded with social, public and economic shifts, we can reconstruct how past communities have responded to droughts (Eriksen and Watson, 2009).

2. Aim of the study

The study aims to advance knowledge of long term ecosystem dynamics from equatorial East Africa and to provide contrasting perspective that cover low and high altitude sites in Kenya. The studied lowlands and highlands of Kenya are vulnerable to changes related to both climate and land use. These areas have undergone rapid population increases and development, yet they include some of the most fragile ecosystems being situated in the wettest and driest parts of Kenya. Combined, these three catchments (Mt Kenya, Namelok Swamp and Lake Challa) allow for a comparison of high altitude forest dynamics with savanna ecosystem and offer a contrasting response to environmental and ecosystem human interactions.

The aim of this study was also to reconstruct late Quaternary changes of ecosystems and environments of lowland and high altitude sites using a multi-proxy approach. Reconstructions of late Quaternary palaeoenvironments from Mount Kenya, Namelok Swamp and Lake Challa are presented in this thesis and form the basis of regional analysis. The research objectives to be specified as follows:

1. Palaeoecological evidence is used to determine how the vegetation composition of low and high altitudes has changed throughout the late Quaternary
2. Past anthropogenic activity have been implicated in the origin and expansion of savanna grasslands in East Africa and degradation of Afromontane forests. Palaeoecological analysis is used to determine whether grasslands are a natural and long-standing component of savanna and Afromontane forests
3. Archaeological evidence suggests that low and high altitudes have been subject to extensive forest loss and fragmentation as a consequence of human activity in the late Holocene. Multi-proxy palaeoecological evidence is applied to explore the nature and
timing of long-term human impacts of low and high altitude ecosystems.

3. Study areas

Like other tropical mountains of East Africa, Mount Kenya is characterized by high environmental and climatic sensitivity and offers particularly good sedimentary archives for palaeoecological reconstructions and to identify factors driving ecosystem change. One such site is Rumuiku Swamp at 2154 m is located in the southeast montane rainforest of Mount Kenya. Similarly, in the south of Mount Kenya Namelok Swamp (1146 m) in the Amboseli Basin and Lake Challa (880 m) southeast of Kilimanjaro are also sensitive to record ecosystem change.

Rumuiku Swamp is located on the southeast of Mount Kenya in the montane rainforest ecosystem at 00°11’8.93''S 037°55’9.65”E (Figure 1). The swamp is bordered to the southwest by a small cliff and a small river emerges from the swamp flowing to the east (Plate 1). The site is highly disturbed with original montane forest replaced by Croton macrostachyus, Macaranga kilimandscharica and Neoboutonia macrostachys.

Plate 1. Rumuiku Swamp and surrounding montane forest in the catchment.

The original montane rainforest included taxa such as Ocotea usambarensis, Podocarpus spp., Polyscias spp., Schefflera spp. and Tabarnaemontana
holstii as common elements. *Syzygium cordatum* and *Morella* (previously named (*Myrica salicifolia*) are recorded as small trees close to the swamp margins. Vegetation on the swamp surface is dominated by tussock species of the sedges. Sedges are the main peat forming plants. The large tussock-forming grass *Pennisteum mildbraedii* is locally abundant on the margins as are local patches of the moss *Sphagnum*. Exotic tree species (*Cupressus lusitanica*, *Pinus patula* and *Pinus radiate*) are cultivated towards the north and *Eucalyptus spp* to the south of the catchment under management of the Forest Department of Kenya. The swamp is situated close to communities with half of the catchment used for agriculture: tea and a wide range of crops are cultivated. Cattle and goats are kept and they graze in open areas of forest and during extreme droughts, they are driven into the dense forest.

Namelok Swamp (2°54’52.50”S, 37°30’23.28” E; elevation 1146 m) lies in the Amboseli Basin, in the Kajiado District of southern Kenya (Figure 1). The area is dominated by Poaceae, and a tree and shrub layer of variable densities. Today the area is characterized by strong human impact that has converted much of the savanna into agricultural land being particularly intensive where water is available. The vegetation composition in the Amboseli Basin is determined by climate, soil type (including nutrient availability), and plant symbiotic interactions, disturbance by fire and interaction with herbivores (Gillson, 2004; Skarpe, 1992). Much of the land around Namelok Swamp has been converted to agriculture because water is available throughout the year for irrigation. Livestock is grazed on the swamp during the dry season (Plates 2A and 2B). Grasslands are
dominated by *Chloris rocksburghiana*, *Eragrostis tenuifolia*, *Sporobolus homblei*, *S. robusta* and *S. spicatus*. In the flooded areas, *Psiloemma jaegeri* and common species of *Sporobolus* occur. The woodlands and bushlands are composed of *Acacia drepanolobium*, *A. mellifera*, *A. nubica*, *A. tortilis*, *Aristida keniensis*, *Azima tetracantha*, *Commiphora spp.*, *Eragrostis aspera*, *Salvadora persica* and *Solanum* species. The adjacent riverine areas are mostly dominated by *Acacia xanthophloea*, *Ficus thonningii*, *Salvadora persica* and two species of *Syzygium* (*S. cordatum* and *S. guineense*). *Syzygium cordatum* is recorded as small trees close to the swamp margins.

Plate 2A. Namelok Swamp dominated by *Cyperus immensus*, *Typha sp.*, *Pennisteum mildbraedii* and *Polygonum* spp. On the background the trees are *Acacia xanthophloea*.

Plate 2B. Namelok Swamp in dry season and forms a refuge for livestock.

Fig. 2. Sources of African rainfall showing the annual passage of the ITCZ and direction of the main wind systems. The dotted lines indicate position of the ITCZ, dashed lines the Congo Air Boundary (CAB). Source: Kiage and Liu 2006 and modified from Nicholson (2000)
Vegetation on the swamp surface is dominated by *Cyperus immensus* (Papyrus) with tussock species of the sedge *Carex, principally C. monostachya*. Locally the large tussock-forming grass *Pennisteum mildbraedii* is abundant on the swamp margins.

Lake Challa has a surface area of 4.2 km² and water depth reach 97 m (Plate 3). The lake is situated on the lower east slopes of Mount Kilimanjaro (3° 19’ S, 37° 42’ E) close to the Kenyan-Tanzanian border (Figure 1). The lake is located within the savanna ecosystem and surrounding vegetation is dominated by trees such as *Acacia, Combretum, Lannea* and *Terminalia*. Due to increasing anthropogenic influence including fires, grazing and collecting of firewood, the wooded savanna is increasingly replaced by savanna grassland and agricultural fields of maize, sunflower, millet and beans.

4. Ecosystems of East Africa

The vegetation distribution in East Africa (Figure 2) is largely controlled by rainfall and temperature (Figure 3) distribution compounded by a strong influence of topography (Lind and Morrison, 1974; White, 1983) Six major vegetation types...
have been identified that include Afroalpine and Ericaceous community forests, woodlands (mainly Miombo), Combretaceae and Acacia savannas, montane and lowland coastal forests, dry savanna types including grasslands and thickets, and semi desert and desert. Forest distribution in Kenya (Figure 4) is broadly controlled by rainfall, temperature and topography. Forest cover is abundant along the coast, in the central highlands and in the highlands bordering with Uganda where rainfall is high. Other parts of the country are semi-arid and support woodlands, bushlands and open grasslands commonly referred as savanna ecosystem with scattered trees such as Acacia, Balanites, Combretum, Commiphora and Terminalia species, and herbaceous layer primarily consisting of C₄ grasses (Plate 4). Most highland forests have been extensively cleared and the remnants are mainly located on the high mountains and ranges such as Mt. Elgon, Mt. Aberdares, Mt. Cherangani and Mt. Mau (Figure 4). Forests on the higher slopes between 2200 and 3500 m are dominated by moist forest trees which include Cassipourea, Ocotea, Polyscias, and Podocarpus with Juniperus-Olea abundant on the drier slopes. Most lowland forests have also been extensively cleared and the remnants are contained within.

Plate 3. Anchored platform and boat which were used during the coring in Lake Challa. The lake is shared by the two neighboring countries of Tanzania and Kenya. On the background is Mount Kilimanjaro.

Plate 4. Savanna with Acacia trees and open spaces dominated by C₄ grasses.
protected areas such as Kabarnet, Kakamega, Nandi and the Arabuko Sokoke forest (Figure 4). In the southern part of Kenya forest remnants are found on the Taita Hills, Kasigau Hills, Shimba Hills and Chyulu Hills (Figure 4). This diversity of these forests biogeographically affinities with the diverse Eastern Arc Mountains of Tanzania (Sayer et al., 1992). Riverine forests concentrate along the Tana River and tributaries, Ewaso Ngiro River, Kerio River, Turkwell River and Galana River (Ahmed & Mloy, 1998). Coastal mosaic forests especially mangroves are common around Lamu Town in coastal Kenya (Plate 5) and along the Tana River Delta.

*Plate 5. Mangrove forests along the Kenyan coast.*
References


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